Efficiency, Equity, and Timing in Voting Mechanisms

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Abstract

We compare the behavior of voters, depending on whether they operate under sequential and simultaneous voting rules, when voting is costly and information is incomplete. In many real political institutions, ranging from small committees to mass elections, voting is sequential, which allows some voters to know the choices of earlier voters. For a stylized model, we characterize the equilibria for this rule, and compare it to simultaneous voting, and show how these equilibria vary for different voting costs. This generates a variety of predictions about the relative efficiency and equity of these two systems, which we test using controlled laboratory experiments. Most of the qualitative predictions are supported by the data, but there are significant departures from the predicted equilibrium strategies, in both the sequential and sumultanous voting games. We find a tradeoff between information aggregation, efficiency, and equity in sequential voting: a sequential voting rule aggregates information better, and produces more efficient outcomes on average, compared to simultaneous voting, but sequential voting leads to significant inequities, with later voters benfitting at the expense of early voters.

I Introduction

I.1 Strategy, Efficiency, and Equity

In 2000 the polls closed in the eastern time zone portion of Florida at 7:00 p.m. At 7:49:40 p.m., while Florida voters in central time zone counties were still voting, NBC/MSNBC projected that the state was in Al Gore's column. A few seconds later CBS and FOX also declared the state for Gore. At 8:02 p.m. eastern time, three hours before polls closed in western states, ABC anchor Peter Jennings announced that his network was going to call the state of Florida for Al Gore. Jennings remarked: "Give him [Gore] the first big state momentum of the evening. This is the biggest state where the race has been close, the fourth biggest electoral prize."[1] According to a study by Kathleen Frankovic commissioned by CBS to analyze its election night reporting: "More than 60 percent of the country's 538 electoral votes are cast by states whose polls close by 8:00 PM, EST, a full three hours before polls close in the West. More than 80 percent are cast by states whose polls close by 9:00 PM, EST."[2] It is no surprise then that Frankovic reports that "since at least 1965, losing candidates and Americans in general have assumed that the networks have affected voting behavior by calling elections."

Most of the concerns raised after the early election calls in 2000 were about the problems of inaccuracy; and similar issues were raised about the reporting of the exit poll results in 2004 when they showed early leads for Kerry.[3] As observed by Thompson (2004), however, even accurate reports of early voting outcomes during an election may mean that the election is fundamentally different from one held where voters participate simultaneously in at least three ways. First, when voters participate sequentially and early results are revealed to later voters, the choices facing the voters are complex as later voters use early voting as a noisy information source and early voters try to anticipate the message their votes can send to later voters and how later voters will react to that message. These choices are even more complicated if voting is a costly act, requiring an

[1] Alicia C. Shepard, "How They Blew It," *American Journalism Review*, January/February 2001. Page 20.

[2] Frankovic, Kathleen, "Part Three: Historical Perspective," in Linda Mason, Kathleen Frankovic, and Kathleen Hall Jamieson, *CBS News Coverage of Election Night 2000: Investigation, Analysis, Recommendations, January 2001.*

[3] On the afternoon of election day 2004, "web sites such as slate.com, drugereport.com and dailykos.com . . . were posting excerpts from early exit-poll reports . . . Those postings were then e-mailed around, meaning that potentially millions of people were getting at least glimpses of the information." Fox News anchor Brit Humes announced that exit poll rumors on the internet suggested that things looked "brighter on the Kerry side than the Bush side." The stock market plunged nearly 100 points. See Mark Memmott and Martha T. Moore, Networks Stay Cautious But Hint At Outcome, *USA Today*, November 3, 2004 and Richard Morin, "Surveying the Damage; Exit Polls Can't Predict Winners, So Don't Expect Them To," *Washington Post*, November 21, 2004.

investment of time and resources, such that some voters may choose to abstain. Thompson argues "an election that enables citizens to adjust their votes in this way [according to how others have voted] privileges strategic voting" and the value of a vote would then depend on the "strategic savvy" of the voter.

Second, if voters' behavior does depend on the voting mechanism, then we might expect that sequential and simultaneous voting mechanisms will differ in efficiency. Simultaneous voting can be more informationally efficient than sequential voting if in sequential voting later voters are less inclined to participate or vote to "follow the crowd" rather than their independent judgements as Thompson suggests. On the other hand, sequential voting might be more economically efficient when voting is costly if the outcome of the voting is equivalent but less voters are required to participate to achieve that outcome. Finally, as Thompson points out sequential voting can be inequitable. He notes on (page 58): "simultaneity rests ... on the democratic value of fairness. If citizens vote at the same time (or have only information they would have had if they were voting at the same time), the value of each citizen's choice is no greater than that of any other citizen."

In this paper we address these three concerns about sequential voting–strategic behavior, efficiency, and equity–both theoretically and experimentally. Before we turn to our analyses, however, we establish that sequential voting and the concerns about the effect of sequence exist in many voting contexts–not just election night reporting–and we review the related literature.

I.2 Prevalence of Sequential Voting Mechanisms

Election reporting of early voters' choices during national elections in the U.S. is just one example of the many voting situations in which participants choose in a sequential order and individual choices are publicly revealed as they are made. The term "roll call vote" refers to the mechanism of calling for individuals' votes as their names are called as listed on a roll and is used in many voting contexts from city council meetings to national legislatures (although the advent of electronic voting systems has reduced the sequential nature of voting in large legislatures).

As with election night reporting, the sequential nature of roll call voting sometimes has controversial implications. It is standard procedure in roll calls that the head of the body votes last, under the assumption that otherwise the head would have an undue influence on the outcome of the voting. Voting order is frequently debated in such bodies and in some cases manipulated in order to affect the outcome or to advantage particular members by changing their voting positions. For instance, the Syracuse New York *Post-Standard* reported December 21, 2004 that a member of the Auburn, New York city council was considering a measure to require the mayor to vote first. The mayor argued: "They want to see where I'm going to vote." One of the explanations for the expansion of the use of electronic voting machines in such bodies is a desire to make voting simultaneous. The New Orleans *Times-Picayune* reported on January 12, 1995 that the eleven member St. Bernard Parish School Board was considering buying an electronic voting machine so that individuals could vote simultaneously instead of the alphabetical order they normally followed. A board member who wanted the machine argued that it would save time and show "a true picture of what people think." As a less costly alternative that would lessen the supposed advantage of those with names at the end of the alphabet, Board member Don Campbell advocated a rotating voting order: "When I first got on the board, it was a little uncomfortable for me. ... I want everyone to have the opportunity to vote first."[4]

Another type of controversial sequential voting occurs in U.S. presidential primaries, where voters participate by state and the outcome is the result of the cumulative choices. As discussed in Morton and Williams (2000) many believe that the sequential nature of the primaries gives voters in early states like New Hampshire and Iowa an undue influence on the outcome through their influence on later voters' choices. A similar voting mechanism is used when countries hold sequential referenda over treaties or agreements as in the recent referenda over the proposed European Union Constitution. The order in which countries vote is often argued to have an effect on the voting in countries who choose later in the sequence and attempts are made to manipulate that order. For example, in 1994, when Sweden scheduled its vote on joining the European Union for November, the *Financial Times* of London reported [March 19, 1994]: "The Swedish decision almost certainly ensures that the order of voting in the three Nordic neighbors will be Finland in September, followed by Sweden, and then Norway ... With support for EU membership among the Nordic countries strongest in Finland and weakest in Norway, the east to west sequence has long been regarded as the best way to win a 'yes' vote in the three nations."

Even more significantly, a growing percentage of voters are choosing before election day either by mail or in early voting locations.[5] In Oregon all elections are conducted by mail over a period of weeks. The Annenberg Election Survey at the University of Pennsylvania completed the week before the 2004 election found that 14 percent of registered voters had already voted compared to 11 percent who at the same point had reported voting early in 2000.[6] Over 22 percent of the respondents to the National Election Studies

[4] While electronic voting machines might appear at face value to reduce the strategic issues of timing in roll call votes, evidence suggest that legislators continue to engage in strategic tactics by delaying their vote, as found in Glazer, Griffin, Grofman, and Wattenberg's (1995) study of Congressional vote delay.

[5] Thompson suggests that the use of sequential voting in legislatures and presidential primaries is not problematic.

[6] Les Kjos, "Analysis: Early Voting Keeps Booming," *United Press International*, November 1, 2004.

post 2004 survey reported voting before election day, with over 73 percent of the early voters reporting voting more than a week before election day. Although the information about how early voters choose is assumed to be secret, polls and other surveys are used to estimate these choices making it possible for later voters (or those who mobilize them) to know how early voters chose prior to making their own choices. As it is possible to gather the names of early voters from local and state election officials–campaign managers can then easily estimate based on demographics and poll results early voters' choices.[7]

I.3 Related Literature

Although these sequential voting mechanisms are widespread and commonly debated, most formal models of binary-issue voting under incomplete information assume simultaneous voting even when analyzing sequential voting situations. Such an approach has seemed justified by preliminary formal analysis: Dekel and Piccione (2000) show that any symmetric equilibria in simultaneous voting is also an equilibrium in the equivalent sequential voting game; Wit (1997) and Fey (1998) argue that the beliefs necessary for "follow the crowd" or cascade behavior conjectured by Thompson and others are not reasonable. That is, for a cascade to occur a voter must believe that subsequent voters will ignore their choices and therefore they will be indifferent between following the crowd or choosing what the voter believes is the best option when these conflict. As stressed by this literature, one important implication of these results is that the desirable properties of information aggregation in simultaneous elections proven by Feddersen and Pesendorfer [1997] extend to sequential elections and are independent of the order of moves.

As shown by Battaglini (2005), however, these result are sensitive to apparently innocuous assumptions: in more general environments in which voters may abstain and there is an even arbitrarily small cost of voting, simultaneous and sequential voting mechanisms induce distinct equilibrium behavior. Though Battaglini (2005) presents some preliminary results on efficiency, the comparative study of the properties of alternative voting mechanisms is still an open question. Furthermore, Callander (2004) shows that sequential voting can lead to follow the crowd behavior if voters have a conformity bias.

[7] Various campaign managers report in informal communications that such information on who has voted is available and used by campaigns prior to election day to estimate the current vote totals and which voters have not participated. According to one campaign manager in Los Angeles during the mayoral election campaign of 2005 his office provided a series of blank CD's to the Beverly Hills City Clerk and each day she provided them with an updated CD with the latest information downloaded from the city's computer. In some cases availability of the information is required by law, for example under the Pennsylvania Election Code, 25 P.S. §3146(c): "Not less than five days preceding the election, the chief clerk shall prepare a list for each election district showing the names and post office addresses of all voting residents thereof to whom official absentee ballots have been issued ... Upon written request, he shall furnish a copy of such list to any candidate or party county chairman."

Empirical research on the effect of sequential voting on voter behavior, both experimental and nonexperimental, is also surprisingly sparse. Two experimental studies consider sequential voting without abstention: Hung and Plott (2001) and Morton and Williams (1999, 2000). These two studies provide somewhat conflicting conclusions about the extent later voters use early voters' choices to inform their decisions. Hung and Plott investigate sequential voting with a particular concern for the "follow the crowd" behavior. When they included a treatment which induced preference for conformity with monetary incentives, they observe such behavior, as in Callander's model. Morton and Williams find that in sequential voting later voters do sometimes use the information they infer from earlier voting and that these later voters make more informed choices than in simultaneous voting, supporting Thompson's concerns about the unfairness of sequential voting.

While roll call voting in Congress and other legislatures has been extensively studied, we are aware of no studies of such voting that explicitly considers how sequence affects members' decisions. The only nonexperimental empirical research on sequential voting of which we are aware has focused on the effect of early election calls such as in 2000 on later voter turnout [see for example Wolfinger's and Linquiti's (1981) and Jackson's (1983) studies of the 1980 election]. Frankovic reviews the literature, including several unpublished studies of the 2000 election. Despite the fact that some of the analyses, like Jackson's, find an effect, as Frankovic notes the studies either use surveys of voters after the election where a number clearly have faulty memories (some respondents claim to have heard network calls earlier than they were actually made) or the studies use aggregate data on past elections to estimate voter preferences in the election studied to infer an effect on voter behavior. She points out rightly the difficulty from drawing conclusions based on the available data. She also questions the political motivations of some of the recent studies of the 2000 election. She concludes, no doubt happily for CBS, that "there is little evidence of any impact of calling an election before all the polls are closed." Yet she notes that paradoxically, "there is no doubt that the public perceives this to be a serious problem. While the arguments claiming an effect often are politically motivated, and the research does not support the claim, the public believes otherwise." Is the American public crazy as Frankovic suggests? Or does knowing the results of early voting affect later voters' choices as the advocates of electronic voting for the St. Bernard Parish School Board believe and Thompson argues?

The next section presents our model of simultaneous and sequential voting and our theoretical predictions about the effect of sequence in voting. In section III we discuss our experimental design and we examine the individual level data in Section IV. In section V we discuss the efficiency of sequential versus simultaneous voting. We consider the equity of voting order in section VI and section VII concludes.

II Theoretical Analysis

II.1 Voter Preferences and Information

We consider a game with a set $N = \{1, 2, ..., n\}$ of voters who decide by majority rule. There are two alternatives A,B and two states of the world: in the first state A is optimal and in the second state B is optimal. Without loss of generality, we label A the first state and B the second. The voters have identical preferences represented by a utility function $u(x, \theta)$ that depends on the state θ and the action x:

$$v(A, A) = v(B, B) = v$$
$$v(A, B) = v(B, A) = 0$$

where $v > 0$. State A has a prior probability $\pi = \frac{1}{2}$. The true state of the world is unknown, but each voter receives an informative signal. We assume that signals of different agents are conditionally independent and all have the same precision. The signal can take two values a, b with probability:

$$\Pr(a \,|A\,) = p = \Pr(b \,|B\,)$$

where $p > \frac{1}{2}$.

Although we assume that voters have identical preferences and thus if fully informed would agree on a common choice, we can think of the voters as having different preferences over policy goals as given by their signals, but at the same time having common ultimate goals as in other models of elections such as Canes-Wrone, Herron, and Shotts (2001). Battaglini (2005) shows that the distinctions we find between sequential and simultaneous voting also exist when voters have private values.

II.2 Costly Voting and Why the Order of Voting Matters

There is an apparently natural reason why behavior should depend on the order of the voting procedure: when voters can observe previous voters' behavior, they can be influenced by previous choices which may signal private information. This behavior was conjectured by Bikhchandani et al. [1992], Bartels [1988] and others, who saw an analogy between sequential voting and models of information cascades. In a recent contribution, however, Deckel and Piccione [2000] have questioned this reasoning. Their argument is based on the observation that a rational voter would realize that he is influential only when pivotal. In this case, the expected benefit of voting for alternative A for a voter i who votes at stage t after a history h_t and an observed signal $s_i = a$ can be represented as:

$$U(s_i) = \Pr(PIV_i \,| h_t, s_i = a) \cdot v \cdot \left[\Pr\left(A \,| PIV_i, s_i = a\right) - \frac{1}{2} \right] \quad (1)$$

where $\Pr(PIV_i; h_t, s_i)$ is the probability of being pivotal; and $v \cdot \Pr\left(A \,| PIV_i, s_i\right)$ is the expected utility obtained if A wins conditional on being pivotal and on a signal s_i.[8] The probability of being pivotal depends on the signal s_i observed by i and on the particular history of votes cast in the previous stages of the game, but the expected utility is independent of h_t: in the pivotal event, the agent "knows" how all the others have voted, not only those who choose in the previous stages. The voter decides how to vote on the basis of (1): he votes A when it is positive, and votes B when negative. Since $\Pr(PIV_i \,| h_t, s_i = a)v$ is non negative, his choice will be determined by the sign of $\left[\Pr\left(A \,| PIV_i, s_i = a\right) - \frac{1}{2}\right]$: which implies that his choice will be independent of the history, and informational cascades can not occur.

