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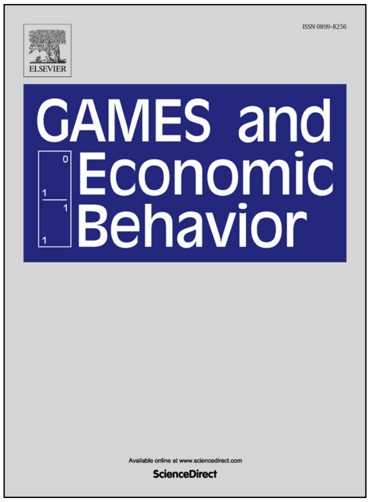

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Common value elections with private information and informative priors: theory and experiments*

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Abstract

We study efficiency and information aggregation in common value elections with continuous private signals and informative priors. We show that small elections are not generally efficient and that there are equilibria where some voters vote against their private signal even if it provides useful information and abstention is allowed. This is not the case in large elections, where the fraction of voters who vote against their private signal tends to zero. In an experiment, we then study how informativeness of priors and private signals impact efficiency and information aggregation in small elections. We find that there is a substantial amount of voting against the private signal. Moreover, while most experimental elections are efficient, we find that it is not generally the case that better private information leads to better decisions.

JEL Classification: D72, D78.

Keywords: Voter turnout, Common Value Elections, Private Information, Swing Voter's Curse, Condorcet Jury Theorem.

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1 Introduction

Consider a meeting of the executive board of a business where a decision by voting is due as to which of two foreign markets to expand. All members of the executive board have the same target, to increase the profits of the business, yet they may have different opinions about which market will be best for their company. Assume all board members have access to a report detailing which market is likely to be the most profitable one. On top of that, board members may have their own private information based on their past experience, their discussions with other colleagues, etc. The question we ask in this paper is twofold: can it be rational for board members to ignore their private information and vote following the report even when private information is informative *and* abstention is allowed? Will the committee arrive at the best possible decision given the information they have available?

To answer these questions we consider a common value election between two candidates where voters are not perfectly informed about who is the best candidate. Instead, each voter receives information about the identity of the best candidate from two sources, one public and one private. The public source of information is a common prior shared by all voters. The private source of information consists of an idiosyncratic signal of a certain quality, which could for example reflect the voter's expertise. Each voter knows the quality of his own signal but not the quality of the signals others receive nor these signals themselves. In this setting it may happen that some voters decide to abstain because they believe that their vote is going to harm the chances of the best candidate winning the election. This is known as *strategic abstention* (see for instance McMurray (2013) or Feddersen and Pesendorfer (1996)), which can occur if the signal quality of these voters is low, so that they prefer leaving the decision of selecting a candidate to other, possibly better informed, voters (self-selected experts). In this paper we ask under which conditions a voter may even vote against his signal and what are the implications of such behaviour for efficiency and information aggregation.

From our theoretical analysis we obtain three main results: first, we find that a significant amount of voting against the signal can be observed in equilibrium. Voting against the signal can be rational if the voter deems the signal of too low quality compared to the information contained in the asymmetric (and hence informative) prior. Second, we find that voting does not generally aggregate information efficiently (due to mis-coordination as a result of equilibrium multiplicity). Still, efficient equilibria can feature voting against the signal in some cases. Third, for elections with a large number of voters we prove that the effect of an asymmetric common prior vanishes to zero and the election resembles one where the common prior is non-informative.

Our analysis is closely related to McMurray (2013), who studies Condorcet (1785)'s classic common value environment with symmetric priors. The main difference between McMurray (2013) and the present paper is that we allow for the common prior to be asymmetric: i.e. not all candidates are equally likely to be the best one a priori. This gives rise to a phenomenon not present in McMurray (2013): voters can vote against their own signal. With symmetric priors any signal is at least as good as the prior in predicting the best candidate. This means that no voter has incentives to vote against his signal and their decision then reduces to whether to abstain or not. In our paper the fact that a signal may be less informative than the common prior means that some voters will choose to vote against their private signal. Contrary to previous literature (Feddersen and Pesendorfer, 1996; Rivas and Rodríguez-Álvarez, 2017), voting against the private signal is observed in a setting without biased voters.

Our experiments test both the predictions of the symmetric case studied in McMurray (2013) as well as the predictions of the asymmetric case introduced here for small elections. As expected from the theoretical analysis, few voters ($< 10\%$) vote against their signal with uninformative (symmetric) priors, but $40 - 80\%$, depending on signal accuracy, do so in the case with informative (asymmetric) priors. Turnout is higher in the asymmetric case ($83 - 86\%$) than in the symmetric case (78%) and slightly higher than theoretically expected. The experiments deliver a surprising result in terms of efficiency. While, as expected, more informative priors lead to higher efficiency, more informative signals do not always have this effect. Specifically, in the case of asymmetric priors more informative signals can lead to lower efficiency. This is because in the asymmetric prior voters do not abstain enough and do not react to signal quality enough, particularly when overall signal quality is high.

Duggan and Martinelli (2001) and Meirowitz (2002) have previously studied common value elections with continuous private signals. Both of these papers study a model where abstention is not allowed and the unique symmetric equilibrium has voters voting for a certain option if and only if their signal quality is past a certain threshold, otherwise they vote for the other option. With abstention, a voter whose signal quality is not high enough may choose to abstain and delegate the decision to other voters. Without abstention, this is not possible and the voter is forced to choose between the two options. Thus, the fact that voters can abstain makes the finding that voters may vote against their signal more robust. On top of that, compared to Duggan and Martinelli (2001) and Meirowitz (2002), in our model with abstention the symmetric equilibrium need not be unique and, in particular, it is possible to find parameter configurations such that there are two equilibria where in one equilibrium no one votes against their private signal while in the other equilibrium there are some voters who do.

Our research contributes to the literature on common value elections and strategic abstention. The classic paper of Austen-Smith and Banks (1996) raised serious questions about Condorcet's implicit assumption that all voters will vote naively, i.e. vote as if they were the only voter. They showed that voting against the signal can arise if abstention is not allowed and all voters have the same signal quality. In Feddersen and Pesendorfer (1996) voters are of three types: partisans, fully informed and uninformed. Partisans support a certain candidate irrespective of the information available while fully informed and uninformed voters prefer the best candidate. Fully informed voters know for certain who is the best candidate while uninformed voters have no information about the best candidate other than the common prior. They show that a positive fraction of uninformed voters abstain even when they strictly prefer one candidate over the other (swingers voter's curse). Battaglini et al. (2010) experimentally tested this model and found results in terms of efficiency, turnout and the margin of victory that are in line with theory. We find theoretically and experimentally that being uninformed is not a requirement for the swingers voter's curse (see also McMurray (2013)). Indeed, the fact that voters posses information of different qualities leads to a self selection in abstention; those with lower quality signals abstain, even if their signal is more informative than the prior, and even if based on the information they have they strictly prefer one candidate over the other.

In Feddersen and Pesendorfer (1997) voters receive information from different sources, where each source may provide information of different qualities. However, they do not allow for abstention, which is a crucial difference to our model. Feddersen and Pesendorfer (1998) allow voters to abstain. However, all voters receive information of the same quality. The reason why voters still do not always vote with their signal is that some voters are biased towards one of the candidates which can induce others to vote against their signal to compensate the bias. In our paper, no voter is biased and the driving force behind what each voter chooses given his signal is the quality of the signal. Hence, while heterogeneous preferences are key in their setting, heterogeneous quality of information is what drives our results.

Also related to our paper is the work of Ben-Yashar and Milchtaich (2007) who study voters with homogeneous preferences and private signals of different qualities. However, they do not consider the possibility of abstention; their focus is on computing the best monotone voting rule. Krishna and Morgan (2012) investigate the welfare effects of introducing voluntary voting when all voters have the same signal quality. Oliveros (2013) presents a model where voters can buy information of different qualities and studies the effects of different ideologies on information acquisition.

A technical difference between our paper and some of the previous theoretical literature (McMurray (2013), Feddersen and Pesendorfer (1996, 1997, 1999) among others) is that we do not consider an uncertain number of voters, i.e. Poisson games (Myerson, 1998), to prove our results. In elections with a small number of voters, as it is the case in the example in our starting paragraph, this assumption may seem hard to justify. The fact that we do not consider Poisson games does not lead to different results when the number of voters is large. In this case, our results mirror those of McMurray (2013).

Finally, our research also contributes to the experimental literature on the Condorcet Jury paradigm. The first published experiment on behaviour in voting games was conducted by Guarnaschelli et al. (2000) who base their experiment on Feddersen and Pesendorfer (1998)'s analysis of strategic voting with the unanimity rule. Closer to our setting are Battaglini et al. (2008) and Battaglini et al. (2010) as described above, and also Morton and Tyran (2011) who extend the setting in Battaglini et al. (2008) by exploring an environment where poorly informed voters are not completely uninformed - they simply receive lower quality signals. This can lead to equilibria where all voters vote and to equilibria where the poorly informed voters abstain. However, as priors are symmetric, there should not be any voting against the signal in this setting. Interestingly, Morton and Tyran (2011) found experimentally that voters abstained more than what is optimal in this setting. Elbittar et al. (2017) found experimentally in a common value election setting with an uninformative common prior, fixed signal quality and costly information acquisition that many voters vote instead of abstaining even after choosing not to acquire information. In the symmetric treatments we find that behaviour is broadly in line with theory, but we find that voters vote too often and do not abstain enough in the asymmetric treatments. Kawamura and Vlaseros (2017) study a setting without abstention, but where - in addition to private signals - voters also receive a public signal (expert opinion). They find that inefficiencies can arise in that setting due to voters placing too much weight on the public relative to the private signal.

Studying experimentally whether participants would be willing to vote against their signal when it is rational to do so raises interesting questions in itself. Violations of Bayesian updating are widely documented in experimental research and there are two types of biases which would lead to opposite results in terms of participants voting against their signal. The well documented phenomenon of base-rate neglect (Kahnemann and Tversky (1972) Grether (1980) and Erev et al. (2008)) will lead agents to overweight sample information and hence would imply that voting against the signal is not commonly observed in the experiment. However, there is also the opposing phenomenon of conservatism (Ward (1982)) which implies that participants overweight the prior and hence would reinforce the strategic incentives to vote against the signal. By studying for the first time common value elections with informative priors our experiment can shed some light on the role of these two opposing biases in strategic voting.

The rest of the paper is organized as follows. In section 2 we introduce the model and present the main theoretical results. In section 3 we describe the design of the experiments and present the experimental results. In section 4 present further theoretical results where we consider the limit case then the number of voters grows large. Finally, section 5 concludes.

2 Theory

2.1 The Model

Consider a setting where $N+1 \geq 2$ voters have to decide between candidate B(lue) or candidate R(ed) by simultaneously casting a vote for either candidate or abstaining. The candidate that receives most votes wins the election. In case of a tie each candidate wins with equal probability.

Each voter derives one unit of utility if the candidate who wins coincides with the state of nature and zero units of utility otherwise. The state of nature is a random variable $s \in \{B, R\}$ where without loss of generality we assume that the probability that the state is B is given by $p \geq \frac{1}{2}$.[1] We restrict our attention to situations where $p \in \left[\frac{1}{2}, 1\right)$ as if $p = 1$ then all voters agree that B is the best candidate and thus will vote for him regardless on any other information they may have available. The value of p is common knowledge and we refer to it as the common prior.

Before the election, each voter i receives a signal $\sigma_i \in \{B, R\}$ with quality $q_i \in \left[\frac{1}{2}, 1\right]$ where

$$P\left(\sigma_i = s | s\right) = q_i.$$

Given the state of nature, signals of different voters are conditional independent. Both the signal received by each voter as well as the quality of such signal are private information. The distribution of signal qualities for each voter in the population is common knowledge, identical, independently distributed and given by the strictly increasing cumulative density function $F : \left[\frac{1}{2}, 1\right] \to [0, 1]$ and integrable probability density function $f : \left[\frac{1}{2}, 1\right] \to \mathbb{R}^{+}$. Define the average signal quality as $\mu = \int_{\frac{1}{2}}^{1} q f(q) \mathrm{d}q$ and consider $\mu \in \left(\frac{1}{2}, 1\right)$ to avoid the trivial cases where all voters receive a useless signal or when all voters receive a perfectly informative signal.

Thus, before the election each voter knows the common prior, his own signal and the quality of such signal, as well as the distribution of the quality of other voters' signals.

[1]The assumption $p \geq \frac{1}{2}$ is without loss of generality as if $p < \frac{1}{2}$ then a relabeling of B to R and vice-versa makes the analysis that follows still valid.

However, he does not know the state of nature, the signals received by other voters, and the quality of such signals.

A strategy for each voter is a map $v : \{B, R\} \times \left[\frac{1}{2}, 1\right] \rightarrow \{\emptyset, B, R\}$ where $v(\sigma_i, q_i)$ is the action of voter i who receives signal σ_i of quality q_i, and $\emptyset$ stands for the action of abstaining. Note that we focus on symmetric strategies: voters that are the same (same signal and quality) behave the same. The fact that we only consider symmetric equilibria does not undermine our main findings: if voting against the signal is possible in an equilibrium with symmetric strategies then it is also possible in an equilibrium when asymmetric strategies are considered.

Note that unlike most recent papers on voting and information sharing we do not assume a Poisson distribution for the number of voters (see the seminal work by Myerson (1998) and Myerson (2000) and more recent references by Myatt (2012) and Nunez (2010) among others). This assumption is often employed given its technical conveniences, namely, independent common public information and independence of actions. However, a drawback of assuming a Poisson distribution for the number of voters is that voters are uncertain of how many other voters there are in the population. While this seems a suitable assumption in large elections, with small elections (committees, for example), which are the focus of this paper, it seems unreasonable to assume that voters ignore how many other voters there are.

2.2 Analysis

When a voter decides whether to vote for B, R or to abstain, he compares the payoff he obtains under these three actions given the actions of all other voters. However, a voter can influence his own payoff only when his vote can change the outcome of the election (i.e. he is pivotal). This can happen if and only if candidates B and R are at most one vote apart when counting the votes of the other N voters. Thus, let $\pi_t(v, s)$ be the probability that candidate B receives the same number of votes as candidate R (i.e. there is tie) when N voters use strategy v and the state is s. Similarly, let $\pi_B(v, s)$ be the probability candidate B receives exactly one vote less than candidate R when N voters use strategy v and the state is s. Finally, let $\pi_R(v, s)$ be the probability candidate R receives exactly one vote less than candidate B when N voters use strategy v and the state is s.

Before we write down the payoff each voter obtains from playing the three different actions, it is useful to understand how likely each state is when a voter only considers his available information (i.e. ignoring strategic considerations). We have the following:

$$\begin{aligned}
P\left(s=B|\sigma_i=B,q_i\right) &= \frac{pq_i}{pq_i+(1-p)(1-q_i)}, \\
P\left(s=R|\sigma_i=B,q_i\right) &= \frac{(1-p)(1-q_i)}{pq_i+(1-p)(1-q_i)}, \\
P\left(s=B|\sigma_i=R,q_i\right) &= \frac{p(1-q_i)}{p(1-q_i)+(1-p)q_i}, \\
P\left(s=R|\sigma_i=R,q_i\right) &= \frac{(1-p)q_i}{p(1-q_i)+(1-p)q_i}.
\end{aligned}$$

Notice that the private signal of voter i is more informative than the prior, $P\left(R|\sigma_i=R,q_i\right) \geq \frac{1}{2}$, if and only if $q_i \geq p$.

The expected utility voter i derives from voting for B compared to voting for R when the other N voters use strategy v is then given by

$$\begin{aligned}
u_i(B,R,v) &= P\left(s=B|\sigma_i,q_i\right)\left[\pi_t(v,B)+\frac{1}{2}\pi_R(v,B)+\frac{1}{2}\pi_B(v,B)\right] \\
&\quad -P\left(s=R|\sigma_i,q_i\right)\left[\pi_t(v,R)+\frac{1}{2}\pi_R(v,R)+\frac{1}{2}\pi_B(v,R)\right]. \qquad (1)
\end{aligned}$$

In words, if the state is B then the increase in payoff from voting B instead of R is: 1 if there is a tie when counting all other N votes (the best candidate wins), $\frac{1}{2}$ if R is one vote behind (the best candidate is chosen as opposed to forcing a tie), and $\frac{1}{2}$ if B is one vote behind (a tie is forced as opposed to not having the best candidate win). On the other hand, if the state is R then the increase in payoff from voting B instead of R is: -1 if there is a tie when counting all other N votes (the best candidate does not win), $-\frac{1}{2}$ if R is one vote behind (the best candidate is not chosen as opposed to forcing a tie), and $-\frac{1}{2}$ if B is one vote behind (a tie is forced as opposed to having the best candidate win).

Similarly, the expected utility voter i derives from voting for B or R compared to abstaining when the other N voters use strategy v is given respectively by

$$\begin{aligned}
u_i(B,\emptyset,v) &= P\left(s=B|\sigma_i,q_i\right)\left[\frac{1}{2}\pi_t(v,B)+\frac{1}{2}\pi_B(v,B)\right] \\
&\quad -P\left(s=R|\sigma_i,q_i\right)\left[\frac{1}{2}\pi_t(v,R)+\frac{1}{2}\pi_B(v,R)\right], \qquad (2) \\
u_i(R,\emptyset,v) &= P\left(s=R|\sigma_i,q_i\right)\left[\frac{1}{2}\pi_t(v,R)+\frac{1}{2}\pi_R(v,R)\right] \\
&\quad -P\left(s=B|\sigma_i,q_i\right)\left[\frac{1}{2}\pi_t(v,B)+\frac{1}{2}\pi_R(v,B)\right]. \qquad (3)
\end{aligned}$$

To simplify the exposition, we assume that if voters are indifferent between the two candidates they prefer the one that coincides with their signal. Similarly, if voters are indifferent between voting for a certain candidate or abstaining, they follow their signal. As it will be clear later on, the fact that f is integrable means that the probability that a voter is indifferent between two options (voting to one candidate or the other, or voting to either candidate or abstaining) is zero. As such, the way indifference ties are broken has no effect in our results and it also allows us to ignore mixed strategies.