Though logically impeccable, this argument runs against the common perception that the order of voting matters for the outcome. So why should we expect that sequential voting mechanisms are different from simultaneous ones?[9]

An explanation is provided in Battaglini [2005]. When there is a cost of voting c and the agent can abstain, the decision depends on the sign of:

$$\Pr(PIV_i \,| h_t, s_i = a) \left[v \cdot \Pr\left(A \,| PIV_i, s_i = a\right) - \frac{1}{2} \right] - c$$

In this case the decision is determined by the magnitude of $\Pr(PIV_i \,| h_t, s_i)$, which depends on h_t. We should therefore expect to see rates of abstention that depend on the history, and that increase as the probability of being pivotal decreases. This strategic abstention phenomenon also suggests that the set of equilibria and the informational properties of the two elections will also differ: the set of equilibria are disjoint and simultaneous voting should be superior when the size of the election is large enough.[10]

[8] In particular $v \cdot \left[\Pr\left(A \,| PIV_i, s_i = a\right) - \frac{1}{2}\right]$ is the net benefit of voting. Assume that if the agent does not vote then there is a tie. If the agent votes he obtains v with probability $\Pr\left(A \,| PIV_i, s_i = a\right)$ (i.e., the posterior that the state is A given the fact that he is pivotal and he has observed an a signal), and if he does not vote there is a tie and the policy is correct with probability $\frac{1}{2}$. As it can be easily verified, the case in which if the agent does not vote alternative B wins and if he votes A there is a tie is equivalent.

[9] Using a different approach, Gerardi and Yariv (2005) show that a very wide class of voting procedures, including both sequential and simultaneous methods, yield the same set of equilibrium outcomes if voting is preceded by a deliberation stage where the voters can communicate costlessly with each other. This neutrality result does not hold if either deliberation OR voting is costly.

[10] Callander (2004) suggests that the differences between simultaneous and sequential elections can be

In an election this cost straightforwardly represents the cost of the physical time and effort of voting and can also be interpreted as the cost of mobilizing a group of voters to participate. In a legislative situation the cost can be interpreted as the opportunity cost of engaging in other legislative activities–the cost of leaving a meeting of a committee, constituents, or executive officials to cast a ballot in a roll call vote. Legislators are often aware of the progress of voting on contested matters while engaging in other activities and can and do choose whether to return to the chamber. The cost could also be interpreted as a cost of position taking if we assume that these costs are independent of the position taken or the outcome of the voting; that is legislators may see it as desirable to not take any positions on issues. A number of researchers have found evidence that members of Congress, both House and Senate, avoid voting either because of the demands of campaigning or a desire to not to take a policy position [see Thomas (1991), Rothenberg and Sanders (1999, 2000), and Jones (2003)].[11] News accounts complaining of excessive abstention in city councils and other legislative bodies and mandatory rules requiring that members only abstain if they have a conflict of interest also suggests that these members see the act of voting itself as costly.[12]

explained with behavioral assumptions on voters. He assumes that voters prefer to vote for winners, so their decision would depend on the voting history. Such a voter would vote for a winning candidate even if he or she is not pivotal.

[11] These studies examine the abstention or position avoidance by members of Congress over a number of bills. Cohen and Noll (1991) present a case study of Congressional abstention on a series of bills on a single issue and Poole and Rosenthal (1997) analyze aggregate abstention rates as a function of overall legislative ideological preferences.

[12] For example, the Los Angeles Times reported on August 28, 2005 that the Foundation for Taxpayer and Consumer Rights in Santa Monica has become so alarmed at rising abstention rates in the California legislature (according to a study by public policy students at University of Southern California found that the average abstention rate for Democrats in the California Assemby was 32% of Democrats and 13.5% of Republicans) it has drafted a ballot initiative that would withhold the pay of lawmakers on days when they don't vote. An editorial in the San Francisco Chronicle on June 25, 2002 complained about "an outbreak of spinelessness" in the California Assembly and argued: "Members ... are elected to make tough choices and to serve their constituents. And they are elected to vote, as defined by 'yes' and 'no.' Too many ... are not doing their job." Similarly, a December 14, 2004 editorial in the *Birmingham, Alabama News* complained that too many city council members were abstaining on roll calls. An alternative argument may be that legislators' find only incorrect positions costly. However, if this was the case we would expect last voters, who tend to be the chairs or heads of the voting bodies, abstaining less than earlier voters since they may be able to update from earlier voting about the "correctness" of a position. Casual observation suggests that this is not the case. Complainants about abstention in the California Assembly have argued that the increase is related to the use of term limits and that legislators are uncertain about the effect voting records may have on their future prospects independent of the positions that are optimal at the time of voting so find taking any position on an issue costly. One of the reasons why a member of the Auburn City Council of New York wished to changed the rule such that the mayor voted first (discussed in the introduction) was because the mayor had abstained more often than other voters. The councilor argued that the mayor was not doing his job: "I'm doing it to ask him to take a leadership role. He's abstained and said no when it's meaningless." The Birmingham news report cited above singled out the Council President for abstaining 37 times in 2004.

With costly voting, the net utility function of a voter who votes is therefore:

$$u(x, \theta) - c$$

in state θ if option x is chosen. We assume that a voter who decides alone would always prefer to pay the cost and determine the outcome of the election: so $c < \frac{1}{2}(2p-1)v$, where $\frac{1}{2}(2p-1)v$ is the expected utility of voting for A (B) conditional on a a (b) signal. It is therefore convenient to re-parametrize the cost as $c = \frac{\gamma}{2}(2p-1)$, where $\gamma \in (0,1)$.

II.3 The Voting Games

We will consider two game forms, which we call the *simultaneous voting game* and the *sequential voting game*. In both games the outcome is chosen by majority rule and we assume that when A receives the same votes as B, or when all voters abstain, then one of the two alternatives is chosen with probability 1/2.

II.3.1 Strategies

In the simultaneous voting game all voters vote simultaneously. In this case, a (pure) voting strategy for voter i is a map $v_i : \{a, b\} \to [A, B, \phi]$: i.e., given the signal, the voter may vote for A, B or abstain. A mixed strategy assigns a probability of abstaining $\sigma_i(\phi; s_i)$, and, conditional on voting a probability of voting for each alternative, $\sigma_i(x; s_i)$, $x = A, B$. In the simultaneous game we focus on strategies that are not weakly dominated and assume without loss of generality that $\sigma_i(A; a) = \sigma_i(B; b) = 1$.

In the second game form voters vote sequentially. In this case, a strategy is a function $v_i : H_i \times \{a, b\} \to [A, B, \phi]$ where H_i is the set of histories that voter i can observe. In this case too we will denote $\sigma_i(\phi; s_i, h_i)$ the probability that voter i abstains after observing a signal s_i and a strategy h_i; and $\sigma_i(x; s_i, h_i)$ the respective probability of voting for x, conditional on not abstaining.

II.3.2 Equilibrium

An equilibrium of the sequential game (resp. simultaneous game) is *symmetric* if $\sigma_i(\theta; s, h_t) = \sigma_j(\theta; s, h_t)$ for all i,j and all $h_t \in H_t$, and $\theta \in \{a, b, \phi\}$, $s \in \{a, b\}$ (resp. if $\sigma_i(\theta; s) = \sigma_j(\theta; s)$ for all i,j and for $\theta \in \{a, b, \phi\}$, $s \in \{a, b\}$). In this symmetric environment there is no a priori difference between state A and B: it is therefore natural to assume that the names associated with these two states are irrelevant for the strategic considerations of the agents. Let us define $N_a(h_t)$ $(N_b(h_t))$ the number of a (b) votes in a history h_t; and let $H_t^0 = \{h_t \text{ s.t. } N_a(h_t) = N_b(h_t)\}$. After any of these histories the states continue to be symmetric. We define an equilibrium of the sequential game (resp. simultaneous game) to be *neutral* if two requirements are satisfied: i) $\sigma_i(\phi; a, h_t) = \sigma_i(\phi; b, h_t)$ for any $h_t \in H_t^0$ (resp. $\sigma_i(\phi; a) = \sigma_i(\phi; b)$); and ii) $\Pr(\theta | h_t) = \Pr(\theta | h_{t+1})$ for any $h_t \in H_t^0$, $h_{t+1} = \{h_t, \phi\}$, and $\theta = A, B$.[13] Neutrality, therefore requires that if there is no reason imposed by how previous voters have voted to treat the alternatives in a asymmetric way, then their names should be irrelevant for the decision to vote or abstain. In our experiments we find that no significant relationship between voters' choices and the labels of the alternatives.[14] In the rest of the analysis we focus on symmetric, neutral perfect Bayesian Nash equilibrium in undominated strategies; for simplicity we will refer to such an equilibrium as "an equilibrium."

II.4 Equilibrium Characterization

In order to test the theory that when voting is costly sequential and simultaneous voting mechanisms lead to differences in voting behavior and outcomes because of strategic abstention, we first characterize the equilibria. A difficulty with analyzing sequential voting models is that as the number of agents increases the set of equilibria can expand. If we want to test rational behavior, however, we need an environment in which the predictions of the model can be pinned down. To this goal we specialize the model presented in the previous section by assuming that there are only three voters. Therefore, the model may be seen by some as more applicable to legislative roll call settings than to large elections. However, our model can also be thought of as sequential voting in elections where large groups of voters with correlated signals vote sequentially. As we show in the next two sections, under natural conditions, the voting mechanisms generate unique predictions that easily separate behavior in simultaneous and sequential voting procedures.

II.4.1 Simultaneous Voting

The characterization of equilibria in the simultaneous game is simplified by two observations. First, in any Nash equilibrium with undominated strategies voters never vote

[13] Clearly the second requirement is not implied by the first only out of equilibrium.

[14] It is worth pointing out that non-neutral equilibria exist for some voting costs. Consider the case where voting costs are very low and there are three voters. Then there is an equilibrium where voter 1 abstains with an a signal, but votes for B with a b signal. Voter 2 abstains with an a signal if and only if voter 1 abstained, and abstains with a b signal if an only if voter 1 voted B. Voter 3 votes to break ties, voting for A (regardless of signal) to break a $0-0$ tie and voting sincerely in a $1-1$ tie. Voter 3 also votes for A with an a signal if the first voter abstained and the second voter voted for B. We see no evidence of this kind of behavior in our experiment. Reaching such an equilibrium would require some form of pre-play coordination, so that it is common knowledge among all three voters that an abstention by voter 1 implies an a signal. As an illustration, Example 1 in the Appendix constructs a non-neutral perfect Bayesian equilibrium.

against their signal; they either vote sincerely or abstain: therefore, to characterize the equilibrium we only need to determine the abstention probabilities, $\{\sigma_i(\phi; s_i)\}_{i=1}^3$. Second, neutrality implies that $\sigma_i(\phi; a) = \sigma_i(\phi; b) = \sigma_i(\phi)$, and symmetry implies $\sigma_i(\phi) = \sigma_j(\phi) = \sigma(\phi)$ for all i,j. Therefore we can focus on one variable only: $\sigma(\phi)$, and we drop the dependence on ϕ, simply writing it as σ.

The equilibrium value of σ is determined by the cost of voting c and the equilibrium expected benefit of voting, which is balanced againt the expected utility of not voting, so the usual cost benefit calculus applies by conditioning on pivotal events. Consider voter i with a signal $s_i = a$. His vote is pivotal only in three events. First, when no other voter participates, event P_0. This event occurs with probability σ^2; and, in this event, the expected benefit of voting for A is equal to pv and the expected benefit of not voting is simply $\frac{1}{2}$. Hence the expected gain from voting in event P_0 equals $\frac{1}{2}(2p-1)v$, where p is the posterior probability of state A after one signal a. Second, a voter is pivotal when exactly one other player votes, and this player voters B, event P_1. In this case, however, the posterior is $\frac{1}{2}$ because in P_1 there are exactly two opposite signal which offset on the other, so the expected gain from voting is $\frac{1}{2} - \frac{1}{2} = 0$. The third possibility, is when the two other voters vote, and they vote for opposite alternatives, event P_2. In this case, voter i knows that there are two a signals and one b signal. The posterior is:

$$\Pr(A\,|a, P_2) = \frac{\frac{1}{2}p^2(1-p)}{\frac{1}{2}p^2(1-p) + \frac{1}{2}p(1-p)^2} = p$$

and the expected benefit of voting is, again, $\frac{1}{2}(2p-1)v$. From the point of view of i, this event occurs with probability: $\Pr(P_2\,|a) = 2(1-\sigma)^2 p(1-p)$. The expected utility of voting for A for agent i is therefore:

$$u(\text{vote } A\,|a) \equiv \text{EU}(\sigma) = \frac{1}{2}(2p-1)v\left[\sigma^2 + 2(1-\sigma)^2 p(1-p)\right] \tag{2}$$

Comparing with the cost of voting we have a pure strategy equilibrium in which all agents vote when $(2p-1)p(1-p)v \geq c$; we have a mixed equilibrium at any value of $\sigma \in (0,1)$ such that:

$$\text{EU}(\sigma) = c$$

The equilibrium conditions can be easily seen from Figure 1, which represents the right hand side of (2) when $p = 0.75$ and $v = 40$, which are the parameters we use in the experiment. When c is above $\frac{1}{2}(2p-1)v$ there is only a pure strategy equilibrium, $\sigma^* = 1$ with all voters abstaining. When c is between $p(1-p)(2p-1)v$ $(= 3.75)$ and $\frac{1}{2}(2p-1)v$ there is a unique mixed strategy equilibrium that is increasing in c; when c is below the minimum point of the right hand side of (2) (i.e., point $\text{EU}\left(2\frac{p(1-p)}{1+2p(1-p)}\right) =$

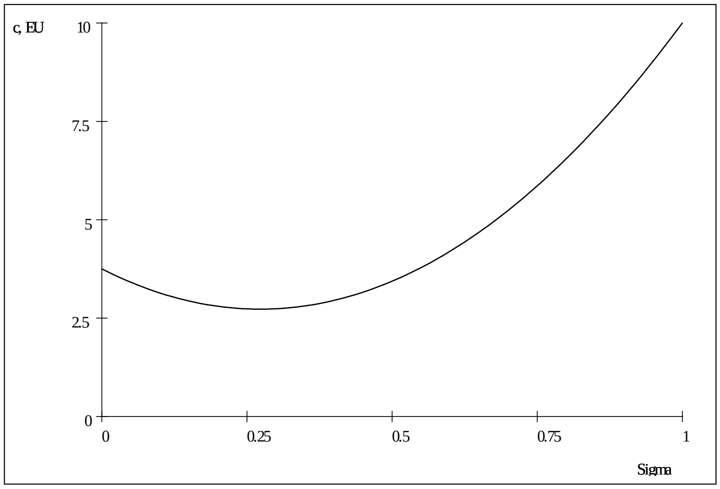


Figure 1: Symmetric Equilibria in the Simultaneous Game

$\frac{p(1-p)}{1+2p(1-p)}\,(2p-1)\,v = 2.7273$), then we can have only a pure strategy equilibrium in which $\sigma^* = 0$. When c is between and $\frac{p(1-p)}{1+2p(1-p)}(2p-1)v$ and $p(1-p)(2p-1)v$, then there are three equilibria: the pure strategy equilibrium $\sigma^* = 0$ and two mixed equilibria. We can summarize these results in the following proposition which characterizes the set of symmetric equilibria in the simultaneous game.