A voter votes for B if and only if $u_i(B, R, v) \geq 0$ and $u_i(B, \emptyset, v) \geq 0$. A voter abstains if and only if $u_i(B, \emptyset, v) < 0$ and $u_i(R, \emptyset, v) \leq 0$, and votes for R if and only if $u_i(B, R, v) < 0$ and $u_i(R, \emptyset, v) > 0$. Thus, expressions (1), (2) and (3) are what determines how a voter behaves given how the other voters behave.

We have the following characterization of all symmetric equilibria (all mathematical proofs are presented in the appendix):

Theorem 1. *There exists an equilibrium. The equilibrium is either of two types:*

- *Type 1, characterized by two cutpoints $\frac{1}{2} \leq q_R^- \leq q_R^+ \leq 1$ with $q_R^- \leq p$ such that*

$$v(\sigma_i, q_i) = \begin{cases} B & \text{if either } \sigma_i = B \text{ or } \sigma_i = R \text{ and } q_i < q_R^-, \\ R & \text{if } \sigma_i = R \text{ and } q_i \geq q_R^+, \\ \emptyset & \text{otherwise.} \end{cases}$$

- *Type 2, characterized by two cutpoints $\frac{1}{2} \leq q_B^+ \leq q_R^+ \leq 1$ such that*

$$v(\sigma_i, q_i) = \begin{cases} B & \text{if } \sigma_i = B \text{ and } q_i \geq q_B^+, \\ R & \text{if } \sigma_i = R \text{ and } q_i \geq q_R^+, \\ \emptyset & \text{otherwise.} \end{cases}$$

In equilibrium of Type 1 all voters who receive signal B vote and they do so for candidate B. These are the voters who receive a signal that agrees with the common prior. On the other hand, voters who receive a signal against the common prior, i.e. signal R, behave as follows: those with a low quality signal ignore their signal and vote according to the common prior, those with a moderately informative signal abstain, and those with a sufficiently informative signal vote according to their signal.

In equilibrium of Type 2 no voter votes against his signal. Note that $q_B^+ \leq q_R^+$ implies that those voters who receive a signal that agrees with the common prior are less likely to abstain than those who receive a signal against. This is the case because $p \geq \frac{1}{2}$ and, thus, if a voter receives signal B the common prior makes him trust is signal more whereas if voter receives signal R he is less convinced about candidate R than his signal quality suggests as the common prior goes against R.

The reason why there is not an equilibrium where voters who receive signal B vote for R is that $p \geq \frac{1}{2}$ and, thus, a voter whose signal agrees with the common prior believes that B is the best candidate so he either abstains or votes for B. Figures 1 and 2 present a graphical representation of both types of equilibria.

Figure 1: Equilibrium of Type 1

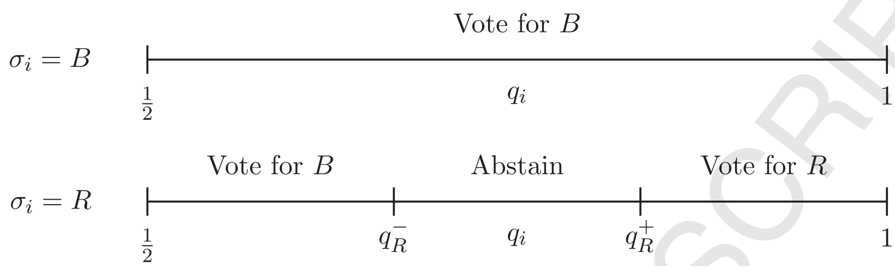
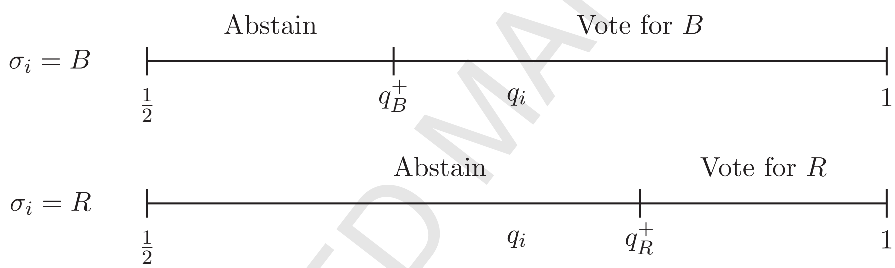


Figure 2: Equilibrium of Type 2



The expected fraction of voters who vote against their signal in equilibrium of Type 1 is given by $p \int_{\frac{1}{2}}^{q_R^-} (1-q) f(q) \mathrm{d}q + (1-p) \int_{\frac{1}{2}}^{q_R^-} q f(q) \mathrm{d}q$ which, as we shall see with examples, can be a strictly positive number. The fraction of voters who abstain is given by $p \int_{q_R^-}^{q_R^+} (1-q) f(q) \mathrm{d}q + (1-p) \int_{q_R^-}^{q_R^+} q f(q) \mathrm{d}q$ in equilibrium of Type 1 and $p \int_{\frac{1}{2}}^{q_R^+} (1-q) f(q) \mathrm{d}q + p \int_{\frac{1}{2}}^{q_B^+} q f(q) \mathrm{d}q + (1-p) \int_{\frac{1}{2}}^{q_R^+} q f(q) \mathrm{d}q + (1-p) \int_{\frac{1}{2}}^{q_B^+} (1-q) f(q) \mathrm{d}q$ in equilibrium of Type 2. This is the so-called strategic abstention (and swing voters curse), found for instance in McMurray (2013) and Feddersen and Pesendorfer (1996).

The reason why some voters vote against their signal is the following. Consider a very simple example where there are only two voters. In this case a voter is always pivotal and thus learns very little from the fact that he is pivotal (he still does learn some information, as there are three different possibilities for a voter to be pivotal). In this case if a voter receives a low quality signal against the common prior, given that he does not learn much from being pivotal, he may still prefer to vote for what the common prior suggests if the common prior is informative enough. This reasoning extends to more than just two voters. Assume that a voter receives a low quality signal supporting the candidate that goes against the common prior. If such voter is pivotal, he knows that there are mixed signals in the population, which suggests that the common prior may be wrong. However, his information may still support the same candidate as the common prior given that his updated belief stills put a significant probability on such candidate because the voter's signal is of low quality. Thus, the voter may have incentives to disobey his signal and vote against it.

The reason why strategic abstention is possible is that if a voter receives a signal of moderate quality and the common prior is not very informative (or he receives a signal of high quality against an informative the common prior, but not of sufficiently high quality), then if the voter is pivotal he may prefer to abstain and leave the decision to those who are presumably better informed. This is because if the voter is pivotal there is a significant chance that the best candidate is ahead by one vote as opposed to the other candidate ahead by one vote or there being a tie. Hence, by voting the voter runs the risk of contradicting the opinion of most other voters who do not abstain and who have a better signal quality than himself. In this situation the voter is better off by abstaining, even if he prefers one candidate over the other, and leaving the decision of electing a candidate to the other more informative voters.

Note that from the information revelation point, voting against the voter's signal is worse than abstaining. When a voter abstains he reveals that his signal is not very informative. However, in an equilibrium where voters may vote against their signal, if a voter votes for B it is not clear whether such voter received signal B or R. That is, voting against the signal harms the chances of the best candidate winning the election more than abstention.

Theorem 1 states that in an equilibrium of Type 1, $q_R^- \leq p$. Numerical examples show that this inequality can be strict. If instead of a group of voters a single voter (dictator) chose the winning candidate, straightforward calculations show that this voter will choose to follow his signal if and only if his signal points at candidate B or if it points at candidate R and the signal quality is at least p. In the language of the model, if $N+1=1$ then the unique equilibrium is Type 1 with $q_R^- = q_R^+ = p$. Thus, the fact that the group of voters includes more than just one voter means that voters are less likely to vote against their signal. That is, more voters means that each of them has more incentives to share their signal even if such signal is of a quality lower than the prior. Later in the paper we show that the fraction of voters who vote against their signal converges to zero as the number of voters increases to infinity.

As discussed in the introduction, McMurray (2013) considers a setting very similar to ours where the main difference is that he assumes $p = \frac{1}{2}$. The consequence of this is that in his setting the only possible equilibria is Type 2 with $q_B^+ = q_R^+$. The fact that $p > \frac{1}{2}$ is what allows the existence of an equilibrium of Type 1 with $q_R^- > \frac{1}{2}$ and an equilibrium of Type 2 with $q_B^+ < q_R^+$. The comparison of our results to McMurray (2013) is explored in more detail later on when we consider elections with a large number of voters.

It is worth pointing out the similarities between our result in Theorem 1 and Proposition 1 in Feddersen and Pesendorfer (1998) (particularly striking is the resemblance between figures 1 and 2 and figure 1 in Feddersen and Pesendorfer (1998)). However, both results originate from very different sources. In our paper, voters' behavior depends on the signal they receive, but also on the quality of such signal. In Feddersen and Pesendorfer (1998), voters' behavior depends on the signal they receive and on their and others' bias towards each of the candidates.[2] Thus, the fact that unbiased voters receive signals of different qualities mimics the behavior observed when biased voters receive information of equal quality. A fundamental difference between these two situations is that a voter who is biased takes such bias as given while an unbiased voter is aware of the fact that his signal may or may not be very accurate.

One may wonder if voters would still vote against their signal if information was endogenous and costly, i.e. if voters have no private information but they can buy it (as in Persico (2003) and Martinelli (2006)). In this case it can still happen that a voter buys information that he then chooses to ignore. Consider a setting where voters have no private signals but they can buy them. Say that the cost of buying a signal is fixed and the quality of the signal received is random (this is in between Persico (2003) where the quality is fixed and Martinelli (2006) where quality is contractible). In this case, in expected terms (ex-ante) having a signal helps the voter make a better decision and thus he is willing to pay some cost for it, even if it turns out that given the realization of the signal and its quality the voter chooses (ex-post) to ignore his signal and vote following the common prior. This can be interpreted as the voter paying a cost to search for information but only finding poor information that he chooses to ignore.

2.2.1 Numerical Examples

Next we present some examples that illustrate the results of Theorem 1. In tables 1 and 2 we calculate the possible symmetric equilibria when there are 4 and 5 voters respectively and signal qualities are distributed uniformly. The parameter constellations in table 1 are the

[2]In Feddersen and Pesendorfer (1998) unbiased voters may also vote against their signal but only to offset the effects of the vote of biased voters.

ones used in the experiments. Note that given the distribution of signal qualities in table 1 the symmetric equilibrium is unique and of type 1 for $p = 0.95$ and type 2 for $p = 0.5$.

Table 1: Equilibria, $N + 1 = 4$

$p = 0.5,\ q \sim U\left[\frac{1}{2}, 1\right]$	$p = 0.5,\ q \sim U\left[\frac{1}{2}, \frac{3}{4}\right]$	$p = 0.95,\ q \sim U\left[\frac{1}{2}, 1\right]$	$p = 0.95,\ q \sim U\left[\frac{1}{2}, \frac{3}{4}\right]$
$q_B^+ = 0.67$	$q_B^+ = 0.58$	$q_R^- = 0.54$	$q_R^- = 0.64$
$q_R^+ = 0.67$	$q_R^+ = 0.58$	$q_R^+ = 0.86$	$q_R^+ = 0.81$

Table 2: Equilibria, $N + 1 = 5$

$p = 0.5,\ q \sim U\left[\frac{1}{2}, 1\right]$		$p = 0.8,\ q \sim U\left[\frac{1}{2}, 1\right]$		$p = 0.95,\ q \sim U\left[\frac{1}{2}, 1\right]$	
$q_B^+ = 0.5$	$q_B^+ = 0.68$	$q_B^+ = 0.60$	$q_R^- = 0.59$	$q_B^+ = 0.51$	$q_R^- = 0.68$
$q_R^+ = 0.5$	$q_R^+ = 0.68$	$q_R^+ = 0.75$	$q_R^+ = 0.59$	$q_R^+ = 0.82$	$q_R^+ = 0.68$

Numerical results suggest that the equilibrium is unique if and only if $N + 1$ is even and that if $N + 1$ is odd then there are exactly two equilibria. However, we have been unable to prove this formally. The problem of uniqueness of equilibrium in voting models such as this is far from trivial (McMurray, 2013) and is often ignored (Feddersen and Pesendorfer (1996, 1997, 1999)). Nevertheless, uniqueness of equilibrium is not necessary for our results. Our characterization in Theorem 1 together with the examples above already illustrate one of the points of this paper: the possibility for rational voters voting against their signal when such signal is informative and abstention is allowed. On top of that, uniqueness of equilibrium is also not required for the experimental results; we are not interested in making point-wise prediction but in understanding whether the behavior of subjects responds the way the theoretical results predict when we change the parameters of the model.

2.2.2 Efficiency

We say that an equilibrium strategy profile is efficient if the voting strategies maximize the probability with which the best candidate wins the election. It is known from McLennan (1998) that in symmetric common value elections, as its the case in this paper, the symmetric strategy profile that maximizes the probability with which the best candidate wins is an equilibrium.[3] The reason for this result is intuitive: if voters are playing according to the strategy profile that maximizes their payoff then no voter has incentives to deviate as his

[3]In particular, McLennan (1998) states that the symmetric mixed strategy that maximizes voters utility is a Nash equilibrium (Theorem 2). We do not need to worry about mixed strategies as no player is ever indifferent between voting for either option or abstaining. This is due to our assumption about the way indifference ties

utility is already being maximized. Thus, if there are any efficiency losses in our model they must come from equilibrium multiplicity.

Equilibrium multiplicity can cause inefficiencies as it presents voters with a coordination problem. Further, as just discussed above, the strategy profile that maximizes the probability with which the best candidate wins is an equilibrium. Thus, if the equilibrium is unique then it is efficient for sure. However, with more than one equilibrium there is no guarantee that all of them will be efficient. The examples in Table 2 shed light about this issue. On the one hand, the numerical example there tells us that the equilibrium may not be unique. On the other hand, it can be calculated that if $N+1=5$ and $p=0.8$ then the probability with which the best candidate wins is 0.92 in Equilibrium of Type 1 and 0.93 in the equilibrium of Type 2. Numerical results show that this difference decreases with the number of voters. Indeed, as we shall show in section 4.1, for elections with a large number of voters the best candidate wins the election with probability one regardless of the equilibrium played.

Note also that it is not necessarily true that the equilibrium of Type 1, where some voters vote against their signal, is inefficient. As just discussed, if the equilibrium is unique then an equilibrium with this property is efficient. For example, according to Table 1 the equilibrium with $N+1=4$ and $p=0.95$ is unique and of Type 2 both for $q \sim U[\frac{1}{2}, 1]$ and $q \sim U[\frac{1}{2}, \frac{3}{4}]$, which means that this equilibrium is efficient.

2.3 Testable Predictions and Empirical Questions

In this section we describe some key qualitative properties that we are interested in testing in the laboratory. One of the new findings in this paper is that, unlike in the symmetric prior case studied in McMurray (2013), participants may vote against their signal if it is not accurate enough. We ask the following question:

Voting against one's signal *How is the propensity to vote against the signal affected by changes in the prior p and the signal accuracy q?*

From theory we would expect to see voting against the prior only if priors are asymmetric and if signal accuracy is "low enough". Empirically, whether this prediction holds depends crucially on how people update their prior on the basis of the information they received. Two different failures of Bayesian updating have been robustly documented in the literature: (i) base-rate neglect, which leads to overweighing sampled information (Kahnemann and

are broken. Note also that only voters with a particular signal quality will be indifferent between more than one action and given the continuous distribution of signal qualities the probability of a voter having such particular signal quality is zero.

Tversky (1972), Grether (1980) and Erev et al. (2008)) and (ii) conservatism, which leads to underweighing or even ignoring the sample (Ward (1982)).

Base rate neglect is not important if priors are symmetric ($p = 0.5$). With asymmetric priors, however, it could potentially play an important role. Under base-rate neglect participants would vote with their signal more often, leading to possibly worse outcomes in terms of the efficiency of the majority decision. Conservatism would lead to the opposite prediction. Participants would vote with the prior too often leading to worse information aggregation and lower efficiency. Hence, while theory might be a good predictor of behavior for symmetric priors, its predictive accuracy could be far worse in the case of asymmetric priors if base-rate neglect or conservatism play important roles in this setting. If participants vote too often or too seldom against their signal, information aggregation and efficiency are impacted as well. We hence ask:

Efficiency *How is the efficiency of voting outcomes affected by changes in the prior p and the signal accuracy q?*

We would expect efficiency to increase both as priors become more asymmetric (hence containing more information) and as signals become more accurate. However, in the presence of biases, such as base-rate neglect or conservatism, this may not necessarily be the case. Our experiments will provide an empirical test of how the symmetric and asymmetric settings differ with regard to these issues and how potential biases affect the explanatory power of the theory in both these two settings.

3 Experiments

3.1 Design of the Experiments

Our experiment implements the setting described in the theoretical section for $N + 1 = 4$, i.e. four voters. In all treatments participants played a voting game for 30 rounds. After each round they were randomly re-matched in a new group of four voters. Each round proceeded as follows. First, participants were reminded of the value of p illustrated by a wheel as shown in the Instructions in Appendix B. They were then shown their private signal and informed about the accuracy of their signal q_i. Figure 7 in Appendix C shows a screenshot of how the signal and signal quality were communicated in the experiment. They were afterwards asked to vote for either RED, BLUE or to ABSTAIN, where the order of the first two options was randomized. At the end of each round they were informed about their own vote, the majority vote in the group, the realized state and their payoff. Participants received 10 experimental tokens if the majority vote matched the state and 2 tokens if it did not. At the end of the experiment one round was randomly drawn and participants were paid for that round only plus a show up fee of 3 tokens. Tokens were converted into GBP at a rate of 1:1.