Proposition 1 *When there are three voters:*

i. *If* $c \in \left[0, \frac{p(1-p)(2p-1)}{1+2p(1-p)}v\right)$ *there is a unique pure strategy equilibrium* $\sigma^* = 0$.

ii. *If* $c \in \left[\frac{p(1-p)(2p-1)}{1+2p(1-p)}v, p(1-p)(2p-1)v\right]$ *there are three equilibria: one pure strategy equilibrium* $\sigma^* = 0$, *and two mixed strategy equilibria.*

iii. *If* $c \in p(1-p)(2p-1)v, \frac{1}{2}(2p-1)v)$, *there is a unique mixed strategy equilibrium* $\sigma^* \in (0,1)$

iv. *If* $c \geq \frac{1}{2}(2p-1)v$, *there is a unique pure strategy equilibrium* $\sigma^* = 1$

II.5 Sequential Voting

In a sequential game the action of an agent affects the outcome in two ways. First, we have a direct effect: given the vote of the others, a vote in favor of an option increases its plurality. But the vote of early voters has an indirect influence on later voters as well: the vote signals the voter's information to the remaining voters. This allows information to be leaked in a way that is not possible with simultaneous voting, and this leakage may lead to efficiency gains since later voters will rationally (and efficiently) abstain after some sequences of decisions by earlier voters.

We focus on *sincere equilibria* in which no voter votes against his own signals. While there can exist equilibria where early voters vote *against* their signals, they are intuitively implausible, inefficient, and not observed in our experiments.[15] At least one sincere equilibrium always exists, and it is unique in the three-voter case we are considering here. The following proposition summarizes the unique path of equlibrium play as a function of the voting cost, and informativeness of the signal.

Proposition 2 *When there are three voters there exists a unique sincere, neutral equilibrium path, for all voting costs, and this equilibrium is in pure strategies. The equilibrium path is as follows:*

i. *if* $c \in \left[p(1-p)(2p-1)v, \frac{1}{2}(2p-1)v\right]$*, the first two voters abstain and the third voter votes (sincerely);*

ii. *If* $c \in [0, p(1-p)2p-1)v]$*, the first voter votes (sincerely), the second voter votes only if the first voter has voted and he has a different signal than the first voter; and the last voter only if the first two voters vote for opposite alternatives or if no voter votes before. All voters vote informatively when they vote.*

Off the equilibrium path behavior is a bit more complicated. Table 1 below shows equilibrium strategies at all information sets in which the voter received an a signal including the off the equilibrium path strategies that support these two equilibria.[16] Case i is referred to as "high cost" and case ii is "low cost." Notice that the only difference between the two equilibria is whether the first voter abstains or votes. The equilibrium

[15] Insincere equilibria may exist, as shown in Example 2 in the appendix.

[16] Equilibrium strategies following b signals are analogous.

behavior strategies at all other nodes remain the same.

Table 1. **Equilibrium Abtension Rates**			
Sequential Voting Game			
Information Set		**Equilibrium Strategy**	
Voter	**History**	**High Cost**	**Low Cost**
1		1	0
2	Abstain	1	1
2	A	1	1
2	B	0	0
3	Abstain, Abstain	0	0
3	Abstain, A	1	1
3	Abstain, B	1	1
3	A, Abstain	1	1
3	B, Abstain	1	1
3	A,A	1	1
3	B,B	1	1
3	B,A	0	0
3	A,B.	0	0
Simultaneous Voting Game			
Symmetric Equilibrium		.89	0

II.6 Theoretical Implications for Efficiency and Equity

Propositions 1 and 2 present a clear characterization of the equilibria. When $c < \frac{p(1-p)(2p-1)v}{1+2p(1-p)}$ and $c > p(1-p)(2p-1)v$, we have a unique equilibrium in the simultaneous and in the sequential models and these equilibria are different. In particular:

- When $c > p(1-p)(2p-1)v$ there is a unique equilibrium of the simultaneous game in which the voters obtain with probability $\Xi^{-1}(c) \in (0,1)$ and vote informatively with the complementary probability. In the sequential game there is a unique equilibrium in pure strategies in which only the last voter votes in equilibrium, as described in point *i.* of Proposition 2.

- When $c < \frac{p(1-p)(2p-1)v}{1+2p(1-p)}$ there is a unique equilibrium of the simultaneous game in which the voters vote informatively and never abstain. In the sequential game there is a unique equilibrium in pure strategies as described in point *ii.* of Proposition 2.

In the rest of the paper we focus on parameters only in these two regions to avoid multiplicity of equilibria. We refer to the first case as the high cost case and to the second case as the low cost case.[17] Given this, we should expect very different behavior between

[17] See Section II.4 for the specific parameters chosen in the experimental design.

simultaneous and sequential elections, and given the voting mechanism between high and low costs. In particular:

- In simultaneous elections, we should expect the probability of abstention to be decreasing in the cost of voting: the probability should be positive in the high cost region and zero in the low cost region.
- Sequential elections with high costs should be characterized by free riding from early voters who should abstain counting on the participation of late votes. In sequential elections with low costs the opposite should occur: the first voter should always vote and late voters should vote only if they find it optimal to correct the choice of earlier voters and if they are pivotal.

These difference have an impact on the theoretical efficiency and equity properties of the voting mechanisms as well as noted in the Introduction. With respect to equity, in a symmetric equilibrium all voters obtain the same expected utility, in the sequential mechanism expected utility depends on the stage in which the agent votes. When the cost is high and the early voters free ride, late voters receive a lower utility level; in a low cost regime, on the contrary, late voters benefit from the participation of early voters obtain and higher expected utility. The predictions with respect to efficiency will be discussed in greater details in Section IV where we develop the appropriate benchmark case for efficiency: here we note that when the cost is low we should expect lower abstention than with high voting costs: and, therefore, we should expect a more efficient collective when the cost of voting is low.

III Experimental Design

The experiments were all conducted at a major research university and used students from that university. All the laboratory experiments used $p = 0.75$ and $v = 40$ cents. We used two different treatments for the cost of voting: $c = 8$ cents and $c = 2$ cents. As noted above, these parameters allow us to have distinctive predictions about voter behavior, efficiency, and equity. Table 1 summarizes the predictions according to the cost parameters. Six sessions were conducted, each with either 9 or 12 subjects.[18] Each subject participated in exactly one session. Each session was divided into two half-sessions, each of which lasted for 20 rounds and the treatments were different in the two sessions. Table 2 summarizes all the sessions.

[18] Each session included one additional subject who was paid \$20 to serve as a monitor.

Table 2: Experimental Design			
Session	**First 20 rounds**	**Second 20 rounds**	**#Subjects**
1	High Cost Simultaneous	Low Cost Sequential	9
2	Low Cost Simultaneous	High Cost Sequential	12
3	Low Cost Sequential	High Cost Simultaneous	12
4	High Cost Sequential	Low Cost Simultaneous	12
5	High Cost Sequential	Low Cost Sequential	12
6	Low Cost Sequential	High Cost Sequential	12

Subjects were randomly divided into groups of three for each round and in the sequential voting treatments were randomly assigned within each new group voting positions (first, second, or third voter). Instructions were read aloud and subjects were required to correctly answer all question on a short comprehension quiz before the experiment was conducted. Subjects were also provided a summary sheet about the experiment which they could consult. The experiments were conducted via computers.[19] Subjects were told there were two possible jars, Jar 1 and Jar 2. Jar 1 contained six red balls and two blue; jar 2 contained six blue balls and two red. For each group, one of the jars was randomly selected by the computer, with replacement. The balls were then shuffled in random order on the each subject's computer screen, with the ball colors hidden. Each subject then privately select one ball by clicking on it with the mouse and thereby reveal its color to that subject only. The subject then chose whether to vote for the jar 1, vote for jar 2, or abstain. If the majority of the votes cast by the group were for the correct jar, each group member, regardless of whether he or she voted, received a payoff of 50 cents (minus the cost of voting if they voted). If the majority of the votes cast by the group were incorrect guesses, each group member, regardless of whether he or she voted received, a payoff of 10 cents (minus the cost of voting if they voted). Ties were broken randomly. This was repeated for 40 rounds, with the group membership shuffled randomly after each round. Each subject was paid the sum of his or her earnings over all 40 rounds in cash at the end of the experiment. Average earnings were approximately $25, with each session lasting about 90 minutes.

[19]The computer program used was similar to Guarnaschelli, McKelvey, and Palfrey (2000) for jury decision making experiments without abstention, rewritten as an extension to the open source Multistage game software. See http://multistage.ssel.caltech.edu. The extension was developed by Christopher Crabbe at the Princeton Laboratory for Experimental Social Science (PLESS).

IV Experimental Results

IV.1 Individual Choices: Does Sequence Matter?

IV.1.1 Simultaneous Voting Choices

Our theoretical analysis of simultaneous voting suggests that we should see zero abstention in the low cost treatment and positive abstention in the high cost treatment. Table 3 summarizes the voting choices of participants in the simultaneous voting games. Of the 900 individual voting decisions in the simultaneous voting games, only 17 (<2%) were votes against a subject's signal and of these 11 were cast by two subjects in the low cost treatment. We drop those cases from the analysis in this paper. Abstention was significantly higher in the high cost treatment than in the low cost games (67.86 percent compared to 38.96 percent).

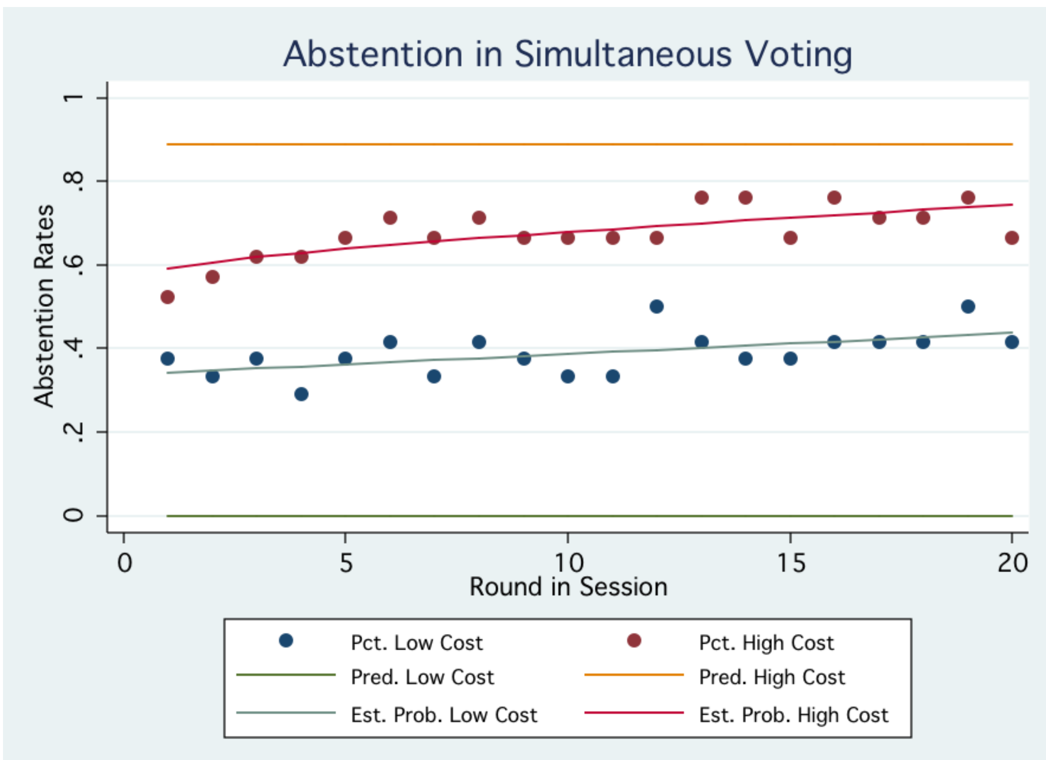
Table 3: Voter Choices in Simultaneous Voting Games

	Low Cost	High Cost	Total
Abstained	.39	.68	.52
Voted Signal	.58	.31	.46
Voted Contrary to Signal	.029	.007	.019
Total Observations	480	420	900

Table 4 below presents a multinomial probit maximum pseudo likelihood estimation of simultaneous voting choices by round and cost treatment. The standard errors have been adjusted for correlation by subject.[20] From Table 4 we calculate the effect of the difference in cost and how this difference changes by round. Abstention increases by round, although to a greater extent in the high cost treatments. A voter in the first round in the low cost treatment is estimated to abstain with probability of 34 percent while a voter in the first round of the high cost treatment is estimated to abstain with a probability of 59 percent. In the 20th round of the low cost treatment a voter is estimated to abstain with probability of 44 percent while the probability of the voter abstaining in the same round in the high cost treatment is estimated at 74 percent. Although increasing abstention for the high cost treatment might demonstrate learning, increasing abstention is contrary to the prediction for the low cost treatment. Figure 2 below shows the relationship between actual abstentions, predicted abstentions, and the probability of abstaining as estimated from the multinomial probit by round and cost treatment.

[20] See Wooldridge (2002) pages 500-503 for a discussion of multinomial probit. Estimation in Stata 9 with observations clustered by subject.

Table 4: Multinomial Probit of Simultaneous Voter Choices				
Null Case Abstention in Low Cost 1st Round				
(Std. Err. adjusted for 45 subject clusters, 900 observations)				
Equation 1: Voting Signal				
Variable	**Coef.**	**Robust Std. Err.**	**z**	**P>|z|**
High Cost	−0.93	0.47	−2.03	0.043
Round in Low Cost	−0.02	0.01	−1.63	0.10
Round in High Cost	−0.03	0.01	−1.92	0.055
Constant	0.51	0.32	1.61	0.11
Equation 2: Voting Contrary to Signal				
High Cost	−0.38	0.65	−0.59	0.56
Round in Low Cost	−0.02	0.03	−0.75	0.45
Round in High Cost	−0.20	0.02	−9.22	0
Constant	−1.46	0.47	−3.12	0
Log Pseudolikelihood	−649.90			



Firgure 2: Probability of Abstaining in Sequential Voting

Quantal Response Equilibrium Predictions As is clear from Figure 2, we find little support for the exact quantitative Nash equilibrium predictions in simultaneous voting: low cost voters abstain significantly more than predicted, and high cost voters abstain significantly less than predicted. However the Nash solution assumes voters behave perfectly rationally with no error. Given the complexity of the game they are playing, such a strong assumption seems implausible. An alternative approach, following McKelvey and Palfrey (1995, 1998), is to consider a statistical version of Nash equilibrium in which we assume that for each actor all possible actions have a positive probability but that the probabilities are ordered by the expected payoffs of the actions according to a quantal response function, which is a statistical version of a best response function. Of course, these responses will also be influenced by the probability distribution chosen by the other players in the game and so on. A QRE is the fixed point of this iterative process. To simplify computations, we consider QRE of only the simplified version of the simultaneous voting game in which players choose either to vote sincerely or to abstain. In order to provide parametric estimates, we use the logit specification of QRE, where the quantal response functions are logit curves and λ is the response parameter. When $\lambda = 0$, the response curves are flat and all strategies are used with equal probability, or zero rationality. As λ approaches ∞, the logit response curves converge to the best response curves or perfect rationality. Thus, the Nash equilibrium predictions correspond to a boundary case of the QRE model.

Table 5 presents our estimates of the logit QRE, computed using the voting decisions of subjects in the simultaneous voting games. We estimated three values of λ, one where λ is constrained to be equal across cost treatments and two unconstrained values of λ by cost treatment, λ_H and λ_L for high and low cost treatments respectively. We find little change in the values of λ_H and λ_L over time, except for some apparent convergence towards each other (and to the constrained value). For all rounds, using a likelihood ratio test, the difference between λ_H and λ_L is not significant at the 5% level (the χ^2 statistic equals 2.9) and for the last ten rounds we find the difference not significant at any conventional level (the χ^2 statistic equals 1.2). This finding suggests that a unique parameter can explain behavior of the subjects in seemingly remarkably different strategic environments since, as seen above, the equilibria are extremely different in the high and low cost treatments. Figure 3 presents the relationship between the probability of abstaining and the equilibrium values of λ for both the low and high cost treatments along with the estimated values for our treatments.

Table 5: QRE Pooled Estimation: Simultaneous Game					
Cost	**Abstention Rate**		**λ**	**Log Likelihood**	
	Data	**QRE**			
High	0.68	0.68	0.25	263.74	Unconstrained
Low	0.39	0.39	0.49	320.91	Unconstrained
High	0.68	0.70	0.30	586.10	Constrained
Low	0.39	0.42	0.30	586.10	Constrained
Constrained model not rejected ($p = .05$)					

Figure 3 here

IV.1.2 Sequential Voting Choices

In the sequential voting games we expect to find two types of strategic abstention:

- In the low cost treatment, we predict that later voters will strategically abstain when they are not pivotal, voting sincerely otherwise.
- In the high cost treatment, we predict that early voters will strategically abstain, leaving the choice for later voters. If early voters do vote, later voters will choose sincerely if pivotal, otherwise they will strategically abstain.

As predicted, subjects' choices in the sequential voting treatments depended not only on the cost of voting but their position in the voting order and the choices made by previous voters. Table 6 summarizes the aggregate abstention rates at all information sets. We pool observations for voters with a and b signals. In the history column, "V" indicates that a previous voter voted for the alternative *consistent* with the current voter's signal, and "N" indicates that a previous voter voted for the alternative *inconsistent* with the current voter's signal. Out of 1860 voting decisions, we observed only 27 (<1.5%) cases where voters voted against their signal, and these were scattered randomly across the information sets. We drop those cases from the analysis in this paper, and the abstention rates are computed accordingly. We discuss the results of the table in the reverse order of voting. This is also summarized in Figure 4 (the predicted strategies are highlighted in bold), which combines several histories. For example, NV and VN histories are combined because the theory makes identical predictions.

Table 6. Abstention Rates in the Sequential game									
Voter	**History**	**Low Cost**				**High Cost**			
		Data	Nash	QRE	# Obs	Data	Nash	QRE	# Obs
1		.34	0	.46	298	.47	1	.63	309
2	Abstain	.39	1	.51	99	.51	1	.61	140
2	V	.72	1	.55	128	.87	1	.70	105
2	N	.41	0	.29	71	.69	0	.68	67
3	Abstain, Abstain	.31	0	.19	39	.33	0	.44	72
3	Abstain, V	.94	1	.59	34	.95	1	.72	37
3	Abstain, N	.63	1	.59	27	.65	1	.72	34
3	V, Abstain	.99	1	.59	79	.93	1	.72	82
3	N, Abstain	.69	1	.72	42	.71	1	.74	55
3	V,V	1.00	1	.59	23	.88	1	.72	8
3	N,N	1.00	1	.59	12	1.00	1	.72	7
3	V,N	.24	0	.19	17	.36	0	.44	14
3	N,V	.32	0	.19	25	.56	0	.44	9
		All Periods		Periods 11-20		All Periods		Periods 11-20	
	Lambda	0.19		0.16		0.13		0.16	
	Log Likelihood	−582.41		−281.73		−593.15		−286.90	
	Constrained Lambda	0.15		0.16					
	Log Likelihood	−1178.00		−578.63					

Figure 4 here

Third Voters' Choices We predict that third voters will strategically abstain if their votes are not pivotal. Table 6 displays third voter choices for each history of the first two voters and as a function of the third voter's signal. As with simultaneous voters, only 4 out of 620 voting choices were contrary to third voters' signals. Thus we find essentially no evidence of "follow the crowd" behavior or information cascades, even when third voters are not pivotal. Third voters are significantly more likely to abstain when it is clear that their vote is irrelevant in both the high and low cost treatments–in 270 of the 283 cases (95.4%) where voting their signal would not have altered the outcome third voters abstained. Although theory predicts well voting behavior in such cases, it performs less well in predicting voter choices in situations where their votes are pivotal and we would expect third voters to vote. That is, when both voters 1 and 2 abstain, third voters vote only in 75 out of 111 cases (67.57%) and when voters 1 and 2 votes conflict, third voters vote only in 22 of 67 cases (67.16%).

Second Voters' Choices We make the following predictions about second voter behavior: In both the low and high cost treatments, we predict second voters to strategically abstain if first voters voted their signals or if first voters abstained, and to vote sincerely if first voters voted contrary to their signals.

The decisions of voter 2 in the sequential games is displayed in Table 6, broken down by the decision of voter 1 and the signal of voter 2.

As above, we find few voters voting contrary to their own signals, ten out of 620 voting choices. In the low cost treatment, second voters abstain significantly more than simultaneous voters [t statistic of 3.94] and first voters [t statistic = 5.04]. In the high cost treatment, there is no significant difference between simultaneous voters' abstention choices and second voters' [t statistic = 0.73], but second voters do abstain significantly more than first voters [t statistic = 5.27]. These results reflect the fact that we find strong evidence of strategic abstention when first voters vote second voter's signals. When first voters abstain, however, second voters in the low cost treatment are more likely to vote than abstain while second voters in the high cost treatment are largely indifferent between voting and abstaining. When first voters vote contrary to the second voter's signal, low cost voters are more likely to vote than abstain, while high cost voters are more likely to abstain than vote.[21]

Callander (2004) shows that if voters have comformist preferences, then in a three voter game such as ours, if an information cascade occurs, second voters would vote contrary to their signals when first voters' choices are contrary to second voters' signals. We find little evidence of such behavior by second voters, suggesting that preference conformity, to the extent that it may exist, is dwarfed by the cost of voting even in the low cost case. Second voters are in fact less likely to vote contrary to their signals under such cases. Second voters' votes are the same as first voters' votes only 20.32 percent of the time and of those only 1.96 percent (1 lone observation) are cases where second voters voted contrary to their signal.

First Voters' Choices We predict that first voters will choose sincerely in the low cost treatment and abstain in the high cost treatment. Table 6 summarizes the choices of voter 1 in the sequential games by cost treatment, and provides a comparison to the simultaneous move games.

[21] We also find, but do not report in the table, that second voters are more likely to abstain in both high and low cost treatments in the later rounds.

Table 7: First Voter Choices			
	Low Cost	**High Cost**	**Total**
Abstained	.33	.45	.39
Voted Signal	.67	.52	.59
Voted Contrary to Signal	.007	.03	.02
Total Observations	300	320	620
High versus Low Cost Abs.	t statistic = 2.99		
Seq. versus Simul. in Low Cost	t statistic = 1.6		
Seq. versus Simul. in High Cost	t statistic = 6.35		

As above, few first voters voted contrary to their signal, only 13 out of 620 voting choices. Also as with the voters in the simultaneous voting games, first voters abstained significantly more in the high cost treatment than in the low cost treatment. However first voters in the sequential voting games are significantly less likely to abstain than voters in the same simultaneous cost treatment, and this difference is highly significant in the high cost treatment. Thus, while cost increases abstention, as predicted, first voters in the high cost treatment abstain far less than theoretically predicted. Most first voters do not strategically abstain in the high cost sessions (that is, pass the choice on to later voters). We also find little evidence of changing abstention rates by first voters during the experiment. A multinomial probit estimation similar to Table 4 with corrected standard errors for subject clustering shows that round has an insignificant effect on first voter abstention rates.

QRE and Sequential Voting As with the simultaneous voting game, we also estimate the QRE for the simplified sequential voting game (where voters either vote their signals or abstain); the results from that estimation is presented in Table 6. As in the QRE estimation of the simultaneous game, the assumption is that voters use a statistical version of a best response function (a logit) and we solve for the fixed point of the sequential logit QRE game. As above, λ is our measure of voter response, where higher values of λ imply higher degrees of rationality. We report the estimate where λ is constrained to be the same for both low and high cost sessions as in the simultaneous voting game analysis, and also report the separate estimates. Figures 5a,b,c display the logit equilibrium correspondences for the sequential game for both low and high cost treatments with unconstrained values of λ. Figure 5a displays the correspondences for player 1, Figure 5b for player 2, and Figure 5c for player 3. Note that in Figures 5b,c the equilibrium correspondences depends on the voter's information set. As in the simultaneous voting analysis, we find a lack of significant difference between λ_H and λ_L, and an apparent convergence over time. For all rounds the likelihood ratio test the χ^2 statistic equals 4.88 which is barely significant, but for the last ten rounds the χ^2 statistic is less than 0.01. As with the simultaneous game, this fact suggests that only one parameter estimate can explain behavior in quite different strategic environments. That is, just one parameter explains behavior at different nodes of the game in which subjects are in different stages of voting and information sets.

Figures 5a,b,c about here

Summary of Sequential Voting Choices As the analysis above shows we can conclude the following:

- We find weak evidence of strategic abstention by early voters. First voters do abstain more under the high cost treatment, passing the choice on to later voters, but abstain less than simultaneous voters facing the same cost. First voters respond significantly to expected utility gains from voting.
- We find strong evidence of strategic abstention by later (third) voters when they are not pivotal and second voters "passing" on voting when first voters' choices agree with their signals.
- We find little evidence of "follow the crowd" or information cascades. Second voters either vote their signal or abstain if first voters vote contrary to second voters' signals and third voters abstain rather than vote when first and second voters' choices agree.
- We find that one parameter can explain voters' choices.

V Efficiency of the Voting Mechanisms

V.1 Informational Efficiency: How Accurate are Decisions?

As noted in the Introduction, we distinguish two different kinds of efficiency, informational and economic. First we consider the informational efficiency of the simultaneous and sequential voting games. Informational efficiency is simply defined as decision accuracy, without consideration for the deadweight loss of voting costs. What fraction of the time does the committee make the right decision?

To answer this question and allow comparison with a benchmark, we construct two indices of accuracy. The "optimal" voting mechanism from the standpoint of informational efficiency is a *full information mechanism*, where all voters always vote their signal. For the parameters of our experiment, the best the committee can do on average is to vote correctly with ex ante probability $\frac{27}{32} = .84$. Conditional on the actual signal draws, the best possible decision accuracies are $(.96, .75)$ depending on whether three or two of the committee member's signals agreed with each other, respectively. Using this as a benchmark, we compute an empirical measure of decision accuracy (DA) for each treatment and each combination of signals. The score, S, is simply the fraction of actual decisions that match the decision that would have been made in the full information mechanism, given the committee members' actual signal draws.[22]

Table 8 below reports displays the fraction of actual decisions that were ties, the fraction that were the same as the full information decision (the column labeled FI), and the decision accuracy score, broken down by treatment and whether the committee has 2 agreeing signals or 3 agreeing signals.[23]

As one would expect, in cases where all three voters received the same signal as compared to the cases where only two voters received the same signal, the group decision was significantly more likely to coincide with full information, and there are fewer ties in those cases. Also noteworthy is the frequency of ties, and how it varies with the voting cost and the voting mechanism. Theoretically, the frequency of ties should be highest in the simultaneous high cost, next highest in simultaneous low cost, and lowest in the sequential treatments. This is exactly what happens.[24] Table 9 presents comparisons of informational efficiency across treatments, by computing the difference in scores ($\mathbf{\Delta DA}$). In equilibrium, decision accuracy should decrease with the cost of voting, and should be higher in the sequential mechanism than in the simultaneous mechanism. Indeed the signs for all 15 comparisons are consistent with these equilibrium predictions, and 10 of these differences are significant at p = .05 or less.

Summarizing, the three main findings about informational efficiency are:

1. Increasing the cost of voting reduces informational efficiency holding the type of voting mechanism constant with the exception of the simultaneous voting games where only two voters' signals agreed.

2. Sequential voting is more informationally efficient than simultaneous voting for both high and low voting costs, but the difference is only significant when all three signals

[22] The optimal mechanism never has ties, but the data does. In fact, we observe a $0-0$ tie in ten percent of the elections. In the data, we count each tie as "1/2 success" in computing the score.

[23] For the rest of the paper, we do not drop observations where subjects voted against their signals. If we had dropped them, the efficiency scores would be higher.

[24] In fact, theoretically there should be no ties in the sequential mechanism, where we observe them in about $one-sixth$ of elections.

agree.

3. The most informationally efficient voting mechanism is the low cost sequential voting game and the least informationally efficient mechanism is the high cost simultaneous game. The difference in efficiency between the two is estimated to be 13 percent across all cases, 17 percent when all three signals agree, and 12 percent when only two signals agree.

Table 8: Decision Accuracy

Treatment	**Group Signals**	*Ties*	*FI*	*DA*
Simultaneous Low Cost	All	.24	.68	.80
	3 Sigs. Agree	.08	.90	.94
	2 Sigs. Agree	.33	.55	.71
Simultaneous High Cost	All	.34	.55	.73
	3 Sigs. Agree	.29	.68	.82
	2 Sigs. Agree	.38	.45	.64
Sequential Low Cost	All	.16	.77	.85
	3 Sigs. Agree	.02	.98	.99
	2 Sigs. Agree	.25	.64	.76
Sequential High Cost	All	.19	.68	.77
	3 Sigs. Agree	.10	.87	.92
	2 Sigs. Agree	.27	.53	.66

Table 9: Statistical Comparisons of Informational Efficiency

Cases	**Comparison Treatment Pair***	**ΔDA**	**t statistic**
All Cases	Low Sim. > High Sim.	.08	2.05
	Low Seq. > High Seq.	.08	3.03
	Low Seq. > Low Sim.	.05	1.7
	High Seq. > High Sim.	.05	1.44
	Low Seq. > High Sim.	.13	3.89
3 Sigs. Agree	Low Sim. > High Sim.	.12	2.86
	Low Seq. > High Seq.	.08	3.67
	Low Seq. > Low Sim.	.05	2.01
	High Seq. > High Sim.	.09	2.32
	Low Seq. > High Sim.	.17	4.8
2 Sigs. Agree	Low Sim. > High Sim.	.07	1.3
	Low Seq. > High Seq.	.09	2.41
	Low Seq. > Low Sim.	.05	1.09
	High Seq. > High Sim.	.02	0.49
	Low Seq. > High Sim.	.12	2.42

V.2 Economic Efficiency

V.2.1 The Optimal Mechanism

In order to evaluate the *economic efficiency* of the sequential and simultaneous voting mechanisms it is useful to define a slightly different optimal mechanism as a benchmark. For informational efficiency, since cost was not an issue, the efficient mechanism was simply the one that minimized the probability of a mistake, which we called FI. For economic efficiency, we use as a benchmark the outcomes that would result if all players played the unique neutral equilibrium of the sequential voting game (which is always more efficient than the symmetric equilibrium of the simultaneous game).[25] In the low cost game, in that equilibrium, the first voter votes informatively, the second voter votes only if he has a signal different from the first agent's vote, and the last voter votes informatively (and decides the outcome) only to break a tie. For high voting costs, this is not the correct benchmark. Specifically, as shown in Proposition 2, if $c \in [p(1-p)(2p-1)v, (p-.5)v]$ then the unique neutral equilibrium is for only the last voter to vote and the others to abstain, for all signal profiles.[26] We call the benchmark efficiency E^*. Table 10 shows the voting decisions and outcomes that result in this equilibrium for each of the eight possible profiles of signals by the three committee members.