To answer our questions regarding information revelation and efficiency we systematically vary p and q. Treatment **SYM** implements the symmetric setting analyzed by McMurray (2013). Both states are equally likely and signal accuracy is drawn from $[0.5, 1]$, where in the experiment we only used multiples of 0.1.[4] In **SYM-COARSE** the prior is also 0.5, but signal accuracy is now distributed in $[0.5, 0.75]$ and represented in multiples of 0.05. In treatment **ASYM** an asymmetric prior of 0.95 is implemented. Treatment **ASYM-COARSE** coincides with treatment **ASYM**, but the signal accuracy q is again lower and drawn from $[0.5, 0.75]$. In each treatment we had 48 participants organized in six matching groups (clusters) of size 8. The exception is treatment **ASYM-COARSE**, where due to low show-up, we had 44 participants only. Theoretical predictions for these different treatments can be found in Section 2.2.1 in Table 1.

The experiments were conducted in May 2015 and September 2016 at EssexLab at the University of Essex. Written instructions were distributed at the beginning of the experiment and can be found in Appendix B. Before starting the experiment participants had to answer six control questions checking their understanding of the instructions. These questions can also be found in Appendix B. Participants earned either 13 GBP or 5 GBP depending on whether, in the round randomly drawn for payment, the majority vote matched the state or not.[5] The experiment lasted around 45min, it was programmed in z-tree (Fischbacher, 2007) and participants were recruited using hroot.

3.2 Experimental Results

This section contains our experimental results. We study individual behaviour in Section 3.2.1, what consequences it has for aggregate outcomes in Section 3.2.2, and finally we discuss learning heuristics in Section 3.2.3.

[4]The reason that we did not allow any number, like e.g. 0.61475368, is (i) that it is difficult and potentially confusing for participants to communicate a smaller grid visually and (ii) that we deemed it extremely unlikely that there would be substantial behaviour differences between such a number and the closest multiple of 0.1, i.e. 0.6.

[5]In May 2015, 13 GBP equalled about 20.50 US dollars and 5 GBP around 7.90 US dollars. In September 2016, 13 GBP equalled about 17.91 US dollars.

3.2.1 Individual Behaviour

Table 3 gives a first overview of individual voting behaviour. It shows the distribution of votes depending on state and signal received for the four different treatments.

Symmetric treatments We start by discussing the treatments with a symmetric prior **SYM** and **SYM-COARSE**. In treatment **SYM** participants abstain $\approx 28\%$ of the time ($15-35\%$ depending on state and signal). Given that (i) according to the symmetric equilibrium described in Table 1 voters should abstain if their signal accuracy is below 0.67 and (ii) signals are uniformly distributed in $[0.5, 1]$ we would theoretically expect participants to abstain around 34% of the time. Subjects behaviour is thus roughly in line with these predictions. We also see around 10% of voting against the signal which we should not see theoretically. We discuss possible explanations for this in more detail in Section 3.2.3. In treatment **SYM-COARSE** we see around $10-17\%$ abstentions which is again in line with theoretical expectations (16%, see Table 1). We also see around 25% of participants voting against their signal, which is surprisingly high in this treatment.

	if state is RED							
	SYM		**SYM-COARSE**		**ASYM**		**ASYM-COARSE**	
σ	RED (0.72)	BLUE (0.60)	RED (0.62)	BLUE (0.62)	RED (0.71)	BLUE (0.64)	RED (0.61)	BLUE (0.65)
RED	0.61	0.09	0.59	0.34	0.10	0	0.26	0.24
BLUE	0.08	0.58	0.29	0.55	0.55	1	0.63	0.66
abstain	0.31	0.35	0.12	0.12	0.36	0	0.11	0.10
	if state is BLUE							
	SYM		**SYM-COARSE**		**ASYM**		**ASYM-COARSE**	
σ	RED (0.64)	BLUE (0.73)	RED (0.58)	BLUE (0.63)	RED (0.63)	BLUE (0.73)	RED (0.58)	BLUE (0.63)
RED	0.51	0.08	0.59	0.25	0.19	0.02	0.15	0.06
BLUE	0.23	0.77	0.24	0.66	0.56	0.92	0.65	0.83
abstain	0.26	0.15	0.17	0.09	0.25	0.06	0.20	0.11

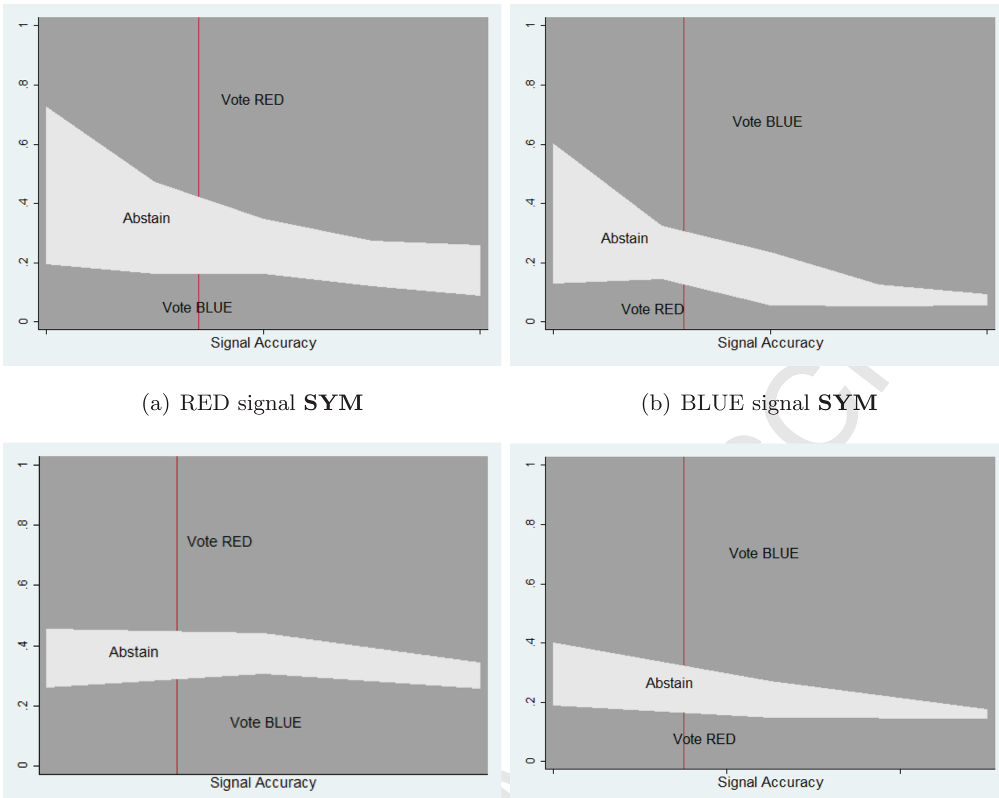
Table 3: Vote distribution (share of participants voting RED, BLUE or abstaining) depending on state and signal received (average signal accuracy in brackets) for the four different treatments. Note that participants do not know the state, but average signal quality depends on the state.

Two previous experiments studied a related common value election setting with a symmetric common prior ($p = 0.5$). Elbittar et al. (2017) found experimentally with fixed signal quality and costly information acquisition that voters tend to vote too often instead of abstaining given the information they have available. In particular, they found that a significant proportion of subjects vote when they have no information at all on what is the best alternative. The authors suggest subjective priors as a possible explanation for this; each voter believes that with some probability other voters may be biased and vote for a particular option when they have no information available. This leads to voters with no information to vote simply to offset the effect of these biased voters. By contrast, Morton and Tyran (2011) found experimentally in a setting with symmetric common prior and two different qualities of information that voters abstained more than what was optimal. In our symmetric treatments the share of participants abstaining is in line with theoretical predictions.

Figure 3 illustrates how voters with RED (top left panel) and BLUE (top right panel) signals vote in treatment **SYM**. As expected, we don't see substantial differences between the two cases. Irrespective of the signal received, only few participants vote against their signal. The share of abstentions is high (around 45%) if the signal is uninformative and decreases sharply around $q \approx 0.6$ in line with theoretical predictions. Also the share of participants voting against their signal decreases from about $15-20\%$ for uninformative signals to $5-10\%$ with very informative signals. While the former could be attributed to subjective priors, as in Elbittar et al. (2017), the latter is likely due to mistakes. The two bottom panels focus on **SYM-COARSE**. Here we see much fewer abstentions ($\approx 20\%$) if the signal is uninformative. Furthermore, this frequency does not decrease by much over the [0.5,0.75] range of accuracies. Participants in this treatment, hence, react less to signal quality compared to **SYM**.