Table 10: Efficient Outcomes (E^*)

			Low Cost				**High Cost**			
Signals			**Votes**			**Outcome**	**Votes**			**Outcome**
Voter #			**Voter #**				**Voter #**			
1	2	3	1	2	3		1	2	3	
a	a	a	A	ϕ	ϕ	**A**	ϕ	ϕ	A	**A**
a	a	b	A	ϕ	ϕ	**A**	ϕ	ϕ	B	**B**
a	b	a	A	B	A	**A**	ϕ	ϕ	A	**A**
a	b	b	A	B	B	**B**	ϕ	ϕ	B	**B**
b	a	a	B	A	A	**A**	ϕ	ϕ	A	**A**
b	a	b	B	A	B	**B**	ϕ	ϕ	B	**B**
b	b	a	B	ϕ	ϕ	**B**	ϕ	ϕ	A	**A**
b	b	b	B	ϕ	ϕ	**B**	ϕ	ϕ	B	**B**

Note that in the low cost treatment these outcomes are informationally efficient, that is the decision always coincides with the full information decision. Furthermore, it minimizes the expected number of votes required to do so in a sequential voting game, since voters 2 and 3 only have to vote half the time, that is, they vote if and only if voter 1 and voter 2 received different signals.[27]

[25] The choice of a benchmark does not affect our results. Other benchmarks yield similar conclusions.

[26] If $c > (p - .5)v$ then it is efficient (and an equilibrium) for everyone to abstain.

[27] Non-neutral equilibria can do better, as demonstrated by the equilibrium constructed in Example 1.

Several other features of the efficient benchmark for our experimental parameters are worth noting. First, for low costs, the outcome can never be achieved as an equilibrium of the simultaneous voting game, even if we were to allow for asymmetric equilibria of the simultaneous game. The reason is that voter 2's voting decision is conditional on voter 1's decision. The simultaneous mechanism can be optimal for higher costs. If costs are very high ($> pv - .5$ in our setting) then the efficient mechanism is just random, with no voting at all. For slightly lower costs, it is efficient to always have exactly one voter for every profile, in which case the asymmetric equilibria of the simultaneous game produce efficient outcomes for some costs. However, in these cost ranges, there is always an equilibrium of the sequential move game that achieves the efficient outcome. In this sense, the sequential mechanism *dominates* the simultaneous mechanism over *all* cost ranges. If asymmetric equilibria are ruled out, this domination is strict, except in the very high cost range where nobody ever votes.

Second, the outcome could never arise from a two stage voting game, because voter 3's voting decision is contingent on *both* voter 1 and voter 2's decisions. Finally, notice that the efficient benchmark does not have ties. There is an odd number of votes cast for every signal profile. We conjecture that this is a property of efficient mechanisms, more generally.

V.2.2 Empirical Economic Efficiency

As a measure of economic efficiency we compare the average group payoffs of voters with the payoffs they would receive under the efficiency benchmark E^*. In order to compare the realized payoffs with the efficient payoffs we calculate the expected group payoffs given the realized signals and group voting choice. Note that these are the expected payoffs before the realization of the state A or B so that any randomness in the state, conditional on signal draws, that might benefit a particular treatment does not affect our comparisons. When we calculate the group optimal benefits for comparisons, we use the expected weight across all sequences of signal draws rather than the realized voting order effects in the sequential voting treatments so that our comparisons can be made across voting mechanisms. We also normalize benefits relative to a natural *lower* bound, given by the random mechanism, which is correct 50% of the time and is costless. The expected benefits reported in the E(B) column is equal to the realized experimental payoffs minus the expected payoffs under the random mechanism. Finally, as with informational efficiency, we report the efficiency measure for the two different signal configurations (3 agree and 2 agree). Table 11 presents a summary of the expected group payoffs as compared to the efficient group payoffs. The last column reports a simple measure of efficiency, which is the ratio (r_{E^*}) of the actual net benefit to the optimal net benefit. Figure 6 presents the information in Table 11 by voting game and cost treatment graphically.

Table 11: Group Mean Benefits and Costs Summary*							
	Actual			**Optimal** (E^*)			r_{E^*}
Signal profiles	**E(B)**	**Cost**	**Net**	**E(B)**	**Cost**	**Net**	
Simultaneous Low							
All	30.48	3.66	26.82	39.80	3.65	36.15	.74
3 Sigs. Agree	49.32	3.77	45.55	55.71	2	53.71	.85
2 Sigs. Agree	18.86	3.60	15.26	30.00	4.67	25.33	.60
Simultaneous High							
All	23.45	7.71	15.74	30.25	8	22.25	.71
3 Sigs. Agree	35.94	7.87	28.07	55.71	8	47.71	.59
2 Sigs. Agree	13.51	7.59	5.92	10.00	8	2.00	.49
Sequential Low							
All	35.44	2.83	32.61	40.2	3.61	36.59	.89
3 Sigs. Agree	54.78	2.44	52.32	55.71	2	53.71	.97
2 Sigs. Agree	22.73	3.09	19.64	30.00	4.67	25.33	.78
Sequential High							
All	28.84	9.68	19.16	29.43	8	21.43	.89
3 Sigs. Agree	46.29	8.59	37.70	55.71	8	47.71	.79
2 Sigs. Agree	15.94	10.48	5.46	10.00	8	2.00	2.73

Figure 6 about here

Table 12 presents statistical comparisons. As with informational differences, we find that the net expected benefits are significantly higher when voting costs are low in both the simultaneous and sequential voting games. We also find that net expected benefits are greater in the sequential voting games compared to the simultaneous ones, although the difference is not significant when voting costs are low and when voting costs are high and only two signals agree.

Table 12: Statistical Comparisons of Economic Efficiency			
		Net E(Ben.)	
Cases	**Comparison**	**Diff.**	**t statistic**
All Cases	Low Sim. > High Sim.	11.08	3.40
	Low Seq. > High Seq.	13.44	5.78
	Low Seq. > Low Sim.	5.76	2.16
	High Seq. > High Sim.	3.43	1.15
	Low Seq. > High Sim.	16.88	5.99
3 Sigs. Agree	Low Sim. > High Sim.	17.48	4.13
	Low Seq. > High Seq.	14.64	6.46
	Low Seq. > Low Sim.	6.79	2.60
	High Seq. > High Sim.	9.63	2.39
	Low Seq. > High Sim.	24.27	7.03
2 Sigs. Agree	Low Sim. > High Sim.	9.35	2.39
	Low Seq. > High Seq.	14.17	4.93
	Low Seq. > Low Sim.	4.37	1.34
	High Seq. > High Sim.	−0.46	−0.13
	Low Seq. > High Sim.	13.71	3.96

V.3 Can Subsidizing Voting Increase Economic Efficiency?

Given that cost significantly reduces payoffs for voters, could the increase in payoffs from reducing the cost of voting offset the cost of the subsidy?[28] Using the data from the observed behavior of subjects when the cost of voting is 2, we calculated the net expected benefit from subsidizing those who voted by 6. That effectively reduced the cost of voting for those subjects to 2. To compute hypothetical expected payoffs with a subsidy, we assume that the voters from the $c = 8$ treatment, *with a subsidy equal to 6*, would vote with the same probabilities as the voters did in our $c = 2$ sessions. We compare those hypothetical average payoffs (minus the subsidies) to the average net payoff in the $c = 8$ committees.

The results from the analysis are presented in Table 13. The results are mixed. When all three signals agree, subsidizing voting in both the simultaneous and sequential voting games results in a significant higher net expected benefit in the low cost voting games than in the high cost games, but the opposite occurs when only two signals agree (an effect that is only significant in the simultaneous voting game) so that for all cases the

[28] This question is the subject of some recent theoretical work, although in models that are different from ours and focus on simultaneous elections. This literature has obtained mixed results. Borgers (2004) argues that the number of voters is inefficiently high. Krasa and Polborn (2005), however, show that in a more general model there are conditions under which the number of voters is inefficiently low and therefore voting should be subsidized, or ruled mandatory.

difference is insignificant.

Table 13: Effect of Subsidizing Voting on Net Expected Benefits				
Simultaneous Voting				
Cases	**W/ Subsidy***	**W/O Subsidy****	**Diff**	**t statistic**
All	16.65	15.73	.92	0.32
3 Sigs. Agree	37.75	28.07	9.67	2.85
2 Sigs. Agree	−0.11	5.92	−6.03	−2.09
Sequential Voting				
All	20.31	19.16	1.15	0.54
3 Sigs. Agree	44.05	37.70	6.35	2.92
2 Sigs. Agree	2.76	5.46	−2.70	−1.25

V.4 Summary of Efficiency Results

We reach the following conclusions from our analysis of informational and economic efficiency:

- Neither the simultaneous nor the sequential voting games achieve the benchmark efficiency level.
- Increasing the cost of voting significantly reduces informational and economic efficiency in both the simultaneous and sequential voting games.
- When the cost of voting is high, sequential voting provides greater economic efficiency.
- Subsidizing voting leads to more efficient outcomes in both sequential voting committees and simultaneous voting committees, but the imporovement is not statistically significant.

VI Equity and Voting Order

As noted in the Introduction, Thompson argues that later voters have an unfair advantage over earlier voters. And as we discussed, St. Bernard Board of Education member Don Campbell felt he suffered a disadvantage being early in the voting order and that everyone should take a turn being first. We have seen that later voters abstain more than earlier voters, even in the high cost treatment where early voters are theoretically predicted to abstain strategically. Is sequential voting inequitable? Do later voters earn greater payoffs?

In Table 14 and Figure 7 we compare the expected mean payoffs in sequential voting by voter position and treatment. We find that there are significant differences between voter payoffs in the sequential voting games, second and third voters make significantly more than first voters in the low and high cost treatments and third voters make significantly more than second voters in the low cost treatment. Thus, we find significant evidence that under sequential voting choosing later in the voting order implies higher payoffs.

Table 14: Observed inequity in Sequential Voting				
	Mean Differences in Net E(B)			
Net E(B)	**Voter 1**	**Voter 2**	**Voter 3**	**Avg. Simul.**
Low Cost: Voter 1				
All Cases		$-.4^{***}$	$-.77^{***}$	1.54^{*}
3 Sigs. Agree		$-.64^{***}$	-1.21^{***}	1.65^{*}
2 Sigs. Agree		$-.24^{**}$	$-.48^{***}$	1.22
Low Cost: Voter 2				
All Cases	$.4^{***}$		$-.37^{***}$	1.94^{**}
3 Sigs. Agree	$.64^{***}$		$-.57^{***}$	2.29^{**}
2 Sigs. Agree	$.24^{**}$		$-.23^{**}$	1.46
Low Cost: Voter 3				
All Cases	$.77^{***}$	$.37^{***}$		2.31^{***}
3 Sigs. Agree	1.21^{***}	$.57^{***}$		2.86^{***}
2 Sigs. Agree	$.48^{***}$	$.23^{**}$		1.69
High Cost: Voter 1				
All Cases		-1.63^{***}	-1.9^{***}	-0.03
3 Sigs. Agree		-2.24^{***}	-2.41^{***}	1.66
2 Sigs. Agree		-1.17^{**}	-1.52^{***}	-1.05
High Cost: Voter 2				
All Cases	1.63^{***}		$-.28$	1.59
3 Sigs. Agree	2.24^{***}		$-.18$	3.90^{***}
2 Sigs. Agree	1.17^{**}		$-.35$	0.12
High Cost: Voter 3				
All Cases	1.9^{***}	.28		1.87
3 Sigs. Agree	2.41^{***}	.18		4.07^{***}
2 Sigs. Agree	1.52^{***}	.35		0.47
$^{***}p < .01$, $^{**}p < .05$, $^{*}p < .10$				

Figure 7 about here

As noted above, we found that sequential voting is more economically efficient than simultaneous voting when voting costs are high. We compare the individual voter net expected benefits to the average net expected benefits with simultaneous voting in order to determine if these benefits are distributed equitably. We find that in both the low and high cost treatments voters later in the voting order receive significantly higher payoffs, particularly when all three signals agree and later sequential voters abstain. In the high cost treatment, early voters (voter 1's) also earn significantly higher net expected benefits, although less so when all three signals agree and less than the additional benefits gained by later voters (voters 2 and 3), which reflects the benefit gain in sequential voting outcomes over simultaneous voting ones in the high cost case.

Note that the equity issue is also present in the E^* outcomes, although to a greater extent in the high cost voting games than in the low cost ones and when not all signals agree. Table 15 illustrates the distribution of net expected benefits with E^*.

Table 15: Theoretical inequity under E^*

	Cases	**Low Cost Net E(B)**	**High Cost Net E(B)**
Voter 1	All	31.4	31.8
	3 Sigs. Agree	46.6	40.6
	2 Sigs. Agree	38.0	25.3
Voter 2 & 3	All	42.6	39.8
	3 Sigs. Agree	48.6	48.6
	2 Sigs. Agree	38.7	33.3
Diff.	All	1.2	8.0
	3 Sigs. Agree	2.0	8.0
	2 Sigs. Agree	0.7	8.0

VII Concluding Remarks

Many voting situations from the St. Bernard Parish School Board in Louisiana to referenda on the European Union's Constitution to mass elections in the United States are not simultaneous. The choices made by earlier voters are often known to those who vote later in the sequence. Despite popular perception that sequence matters in these voting situations, there has been little theoretical or empirical study of the effect of sequence on voter information and the outcomes of voting. In this paper we provide a theoretical and experimental examination of the two systems under costly voting. Our theory suggests that when the cost of voting is low, early voters should participate and later voters should only participate if their votes are pivotal, i.e. they should strategically abstain when not pivotal. In contrast, our theory suggests that when the cost of voting is high, we are likely to observe strategic abstention by early voters as they "pass" the decision on to later voters.

Our experimental analysis allowed us to directly measure the effect of sequence on voter choices, including abstention, controlling for voter preferences and information, which is difficult using naturally occurring data. Our experimental results support the theoretical predictions in general. Not surprisingly, in simultaneous voting abstention increases with voting costs. However, we found that in simultaneous voting elections abstention is higher than predicted when costs are low and lower than predicted when costs are high. We largely found support for our comparative static predictions in sequential voting elections with some notable exceptions. Voters who have an opportunity to vote early are less likely to abstain when voting costs are low, however, we see much greater than predicted voting by early voters when voting costs are high. Similarly, voters who have an opportunity to vote late abstain strategically when their votes are not pivotal, but also abstain more than predicted when their votes could be pivotal, for both low and high cost treatments. Finally, we found very little evidence of information cascades.

We also considered the efficiency of sequential versus simultaneous voting when voting is costly. We found that the actual efficiencies were significantly less than the efficiency benchmark for both sequentail and simultaneous voting and for both high and low voting costs. This was the case for both informational and economic efficiency. We also found significant differences between the performance of committees across the different treatments. Committees with low voting costs fared better than committees with high voting costs, and committees that voted sequentially fared better than committees that voted simultaneously. All of these difference were significant, except there was no significant difference in the performance of high cost sequential committees and high cost simultaneous committees.