Asymmetric treatments In treatment **ASYM** we see that if the signal is BLUE, i.e. consistent with the prior, virtually all participants vote BLUE in line with theoretical predictions (Table 3). If the signal is RED, around 55% of participants vote against the signal and around 30% abstain. Theoretically we should only expect 10% of voting against the signal (Table 1). By contrast, we would expect 64% percent of abstentions. Hence, not only do participants vote against their signal, they even do so excessively at least compared to theoretical predictions. One reason they might do so is the use of simple heuristics as we discuss in Section 3.2.3. In **ASYM-COARSE** participants vote $\approx 65\%$ of the time against a RED signal, which is in line with the 60% theoretically expected in this treatment and abstain around 15% of the time (compared to 40% expected theoretically, see Table 1).

Hence, as expected, participants vote against their signal more often with asymmetric priors. Higher signal accuracy reduces the frequency with which this occurs, but by not as much as we would expect. Compared to the symmetric equilibrium described in Table 1, too many participants vote against their signal in **ASYM** and too many participants vote with their signal in **ASYM-COARSE**. To assess how important these differences are we next explore in more depth how voting changes with signal accuracy.



(a) RED signal **SYM**

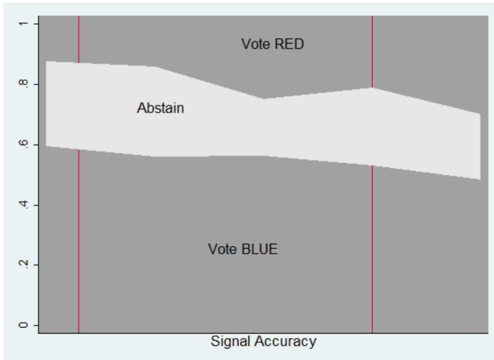
(b) BLUE signal **SYM**

(c) RED signal **SYM-COARSE**

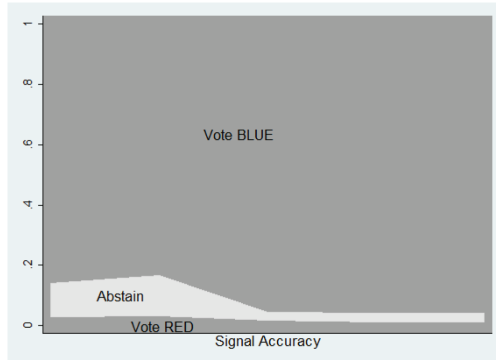
(d) BLUE signal **SYM-COARSE**

Figure 3: The figure shows the vote distribution (red, abstain, blue) conditional on signal accuracy as well as theoretical threshold (vertical line). Mean share of participants voting with/against signal or abstaining averaged for bands of accuracy of length 0.1 (a,b) or 0.05 (c,d). Treatments **SYM** and **SYM-COARSE**.

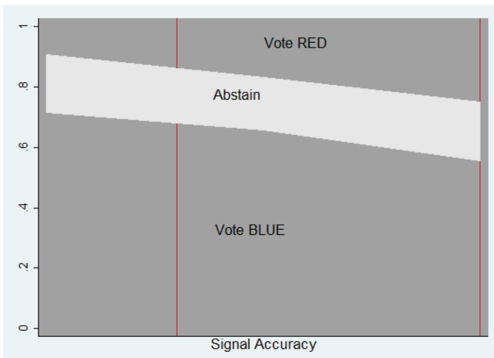
In treatment **ASYM** (top panels Figure 4) participants who receive a BLUE signal essentially always vote BLUE (panel (b)). There is some abstention for low signal accuracy (below 0.65) and a few votes for RED. Conditional on receiving a RED signal the majority of participants do *not* vote RED (between 90% if $q = 0.5$ and around 70% if $q > 0.9$). Around $50-60\%$ of participants vote against their signal, i.e. vote BLUE when their signal was RED. This share is pretty stable across levels of accuracy q. The share of participants abstaining is around 30%. Hence, participants with a RED signal vote according to their signal too much if signal accuracy is low and too little if signal accuracy is high. Rather than a general tendency towards conservatism or base-rate neglect we find that participants do not react enough to the accuracy of their signal. The bottom panels show the analogous graph for treatment **ASYM-COARSE**, where signals are less accurate. Behavior conditional on a



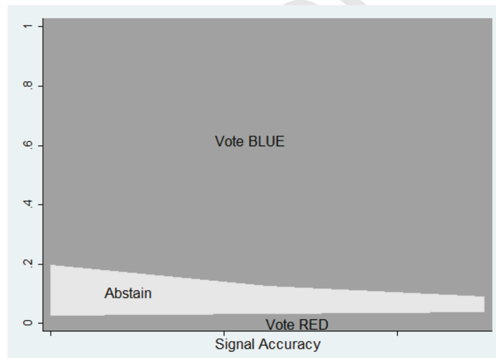
(a) RED signal **ASYM**



(b) BLUE signal **ASYM**



(c) RED signal **ASYM-COARSE**



(d) BLUE signal **ASYM-COARSE**

Figure 4: The figure shows the vote distribution (red, abstain, blue) conditional on signal accuracy as well as theoretical thresholds (vertical lines). Mean share of participants voting with/against signal or abstaining averaged for bands of accuracy of length 0.1 (a,b) or 0.05 (c,d). Treatments **ASYM** and **ASYM-COARSE**.

BLUE signal is very similar to treatment **ASYM** with most participants voting BLUE. Conditional on receiving a RED signal, participants are now more likely to vote against the signal with almost 70% voting BLUE if $q = 0.5$, i.e. if the signal is uninformative. The percentage shrinks for higher levels of q, but remains substantial at 60% even if $q = 0.75$.

Table 7 in Appendix C shows the result of a multinomial logit regression of voting outcomes (categorized as "voting with the signal", "abstaining" or "voting against the signal") on signal accuracy separately for the case where a RED (columns (1)-(4)) or a BLUE (columns (5)-(6)) signal was received. The baseline category is to vote with the signal.[6]

Participants in treatments **SYM** and **SYM-COARSE** are increasingly likely to vote with their signal compared to abstaining or voting against it as the signal accuracy increases.

[6]Tables 9 and 10 in Appendix C show OLS regressions on binary outcomes of "Abstention" and "Voting against the signal", respectively.

In treatment **ASYM** this is only true when the signal is in line with the prior, i.e. BLUE. If participants in these treatments receive a RED signal, by contrast, they become more likely to abstain compared to voting with (or against) the signal as signal accuracy increases. One intuition could be that participants do predominantly vote against the signal in these treatments when signal quality is low, while they resolve the tension between a high signal accuracy on the one hand and a strong prior against it on the other hand by abstaining. This leads to relatively more abstentions as signal accuracy increases. Interestingly, Figure 4 reveals that the mean positive effect of q on abstention is mostly driven by a comparison of "medium levels" of accuracy with "high" levels of accuracy, while the highest number of abstentions can still be found for very low levels of accuracy also in this treatment. Table 8 in Appendix C, which controls for the number of times a participant saw a red signal, shows qualitatively the same results.

To sum up, voting behaviour in the experiment is largely in line with what we expected from theory. Participants are not hesitant to vote against their signal if its quality is low. They even do so excessively in treatment **ASYM**. Furthermore, they do not react enough to signal accuracy.

Result 1 *In line with theoretical predictions, participants in the asymmetric prior treatments vote against their signal if signal quality is low. They do, however, not react enough to signal quality i.e. do not vote enough against the signal if quality is low and too often when signal quality is high.*

3.2.2 Efficiency

We next assess the impact of voting behaviour on aggregate outcomes, in particular on the efficiency of voting outcomes. We would expect efficiency to increase both as priors become more asymmetric (hence containing more information) and as signals become more accurate. In terms of our treatments we would hence expect higher efficiency in **ASYM** compared to **SYM** and higher efficiency in **ASYM** compared to **ASYM-COARSE** as well as **SYM** compared to **SYM-COARSE**.

Figure 5 shows efficiency over time across the three treatments. As expected, efficiency is higher in **ASYM** compared to **SYM**, even though the gap is narrowing over time, as efficiency in **SYM** is steadily increasing. Efficiency in **ASYM-COARSE** is substantially higher compared to **SYM-COARSE**. A more asymmetric prior clearly increases efficiency.

The picture is less clear-cut when it comes to the effect of signal accuracy. Under symmetric priors the effect is as we expected. Higher signal accuracy in **SYM** leads to higher efficiency compared to **SYM-COARSE**. The difference appears for both states with outcomes

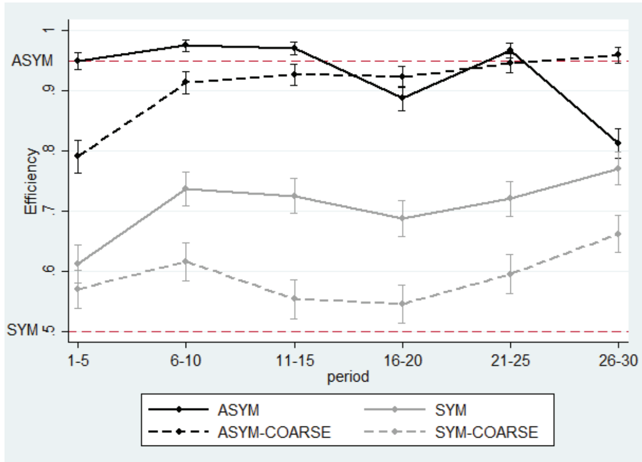


Figure 5: Efficiency: percentage of time the majority vote agreed with the state over time across the four treatments as well as benchmark based on the symmetric or asymmetric prior, respectively.

in **SYM** being around 10% (13%) more efficient than outcomes in **SYM-COARSE** when the state is BLUE (RED). Interestingly, the difference appears only after some learning has taken place, i.e. after the first five rounds (see also Table 4).