Finally, we evaluated the equity of sequential voting. There are significant advantages to later voters in sequential voting, but these gains are at the expense of early voters. This difference is greater with with lower voting costs. In contrast, there is no equity issue with simultaneous voting.

Our results thus yield mixed conclusions about the value of simultaneous versus sequential voting, depending on how one weighs efficiency versus equity. The efficient mechanism is a sequential procedure and sequential voting can lead to more informed group decision making that is economically more efficient for the group, as well. However, we find that in sequential voting there are significant advantages to voters who are later in the voting order since they can choose to strategically abstain and in the high cost treatment, early voters vote more often than predicted.

VIII Appendix

VIII.1 Example 1

This is an example of a non-neutral perfect Bayesian equilibrium of the sequential game if the cost of voting is sufficiently low. The strategy of voter 1 is $\sigma(B;b)=1$ and $\sigma(\phi;a)=1$. The strategy of voter 2 on the equilibrium path is: $\sigma(\phi;b,\{\phi\})=\sigma(\phi;b,\{B\})=1$, $\sigma(A;a,\{B\})=\sigma(A;b,\{\phi\})=1$. That is, following an abstention by voter 1, voter 2 abstains with an b signal, and votes for A with an a signal. Thus, two abstentions will signal to voter 3 that the first two voters received conflicting signals. Following a voter for B by voter 1, voter 2 does exactly the same thing: he abstains with an b signal, and votes for A with an a signal. Off the equilbrium path, voter 2's strategies are $\sigma(\phi;a,\{A\})=1$ and $\sigma(B;b,\{A\})=1$ (as in the neutral equilibrium). Notice that in this equilibrium, voter 1 never votes for A and voter 2 never votes for B.

On the equilibrium path, the strategy of voter 3 is: $\sigma(B;b,\{\phi\phi\})=\sigma(A;a,\{\phi\phi\})=1$, $\sigma(\phi;b,\{B\phi\})=\sigma(\phi;a,\{B\phi\})=1$, $\sigma(A;a,\{BA\})=1$, $\sigma(B;b,\{BA\})=1$. Off the equilibrium path, the strategy for voter 3 is $\sigma(\phi;a,\{BB\})=\sigma(\phi;a,\{AA\})=\sigma(\phi;b,\{BB\})=\sigma(\phi;b,\{AA\})=\sigma(\phi;a,\{A\phi\})=\sigma(\phi;b,\{AA\})=1$, $\sigma(\phi;a,\{\phi B\})=\sigma(\phi;b,\{\phi B\})=1$, $\sigma(B;b,\{AB\})=1$, $\sigma(A;a,\{AB\})=1$. That is, voter 3 votes sincerely to break ties and otherwise abstains. Table YY displays the equilibrium voting decisions and outcomes, for each signal profile.

Table YY: Non-neutral equilibrium in Sequential Game with Low Cost

Signals				Votes				Outcome
Voter #				Voter #				
1	2	3		1	2	3		
a	a	a		ϕ	A	ϕ		A
a	a	b		ϕ	A	ϕ		A
a	b	a		ϕ	ϕ	A		A
a	b	b		ϕ	ϕ	B		B
b	a	a		B	A	A		A
b	a	b		B	A	B		B
b	b	a		B	ϕ	ϕ		B
b	b	b		B	ϕ	ϕ		B

$\sigma(\phi;s_3,\{BB\})=\sigma(\phi;s_3,\{AA\})=1$ for any s_3, $\sigma(A;s_3,\{BA\})=1$ for any s_3, $\sigma(\phi;b,\{B\phi\})=1$, $\sigma(A;a,\{B\phi\})=1$, $\sigma(B;s_3,\{AB\})=1$ for any s_3, $\sigma(\phi;a,\{A\phi\})=1$, $\sigma(B;b,\{A\phi\})=1$, $\sigma(B;b,\{\phi\phi\})=\sigma(A;a,\{\phi\phi\})=1$, and $\sigma(\phi;s_3,\{\phi z\})=1$ for any signal s_3 and any vote $z=A,B$ chosen by vote 2.

VIII.2 Example 2

This is an example of an equilibrium where the first agent always votes against his own signal. The strategy of voter 1 is $\sigma(A;b) = \sigma(B;a) = 1$. The strategy of player 2 is: $\sigma(\phi; s_2, \{\phi\}) = 1$ for any $s_2 = a, b$, $\sigma(A; a, \{B\}) = 1$, $\sigma(\phi; b, \{B\}) = 1$, $\sigma(B; b, \{A\}) = 1$, $\sigma(\phi; a, \{A\}) = 1$. And the strategy of agent 3 is: $\sigma(\phi; s_3, \{BB\}) = \sigma(\phi; s_3, \{AA\}) = 1$ for any s_3, $\sigma(A; s_3, \{BA\}) = 1$ for any s_3, $\sigma(\phi; b, \{B\phi\}) = 1$, $\sigma(A; a, \{B\phi\}) = 1$, $\sigma(B; s_3, \{AB\}) = 1$ for any s_3, $\sigma(\phi; a, \{A\phi\}) = 1$, $\sigma(B; b, \{A\phi\}) = 1$, $\sigma(B; b, \{\phi\phi\}) = \sigma(A; a, \{\phi\phi\}) = 1$, and $\sigma(\phi; s_3, \{\phi z\}) = 1$ for any signal s_3 and any vote $z = A, B$ chosen by vote 2. This strategy profile is a neutral perfect Bayesian equilibrium if $c < p^2(1-p)v$. To see this, first note that it is trivially verified that the strategy used by voters 3 and 2 are always optimal, given voter 1's strategy. Consider now the first voter, assuming that he observed an a signal (the case for a b signal is symmetric and omitted). Table (3) presents the outcome that is induced by voter's 1 as a function of the realization of signals of agents 2 and 3 (labelled "state").

		Action			
		Vote A	**Vote B**	**Abstain**	**First Best**
State	**aaa**	A	A	A	A
	aab	$\frac{1}{2}A, \frac{1}{2}B$	A	B	A
	aba	B	$\frac{1}{2}A, \frac{1}{2}B$	A	A
	abb	B	B	B	B

(3)

Form (3) it can be seen that Vote A is dominated by Vote B: in both case a cost c must be paid, and Vote B induces a better outcome in all possible states. We only need to verify that the voter prefers to vote B than to abstain. The two actions induce the same outcome in all states except $\{aba\}$ and $\{aab\}$. The net expected benefit of voting B is:

$$p(1-p)\left[\Pr(A\,|aba) - \frac{1}{2}\right]v - c = \frac{1}{2}p(1-p)(2p-1)v - c \tag{4}$$

Where $\Pr(A\,|aba)$ is the probability that the state is A given a realization $\{aba\}$ and $p(1-p)$ is the probability that the state is $\{aba\}$ given that voter 1 observes an a signal (which is equal to the probability that the state is $\{aba\}$). From (4) it follows that voting against his own signal is optimal for voter 1 if $p^2(1-p)v > c$. ■

VIII.3 Proof of Proposition 2

Consider now the first case in which $\gamma \in [2p(1-p), 1]$. We proceed in three steps:

Step 1. Consider first voter 3 and assume, without loss of generality, that he has observed signal a. Only three cases are possible. If no other voter has voted, or if the number of voters who voted A is equal to the number of voters who voted for B, then his posterior probability that the state is A would be p. The net benefit of voting in this case is $(1-\gamma)\frac{1}{2}(2p-1) > 0$: so he would vote informatively. The second case is when A has received exactly one vote more than the other (histories ϕA and $A\phi$). In this case, the posterior belief that the state is A is larger than p, and he would like A to win; however he does not need to vote to obtain this outcome, so he abstains. If, on the contrary, B has received one vote more than A from previous voters, then we have two distinct cases. In history ϕB, he believes that A and B have received the same number of signals. In this case, his posterior that the state is $\frac{1}{2}$: the voter is indifferent between the options and would not vote (given that voting is costly). After history $B\phi$, he believes that B has received two votes, so he prefers alternative B and he abstains. Finally, it is possible that one alternative has received more than one vote more that the other: in this case voter n abstains because he would not affect the outcome.

Step 2. Consider now voter 2. We can distinguish two different cases. Assume first that voter 1 has not voted before. If voter 2 votes, then, by step 1, he knows that voter 3 would abstain: his expected utility would be $(1-\gamma)\frac{1}{2}(2p-1)v$. If he abstains, then voter 3 would vote informatively, and his expected utility would be $\frac{1}{2}(2p-1)v$: so he finds it optimal to abstain. Assume now that voter 1 has voted A. If voter 2 has observed signal a, then he would find it strictly optimal to abstain: in this case by voting A would not affect the outcome and by voting for B he would reduce the expected payoff. Assume that voter 2 has observed signal b. If he does not vote, then 3 would not vote as well and A would win: his expected utility would be $\frac{1}{2}v$ (his posterior is 1/2 in this case). Clearly voting for A is suboptimal, so consider the other alternative in which he votes for B. In this case, by step 1, voter 3 would vote informatively and decide the outcome of the election; and the net expected payoff would be $pv - c$. The net benefit of voting is therefore $(1-\gamma)\frac{1}{2}(2p-1)v > 0$, so voter 2 finds it optimal to vote informatively for B.

Step 3. Finally consider voter 1. If he abstains, then voter 2 would abstain. Voter 3 would vote informatively and determine the election: in this case the expected payoff would be pv. If he votes informatively, then he obtains:

$$p\left[p+(1-p)p\right]v+(1-p)\left[p^2 v\right]-c$$

The net benefit of voting is therefore:

$$\left[p(1-p)-\frac{\gamma}{2}\right](2p-1)v$$

If $\gamma > 2p(1-p)$, voter 1 abstains and the election is decided by the last voter.

Consider now the second case in which $\gamma \in [0, 2p(1-p)]$. Assume that 2 and 3 follow exactly the same strategies as in i), but 1 voters informatively. From steps 1-3, this strategy is and equilibrium when $\gamma \leq 2p(1-p)$. The result stated in Proposition 1 follows immediately remembering that $\gamma = c\left[(2p-1)\,v\right]^{-1}$. ■

VIII.4 Sequential Voting Instructions

Thank you for agreeing to participate in this experiment. This is an experiment in group decision making. During the experiment we require your complete, undistracted attention and ask that you follow instructions carefully. Please turn off your cell phones. Do not open other applications on your computer, chat with other students, or engage in other distracting activities, such as reading books, doing homework, etc. You will be paid for your participation in cash, at the end of the experiment. Different participants may earn different amounts. What you earn depends partly on your decisions, partly on the decisions of others, and partly on chance. The entire experiment will take place through computer terminals, except for the rolling of a die by an individual who will act as a 'monitor' for the experiment. It is important that you not talk or in any way try to communicate with other participants during the experiments.

The experiment you are participating in is a group decision making experiment, where you will be making decisions in small committees. We will start with a brief instruction period. During the instruction period, you will be given a complete description of the experiment and will be shown how to use the computers. If you have any questions during the instruction period, please raise your hand and your question will be answered out loud so everyone can hear. If you have any questions after the experiment has begun, raise your hand, and an experimenter will come and assist you. After the Instructions, there will be a practice session. You will not be paid for the matches in the practice session. The practice session will be followed by the paid session. At the end of the paid session, you will be paid the sum of what you have earned, plus a show-up fee of \$10.00. Everyone will be paid in private and you are under no obligation to tell others how much you earned. Your earnings during the experiment are denominated in FRANCS. Your DOLLAR earnings are determined by multiplying your earnings in FRANCS by a conversion rate. For this experiment the conversion rate is 0.01, meaning that 100 FRANCS equal 1 DOLLAR. The computer keeps a record of the payments, but you are also asked to keep track of your earnings on a record sheet that we will provide in a few minutes.

This experiment will consist of two parts. For the entire experiment, there will be a monitor, who will be randomly chosen from one of the student participants. The monitor will assist in running the experiment by rolling a die and generating random numbers for use in the experiment and will be paid a fixed amount ($20.00) for the experiment. We will now roll a multi-sided die to pick the monitor. The student at the desk number that shows up will be the monitor. [20-SIDED DIE IS ROLLED] The monitor is the participant who is seated in front of computer #XX. Please go to Comp no. 19. Please continue to pay attention to the Instructions as they are also relevant to you. If you have any questions, please ask. If you should have questions once the experiment has started, please ask the person sitting next to you at Comp. 19. We will now begin a brief instruction period followed by a Practice session. You will not be paid for the practice session.

This experiment comprises 2 parts. The first part of the experiment will take place over a sequence of 20 matches. We begin the first match by dividing you into ? committees of three members each. Each of you is assigned to exactly one of these committees. You are not told the identity of the other members of your committee.

Your committee can make one of two decisions. The decision is simply to make a choice between one of two "jars", Jar 1 or Jar 2. At the beginning of the match, the monitor secretly rolls a 6-sided die to determine which of the two jars is the correct jar for your committee, and enters this information into the master computer. If your committee chooses the correct jar, everyone in your committee receives a high payoff equal to 50 francs. If your committee chooses the incorrect jar, everyone in the committee receives a low payoff equal to 10 francs. If the die rolled by the monitor comes up 1, 2 or 3, then Jar 1 would be the correct decision for the committee to make; if the die comes up 4, 5 or 6, Jar 2 would be the correct decision; but you are not told which jar is the correct decision until after all the members in your committee have voted. Before voting, each of you will receive a piece of information about which is the correct jar.

The committee decides in a sequential procedure. First, the computer randomly assigns an order in which the members of your committee either vote or abstain. Each member of your committee either votes or abstains when prompted by the computer. He/she can vote for one of the two jars or, to Abstain i.e., not vote for either decision. Voting is costly. Any member who decides to vote, must pay a cost of 8 francs, regardless of the outcome. This cost is automatically subtracted from earnings.

Your committee's decision is made by plurality rule. Whichever jar receives more votes from your committee's members is your committee's decision. Ties (0-0 or 1-1) are broken randomly. After everyone in your committee has made their decisions to either vote or abstain, the group decision and the correct jar is revealed to you. If your committee's group decision is equal to the Correct jar, each member of your committee earns 50 francs. If your committee's group decision is incorrect, each member of your committee earns 10 francs. Of course, voters must also pay their voting cost. So a voter's net payoff is 50-8=42 for a corrrect decision; a voter's net payoff for an incorrect decision is 10-8=2 The table in front of the room fully describes all the possible payoffs. [Experimenter go over table.] The other committees in the room face similar tasks, but the correct decision may be different for different committees. The monitor rolls the die separately for each committee. Remember that committees are completely independent, and they act independently.

After the first match is completed, we proceed to the second match. In the second match, you are all reassigned randomly and anonymously into new 3-person committees, and the process repeats itself for the new committees. The monitor rolls the die again for each committee to determine that committee's correct decision, each committee member again receives a new piece of information and the sequential procedure is carried out as in the first match, but possibly in a different order. This will continue for a total of 20 matches. After 20 matches, we will begin Part 2 of the experiment. We will read you the instructions for Part 2 after we complete Part 1. From now on the experiment will take place through computer terminals only, except for the roll of the die performed by the monitor. I will now hand out Record Sheets on which you will be asked to record certain information as the experiment proceeds.

We will now begin the Practice session and go through two practice matches. During the practice matches, please do not hit any keys until you are asked to, and when have to enter information, please do exactly as asked. At the end of the second practice match there will be a short comprehension quiz. If you have any questions during the quiz, please raise your hand. You must answer all the questions in the quiz before the experiment can begin. Again, you are not paid for these 2 practice matches.

[AUTHENTICATE CLIENTS]

Please double click on the tree icon on your desktop that says j-s. When the computer prompts you for your name, type your First and Last name. Then click SUBMIT and wait for further instructions.

[START GAME]

[SCREEN 2]

You now see the first screen of the experiment on your computer. It should look similar to this screen. Please note that the screen exhibited up front is not exactly identical to any of the screens exhibited on your computers at this time. It only serves as an illustration and is not meant to be suggestive. At the top left of the screen, you see your subject ID. Please record that on your record sheet now. You have been assigned by the computer to a group of 3 subjects. This committee assignment will change after each match. Within your committee, the computer has randomly assigned an order in which the members of the committee vote. You are told your position in the order, i.e. whether you vote or abstain either first, second or third, in your committee. Your position in the decision making order is displayed on your screen here (POINT).

The random order of moves is determined by the computer independently for each committee and in each match. Note this is what the screen looks like for the person who is first in the decision making order.

(POINT to "Order of Moves", with laser.)

Suppose you are the person who is either second or third in the order. Then the screen would look like this:

[SCREEN 3]

On the upper right of your screen are pictures of the two jars, each containing exactly 8 balls. Jar 1 is on the left and contains 6 Red balls and 2 Blue balls. Jar 2 is on the right and contains 2 Red balls, and 6 Blue balls. The monitor will now roll a die, to assign one of the two jars to each committee and will enter this information into the computer. The assigned Jar for a committee represents that committee's correct decision. The die is rolled separately for each committee. You will not be told which Jar was assigned to your committee until everyone in your committee has chosen to vote or Abstain. However, before you choose to vote or abstain, each of you is allowed to see a small piece of information about which jar was assigned to your group. Please wait... we will explain this shortly.

You should also note that the window in the mid-left of the screen exhibits how your payoffs are determined. [POINT TO MID-LEFT PAYOFF TABLE]. It shows how the actual jar and your committees' choice combine to determine your payoff. If your committee's decision matches the committee's actual Jar, you earn 50 francs for the match and you earn 10 if the group decision does not match the actual Jar. In addition to this, 8 francs are subtracted from your payoff if you vote during that match.

[SHOW SCREEN 4]

Once the monitor has assigned the jar for your committee, you see this screen. You now see only your committee's jar on your screen, but the colors of the balls are hidden.

(Emphasize and repeat later)Please note that the balls have been randomly shuffled on each of your screens by the computer so there is no way to guess which color ball is in which location and you cannot tell which Jar was assigned to your committee. The random shuffling is different for each of member.

You will now be allowed to see the color of exactly one of the balls in your committee's jar. To do so, now please use the mouse to move your cursor to whichever ball you want to look at and click once. We call this ball "your sample". It is your piece of private information. The other members of your committee are also choosing balls in a similar way, although the order of their balls is also randomly determined, so it will generally be different. Therefore, it is possible for different members of the same committee to click on different color balls even from the same jar. The colors of all the other balls remain hidden until the end of the match. Please record the color of your sample on your record sheet (R for red or B for blue). Please wait for further instructions.

[SCREEN 5] (Showing screen of first mover)

Now, I will explain the sequential procedure. Please pay close attention to the screen here and the instructions. You will make your individual decisions to vote or abstain in the order that is displayed on your screen. You will be prompted to vote when it is your turn. You will be shown how the previous members voted or abstained before you choose. The person in your committee, who is first in the 'order of moves' moves first. This is what his/her screen looks like.

[SCREEN 6]

Next, the person who was second in the order of moves sees the following screen. Note that the second person is shown the first person's decision, here. (POINT). In this example, the first person voted for Jar 1 and the second person can see this here.

[SCREEN 7]

Finally, the third person sees a screen like this. The third person can see what both of the other two members of his committee did, in this panel here (POINT).

In this example, the first person voted for Jar 1 and the second person abstained. Now it is the third person's turn to vote or abstain.

[SCREEN 8]

Once everyone has voted, the results for the committee are displayed on a screen like this. In this example, the first person voted for Jar 1, the second person abstained and the third person voted for Jar 2. So there was 1 votes for Jar 1 and 1 vote for Jar 2. The committee decision was therefore a tie. Because it was a tie, the computer randomly broke the tie. In this case, they broke the tie for Jar 1, which was the correct jar. Therefore the payoffs were (show). Please remember that this is just an example to illustrate, and is not intended to be suggestive.

This final screen also displays other pieces of information. If you look at the top left corner, it indicates what the actual jar was, and your committee decision. The table with columns in the bottom of your screen is the History panel and summarizes important information. (AS YOU READ, POINT TO RELEVANT COLUMNS) COLUMN ONE indicates the match number, COLUMN TWO indicates your sample color, COLUMN THREE shows your vote, COLUMN four provides a summary of the votes: (Jar1-Jar2-Abstention), COLUMN FIVE shows your committee's decision, COLUMN SIX shows the what the actual jar was, and COLUMN SEVEN shows your earnings (which are not listed here because this was a practice session).

Now, please make sure you have recorded all the information for this practice match on your record sheet. (Please remember the following important things) The committee decision is made by plurality rule. Whichever jar receives more votes is the committee decision, with ties broken randomly. For example, if everyone on your committee abstained, it would be a 0-0 tie, and $\frac{1}{2}$ the time the computer would make the group decision Jar 1 and half the time Jar 2. Committee decisions are summarized in the text in the upper left panel of your screen (POINT), and are also summarized in the history screen at the bottom in column five (POINT). As the experiment proceeds the history screen will show the outcomes of all previous committees you were in.

Remember that you earn 50 francs for the match if your committee's decision matches the committee's actual Jar, and you earn 10 if the group decision does not match the actual Jar. Furthermore, you must pay of voting cost of 8 francs if you chose to vote, which is subtracted from your earnings. This information is also displayed on the screen (POINT to mid-left table). Also, please note that at the end of the match the colors of all the other balls in your jar are revealed to you. This marks the end of the match.

[SCREEN 9: Instructions Part 1]

For the next match you will be randomly re-matched into another committee with different subjects. A new Jar will be assigned to your committee by the monitor in the same way as before. That is, there is a 50/50 chance that your new committee's Jar is Jar 1 or Jar 2. Just as before, you will get a sample from this Jar by clicking on a ball to reveal its color. Then we will have the voting stage and a group decision will be determined. At the end of the next match, you will be asked to take a short comprehension quiz. Everyone must answer all the questions correctly before we go to the paid matches. Also, during the quiz, you must answer all the questions on Page 1 of the quiz to proceed to Page 2 and so on. If you answer a question incorrectly, you will be asked to correct it. Please raise your hand if you have any questions during the quiz, and we will come to your desk and answer your question in private.

[START MATCH 1]

Please proceed through the steps of match 2 at your own pace. . . . Practice match 2 is now over.

Are there any questions before we begin with the paid session? We will now begin with the 20 paid matches of Part 1. Please pull out your dividers for the paid session of the experiment. If there are any problems or questions from this point on, raise your hand and an experimenter will come and assist you.

[START MATCH 1] [AFTER MATCH 21 STOP.]

[After MATCH 21] We have now reached the end of Part 1.

We will now begin Part 2 of the experiment. Part 2 is exactly the same as Part 1 except that the COST of VOTING is now 2 Francs. There will be 20 matches in Part 2. Please go ahead and begin Part 2.

[SCREEN 10: Instruction Part 2]

Part 2

[After MATCH 41] This marks the end of Part 2 and the experiment. Your Total Payoff is displayed on your screen. Please record this payoff on your record sheet. Your total payoff is your payoff from both parts plus the show-up fee of $10. We will pay each of you in private in the next room in the order of your arrival, beginning with the Monitor. Please make sure you have filled out the third page of the record sheet and sign it and turn it when you receive payment. You are under no obligation to reveal your earnings to the other players.

This ends the experiment and your participation for today. Thank you for your cooperation.

IX References

References

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Figure 3: Simultaneous Voters' QRE Abstention Probabilities