Under asymmetric priors, by contrast, the effect is not as expected with no difference in efficiency across the two treatments overall. While across the first five periods efficiency is higher in **ASYM** this effect reverses over time, as efficiency increases in **ASYM-COARSE**, but not in **ASYM**. By the last five periods there is a substantial and statistically significant difference between the two treatments with $\approx 14\%$ more efficiency in **ASYM-COARSE** compared to **ASYM** (column (3) in Table 4). Table 11 in the Appendix additionally explores linear time trends and shows that those are statistically different in **ASYM** compared to **ASYM-COARSE**. Above, we have seen above that voters in **ASYM** vote against their signal too much and do not abstain enough. Furthermore, voters in **ASYM** do not react to signal quality enough, i.e. vote against their signal even when signal quality is very high. Voters in **ASYM-COARSE** still do make this mistake, but to a lesser extent, possibly because the lower signal quality makes them less confident. The fact that average efficiency in the second half of the experiment is only reduced by 4% (in **ASYM** compared to **ASYM-COARSE**) when the state is BLUE, while it is reduced by $\approx 16\%$ when the state is RED, suggests that this type of mistakes could be the underlying reason for why signal accuracy does not increase efficiency with asymmetric priors.

Result 2 *Higher signal accuracy increases the efficiency of voting outcomes in the symmetric case, but not in the asymmetric case. Across the last 5 rounds of the experiment*

VARIABLES	(1) All periods	(2) periods 1-5	(3) periods 26-30
SYM-COARSE(β_1)	-0.118***	-0.041	-0.108**
	(0.027)	(0.060)	(0.050)
ASYM(β_2)	0.218***	0.338***	0.041**
	(0.019)	(0.017)	(0.018)
ASYM-COARSE(β_3)	0.201***	0.178**	0.188***
	(0.039)	(0.079)	(0.017)
Constant	0.709***	0.612***	0.771***
	(0.020)	(0.015)	(0.017)
$\beta_2 - \beta_3$	0.017	0.160*	-0.146***
p-value	0.6671	0.0688	<0.0001
Observations	5,640	940	940
Participants	188	188	188

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 4: Random effects OLS regression of efficiency on treatment dummies. Standard errors are clustered at the matching group level.

*efficiency is even higher in **ASYM-COARSE** compared to **ASYM**.*

How efficient are voting outcomes compared to theoretical benchmarks? There are at least three benchmarks one could consider. The first is the probability of choosing the best candidate if only the common prior was available, which is 0.5 in **SYM** and **SYM-COARSE** and 0.95 in **ASYM** and **ASYM-COARSE**. Figure 5 shows that with a symmetric prior, participants significantly outperform the common prior benchmark, while in **ASYM** and **ASYM-COARSE** participants cannot improve on the common prior on average. It should be noted, however, even if voters played the symmetric strategy equilibrium, which as discussed in section 2.2.2 is the strategy profile that maximizes the chances of choosing the best candidate, they will barely do any better than in the common prior benchmark. In this respect, efficiency in the asymmetric prior treatments seems in line with the common prior benchmark.

A second benchmark could be the ex-ante (i.e. before signals and qualities are realized) probability of choosing the best candidate when the symmetric equilibrium (calculated in Table 1) is played. Under this benchmark the expected probability with which the best candidate wins the election is given by 0.88 in **SYM**, 0.71 in **SYM-COARSE**, 0.97 in **ASYM** and 0.95 in **ASYM-COARSE**.[7] Empirically, efficiency in **SYM** and **SYM-COARSE** is below these levels. Thus, while information from private signals is used somewhat effectively in

[7]In treatment **ASYM-COARSE** signal qualities are so low compared to the quality of the common prior that there is barely any gain in efficiently using private signals when compared to just voting the common prior.

treatments **SYM** and **SYM-COARSE**, as the probability of choosing the right candidate is higher than 50%, it is used less effectively than what the theory suggests.

The third benchmark asks how much efficiency could be obtained if all private information was perfectly aggregated, i.e. if all signals and qualities were observed by all voters. To this end, given the set of signals and qualities for all voters $(\sigma_i, q_i)_{i=1}^{N+1}$ we first compute the probability that the state is Blue:

$$P(s = B|(\sigma_i, q_i)_{i=1}^{N+1}) = \frac{p\Pi_{i=1}^{N+1}\left(\mathbb{1}_{\sigma_i=B}q_i+\mathbb{1}_{\sigma_i=R}(1-q_i)\right)}{p\Pi_{i=1}^{N+1}\left(\mathbb{1}_{\sigma_i=B}q_i+\mathbb{1}_{\sigma_i=R}(1-q_i)\right)+(1-p)\Pi_{i=1}^{N+1}\left(\mathbb{1}_{\sigma_i=B}q_i+\mathbb{1}_{\sigma_i=R}(1-q_i)\right)}.$$

Second, we have that Blue is the most likely state of nature given all private signals and qualities if and only if $P(s = B|(\sigma_i, q_i)_{i=1}^{N+1}) \geq \frac{1}{2}$. Thus, the probability of choosing the best candidate given all private signals and their qualities is $\max\{P(s = B|(\sigma_i, q_i)_{i=1}^{N+1}), 1 - P(s = B|(\sigma_i, q_i)_{i=1}^{N+1})\}$. This benchmark delivers even higher probabilities of choosing the right candidate on average across all 30 rounds (between 0.94 in **SYM** and 0.98 in **ASYM**). In sum, participants in the symmetric treatments use information effectively enough to substantially outperform the prior, but information aggregation is not perfect. In the asymmetric treatments participants do not outperform the (very high) prior substantially.

3.2.3 Heuristics

So far we have taken an equilibrium perspective. In this Section we briefly explore some heuristics participants might use in the experiment. Specifically, we focus on how participants learn from feedback and in particular from three statistics: (i) whether the majority vote in the past period was incorrect (i.e. not coinciding with the state), (ii) whether participant i's vote was incorrect and (iii) whether participant i was pivotal *and* incorrect. We ask what effect these statistics have on abstention as well as on switching behaviour, i.e. the propensity to switch vote across rounds.

Table 5 shows the results for the symmetric prior treatments. In **SYM** none of these statistics matter for abstention and switching. As predicted by theory, abstention is mostly determined by the signal accuracy q, but none of the other variables do seem to matter. This changes in treatment **SYM-COARSE**. Here participants seem to rely somewhat more on heuristics. Again, signal accuracy predicts abstention, but now also whether agent i's vote herself was correct does matter. If they were wrong in the past period participants in **SYM-COARSE** are more likely to abstain subsequently. Whether or not the mistake happened in a pivotal position does not seem to matter.

	Symmetric Prior treatments							
	SYM				**SYM-COARSE**			
	Abstention		Switching		Abstention		Switching	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
q	-1.147***	-1.146***	-0.071	-0.070	-0.737***	-0.738***	-0.143	-0.145
	(0.071)	(0.071)	(0.092)	(0.092)	(0.111)	(0.111)	(0.178)	(0.178)
Majority wrong$_{t-1}$	-0.003	-0.003	-0.002	-0.002	-0.003	-0.003	-0.000	-0.000
	(0.002)	(0.002)	(0.003)	(0.0036	(0.002)	(0.002)	(0.003)	(0.003)
i wrong$_{t-1}$	-0.008	0.013	-0.024	-0.005	0.056**	0.058**	-0.098	-0.091
	(0.017)	(0.029)	(0.034)	(0.033)	(0.015)	(0.015)	(0.055)	(0.073)
i (pivotal$\wedge$wrong)$_{t-1}$		-0.037		-0.032		-0.004		-0.012
		(0.044)		(0.029)		(0.037)		(0.047)
Constant	0.992***	0.992***	0.636***	0.636***	0.518**	0.518**	0.670***	0.670***
	(0.140)	(0.140)	(0.046)	(0.046)	(0.148)	(0.147)	(0.118)	(0.117)
Observations	1,392	1,392	1,392	1,392	1,392	1,392	1,392	1,392
R-squared	0.159	0.160	0.002	0.002	0.039	0.039	0.010	0.010

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 5: Simple Heuristics in Symmetric Prior treatment. Abstention and Switching regressed on signal accuracy and three dummies indicating whether (i) the majority vote in the past period was incorrect (i.e. not coinciding with the state), (ii) participant i's vote was incorrect and (iii) whether participant i was pivotal and incorrect.