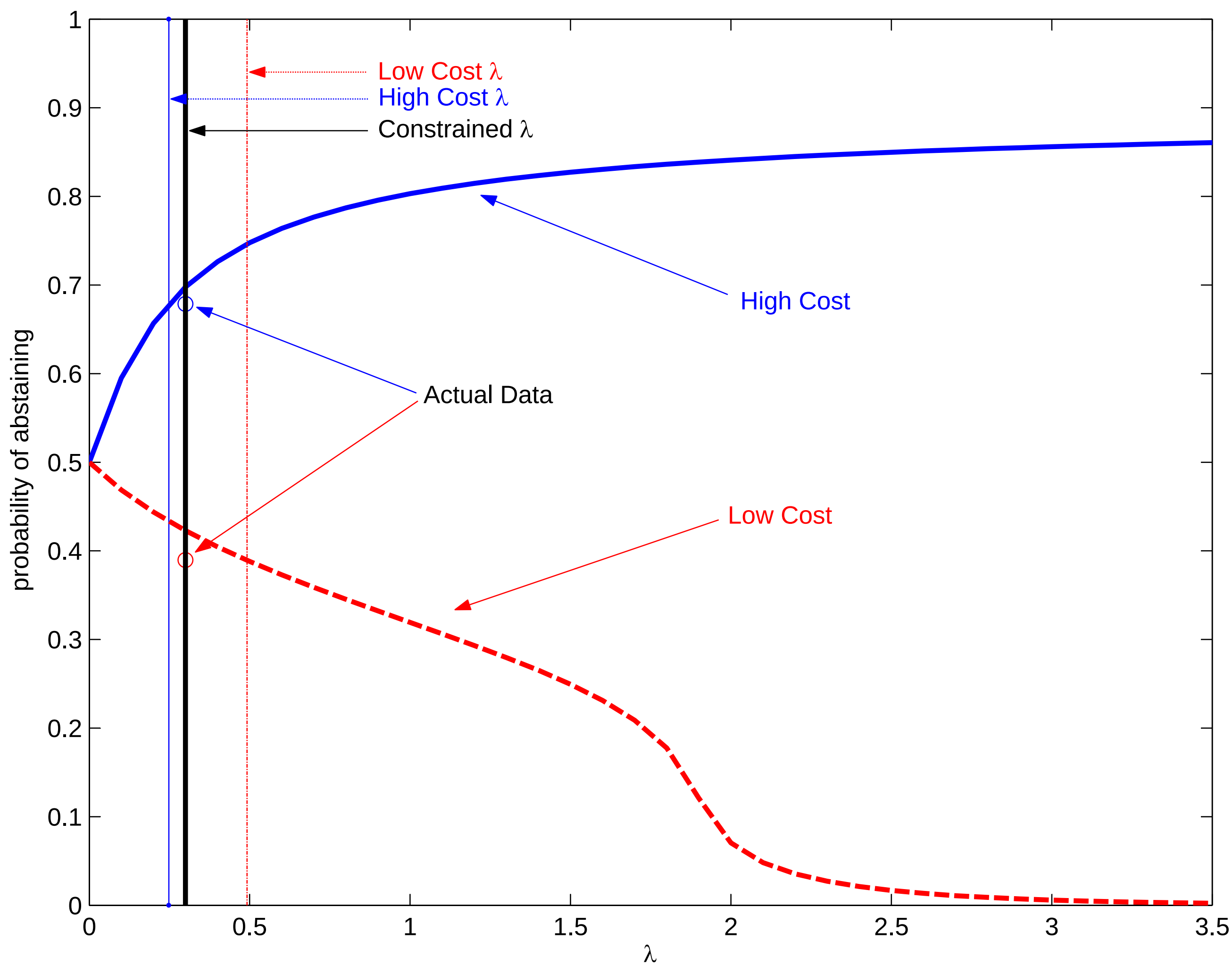

Figure 4: Sequential Voters' Choices

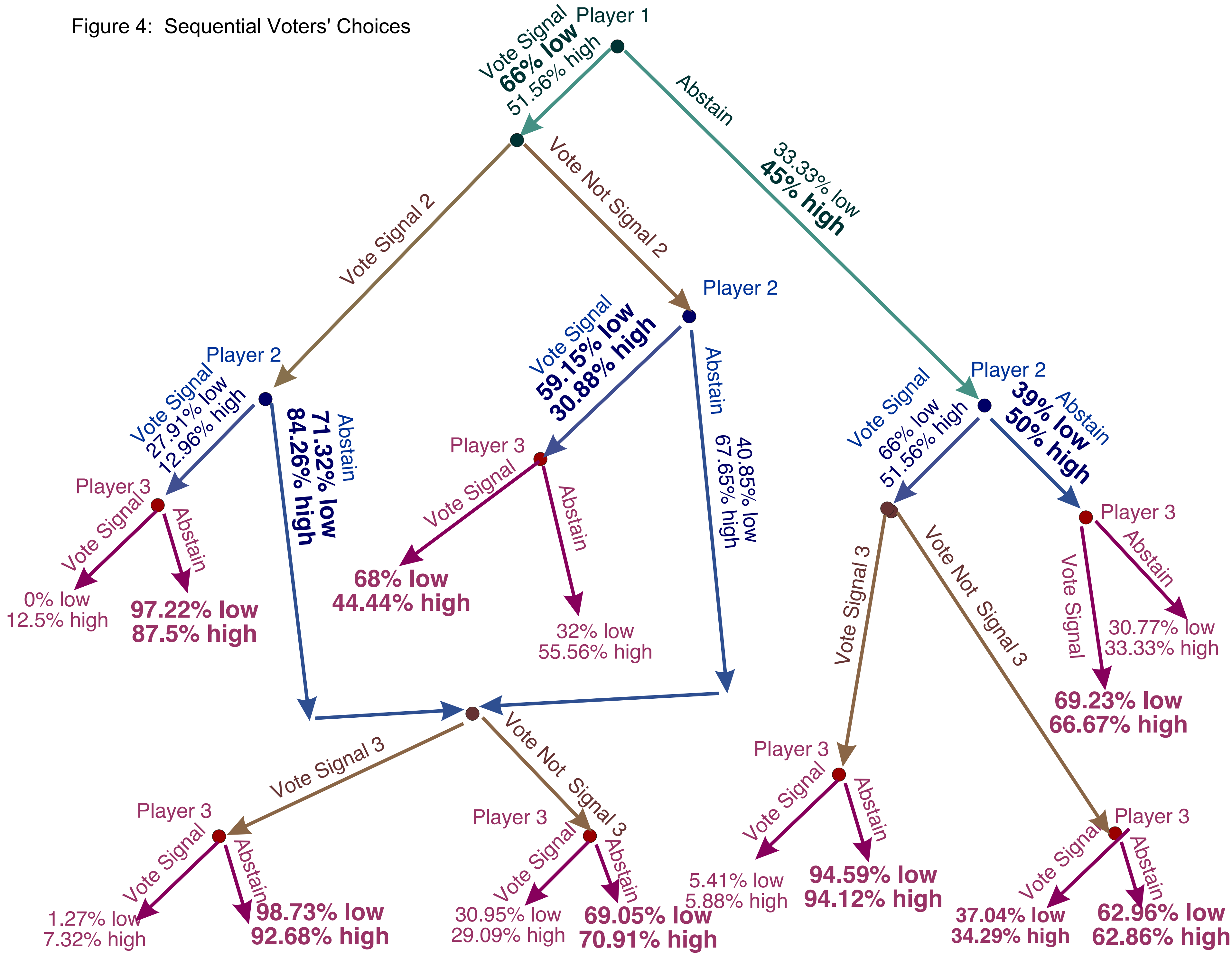

Figure 5a: First Voter QRE Abstention Probabilities

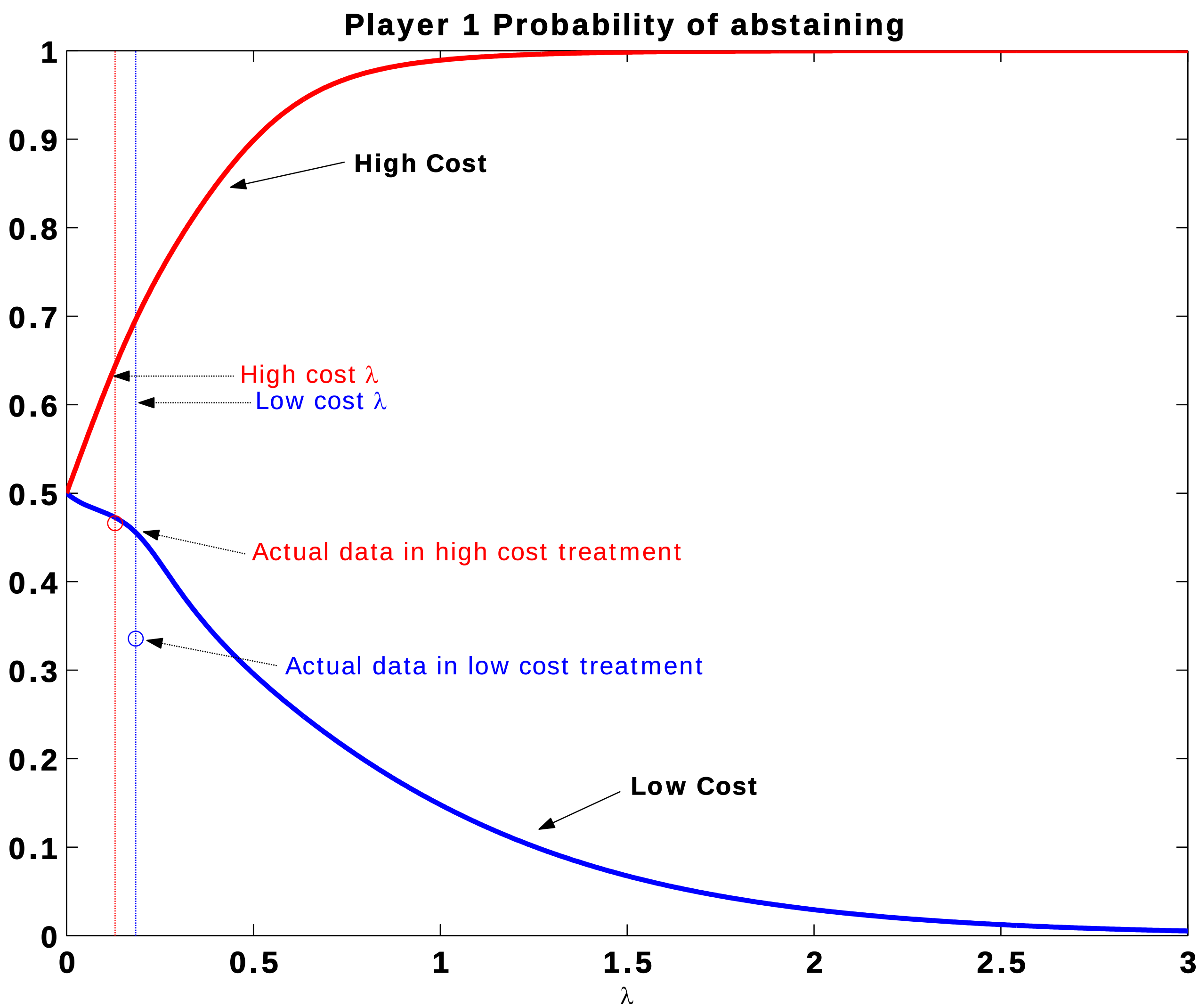

Figure 5b: Second Voter QRE Abstention Probabilities

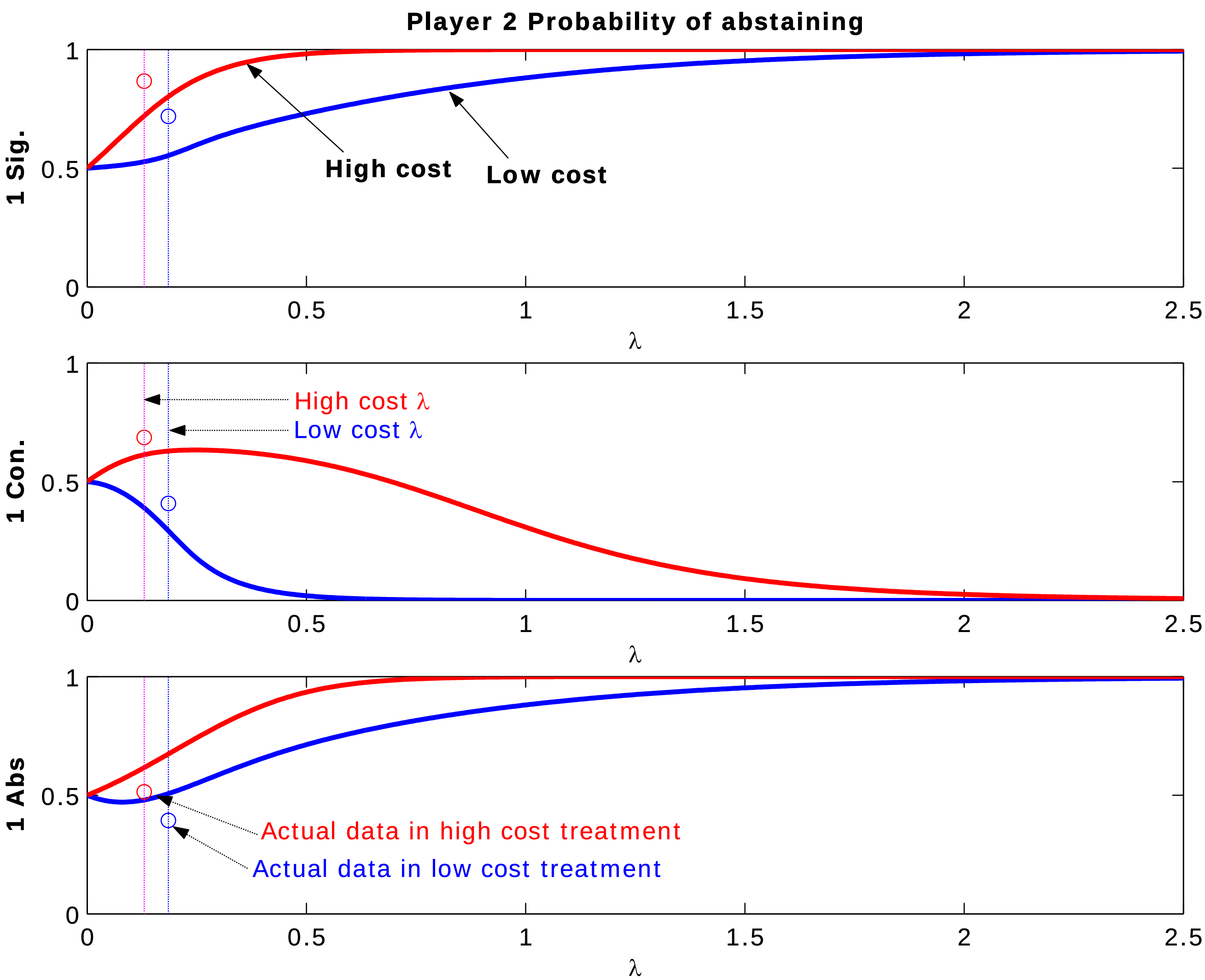

Figure 5c: Third Voter QRE Abstention Probabilities

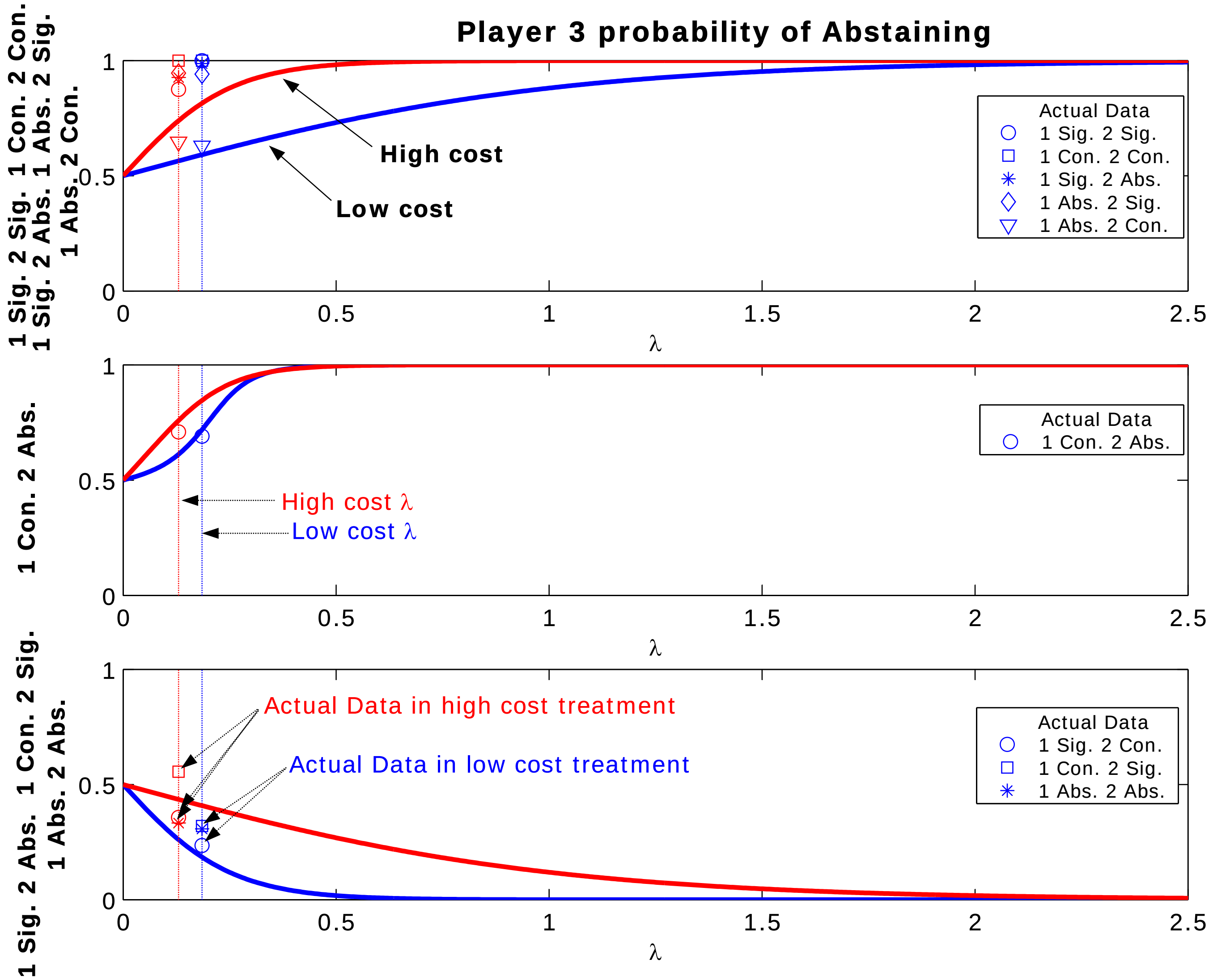

Figure 6:
Net Expected Group Benefits by Mechanism, and Cost

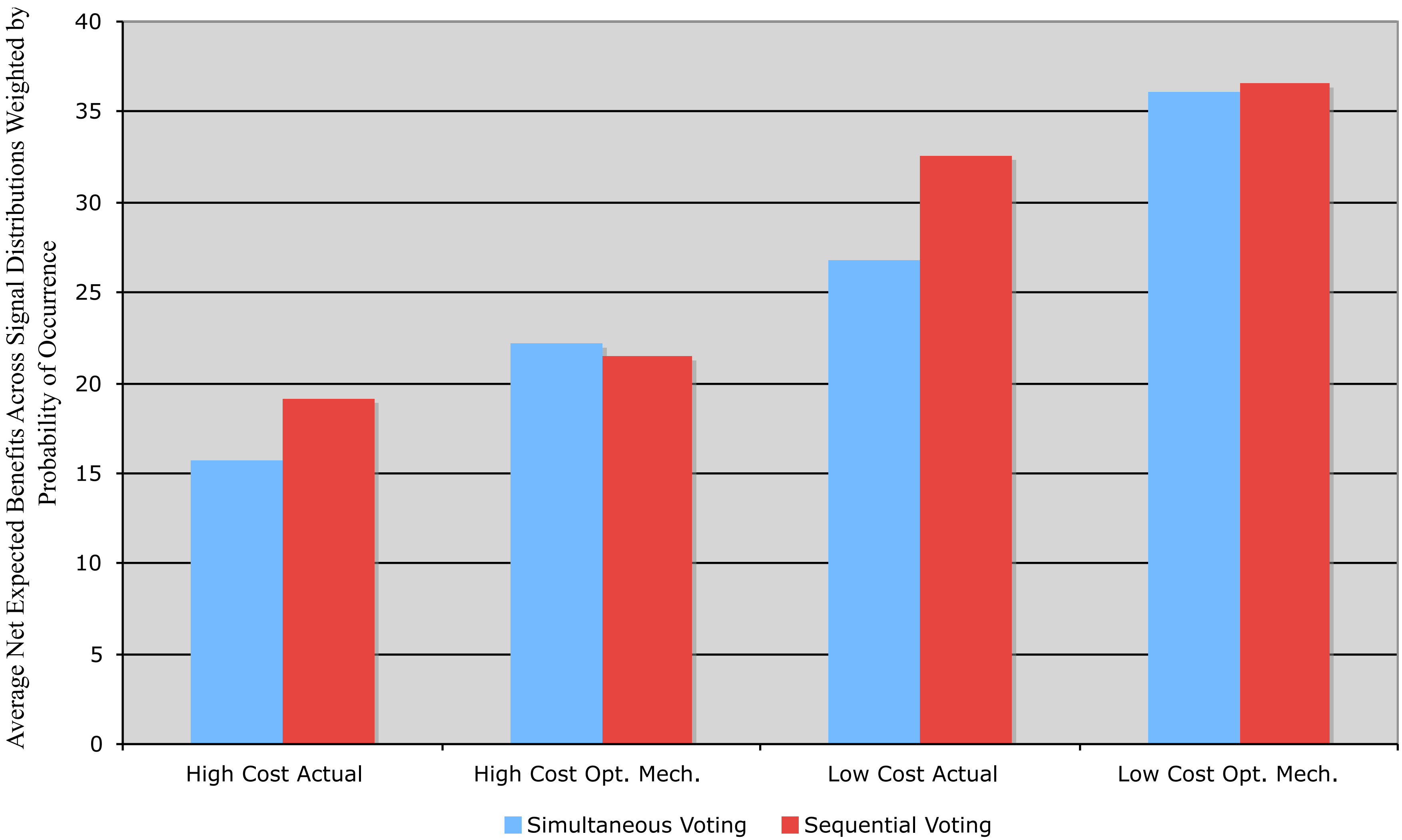

Figure 7:
Individual Net Expected Benefits by Mechanism, Cost, and Voting Order