Table 6 shows the results for the asymmetric prior treatments. While abstention decreases again with signal accuracy, as expected, participants in the asymmetric treatments also seem to rely a great deal on their experience from the previous period. Having voted wrongly makes participants more likely to abstain or to switch (in any way between RED, BLUE or Abstain) in the period immediately after. The effect on switching is particularly strong if participants have been wrong *and* pivotal in the immediately preceding period. Interestingly, having been wrong *and* pivotal makes participants less likely to abstain in the subsequent period in **ASYM-COARSE**. Note also that in the case of switching the R^2 in the asymmetric regressions is almost ten times higher than in the corresponding symmetric treatments.[8] Table 12 in Appendix C additionally controls for the number of times a participant saw a RED signal with qualitatively the same results.

To sum up, participants in the asymmetric prior treatments seem to try and learn from past experience to a much greater extent than participants in the symmetric treatments. One reason could be that the asymmetric environment with two different and sometimes conflicting pieces of information about the state (the prior and the signal) seems more difficult

[8]There is no clear ranking of R^2 in the case of abstention. While past experience explains more of the variation in the asymmetric treatments, signal accuracy explains more in the symmetric treatments.

	Asymmetric Prior treatments							
	ASYM				**ASYM-COARSE**			
	Abstention		Switching		Abstention		Switching	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
q	-0.437***	-0.438***	-0.080	-0.086	-0.329***	-0.321***	0.052	0.043
	(0.062)	(0.062)	(0.078)	(0.078)	(0.115)	(0.114)	(0.148)	(0.148)
Majority wrong$_{t-1}$	-0.005	-0.005	-0.003	-0.003	-0.020**	-0.017***	0.010**	0.008
	(0.004)	(0.004)	(0.005)	(0.005)	(0.003)	(0.005)	(0.005)	(0.005)
i wrong$_{t-1}$	0.086***	0.085***	0.511***	0.456***	0.304***	0.347***	0.367***	0.322***
	(0.022)	(0.025)	(0.027)	(0.032)	(0.021)	(0.023)	(0.044)	(0.055)
i (pivotal$\wedge$wrong)$_{t-1}$		0.002		0.170***		-0.151***		0.157***
		(0.040)		(0.050)		(0.039)		(0.050)
Constant	0.363**	0.363**	0.214*	0.219*	0.073	0.090	0.220**	0.203**
	(0.115)	(0.115)	(0.096)	(0.096)	(0.089)	(0.079)	(0.083)	(0.078)
Observations	1,392	1,392	1,392	1,392	1,276	1,276	1,276	1,276
R-squared	0.043	0.043	0.205	0.212	0.145	0.155	0.144	0.151

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 6: Simple Heuristics in asymmetric Prior treatment. Abstention and Switching regressed on signal accuracy and three dummies indicating whether (i) the majority vote in the past period was incorrect (i.e. not coinciding with the state), (ii) participant i's vote was incorrect and (iii) whether participant i was pivotal and incorrect.

for participants, which is why they try to use past experience to inform their decisions to a greater extent. The fact that some of the decision is based on past experience could also explain why participants in the asymmetric treatments do not react "enough" to signal accuracy.

4 Further Theoretical Results

4.1 Large Elections

In this section we extend our theoretical results by focusing on elections where the number of voters tends to infinite. Our first result is that in large elections the fraction of voters who vote against their signal converges to zero and, moreover, the difference in behavior between those who receive different signals of the same quality also converges to zero.

Theorem 2. *The equilibrium in a large election is either Type 1 with $\int_{\frac{1}{2}}^{q_R^+} f(q)\mathrm{d}q \to 0$ or Type 2 with $\int_{q_B^+}^{q_R^+} f(q)\mathrm{d}q \to 0$.*

The first part of the theorem states that in equilibrium of Type 1 we have $\int_{\frac{1}{2}}^{q_R^+} f(q)\mathrm{d}q \to 0$.

Since in such equilibrium $q_R^- \leq q_R^+$, we have then that $\int_{\frac{1}{2}}^{q_R^-} f(q)\mathrm{d}q \to 0$. Therefore, the proportion of voters that vote against their signal converges to zero. Note that it may happen that the number of voters who vote against their signal is bounded away from zero, that is, it could be that $\lim_{N\to\infty}(N+1)\int_{\frac{1}{2}}^{q_R^-} f(q)\mathrm{d}q > \varepsilon$ for some $\varepsilon > 0$. However, the number of voters voting against their signal in the population is insignificant compared with the number of voters who vote according to their signal.

Another implication of the first part of the theorem is that the difference in behavior between those who receive signal B or R converges to zero. A voter who receives signal B always votes for B while the fraction of voters who do not vote for R when they receive signal R is $\int_{\frac{1}{2}}^{q_R^+} f(q)\mathrm{d}q$, which converges to zero.

The second part of the theorem states that in equilibrium of Type 2 we have $\int_{q_B^+}^{q_R^+} f(q)\mathrm{d}q \to 0$. Again this implies that the difference in behavior between those who receive signal B or R converges to zero. Therefore, Theorem 2 implies that when the number of voters tends to infinity the fraction of voters who vote against their signal ($\int_{\frac{1}{2}}^{q_R^-} f(q)\mathrm{d}q$) and the fraction of voters whose behavior depend on the specific signal received ($\int_{q_B^+}^{q_R^+} f(q)\mathrm{d}q$) vanishes in the limit. That is, as the number of voters increases the effect of an asymmetric common prior ($p > \frac{1}{2}$) vanishes in the limit and the results in McMurray (2013) apply. (i.e. the equilibrium is characterized by a cut-point q that determines who abstains and who votes for his signal independently on the particular signal received).

The reason behind the result in Theorem 2 is the following. Assume that $\int_{\frac{1}{2}}^{q_R^+} f(q)\mathrm{d}q$ does not converge to zero. In this case if a voter is pivotal then it must be that in proportion more voters received signal R than B: as $\int_{\frac{1}{2}}^{q_R^+} f(q)\mathrm{d}q$ does not converge to zero, not all voters who receive signal R vote for R yet all voters who receive signal B vote for B. If more voters receive signal R than B then since the average signal quality μ is greater than $\frac{1}{2}$ by law of large numbers the state of nature is R with probability one. This implies that all voters should vote for R, contradicting the fact that all voters who receive signal B prefer to vote for B.

A similar argument shows that as the number of voters grows large in equilibrium of Type 2 we must have $\int_{q_B^+}^{q_R^+} f(q)\mathrm{d}q \to 0$. If $\int_{q_B^+}^{q_R^+} f(q)\mathrm{d}q$ does not converge to zero then if a voter is pivotal it must be that a greater proportion of voters receive signal R than signal B. This is because a higher fraction of those voters who receive signal R compared to those who receive signal B abstain. Law of large number then means that the state is R with probability one, which implies that all voters should vote for R. This represents a contradiction to the characterization of equilibrium of Type 2.

Our final result states that in large elections the best candidate wins with probability one.

This result is in line with the Condorcet Jury Theorem and the findings in previous literature (see for instance Feddersen and Pesendorfer (1996, 1997, 1999) and McMurray (2013)).

Proposition 1. *The equilibrium in a large election is such that the best candidate wins with probability one.*

Given the result in Theorem 2, whether a voter chooses to vote or to abstain depends on the quality of his signal, not on the value of the signal itself. Thus, for a given state of nature and given level of abstention, the best candidate is expected to receive a share μ of the votes while the other candidate is expected to receive a share $1 - \mu$ of the votes. Since $\mu > \frac{1}{2}$ law of large numbers implies that the best candidate wins with probability one.

5 Conclusions

We presented a common value election setting where voters have private information of different qualities. We showed both theoretically and experimentally that voters may have incentives to vote against their private information, even if such private information is useful, all have the same preferences, and abstention is allowed. Moreover, we found that elections do not generally aggregate information efficiently. Experimental participants used their private information not always as predicted by Bayesian equilibrium analysis. This produced the unexpected result that higher quality of information is not always better. We also found that participants seem to rely on simple heuristics to a greater extent when priors are asymmetric.

Future research could build on our work and study behaviour in asymmetric prior settings in more detail. Our research has shown that, both theoretically and empirically, there are interesting and non-trivial differences between the asymmetric and symmetric prior cases.

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A Appendix: Proofs

The following lemma is used in the proof of Theorem 1.

Lemma 1. *The best response of any voter i against any strategy v played by the other N voters is given v', which is characterized by four cutpoints q_B^-, q_B^+, q_R^- and q_R^+ in $\left[\frac{1}{2}, 1\right]$ such that*

$$v'(\theta_i, q_i) \quad = \quad \begin{cases} B & \textit{if either } \sigma_i = B \textit{ and } q_i \geq q_B^+ \textit{ or } \sigma_i = R \textit{ and } q_i < q_R^-, \\ R & \textit{if either } \sigma_i = B \textit{ and } q_i < q_B^- \textit{ or } \sigma_i = R \textit{ and } q_i \geq q_R^+, \\ \emptyset & \textit{otherwise.} \end{cases}$$

Proof. Take any arbitrary voter i and assume all voters except i use strategy v. Consider equations (1), (2) and (3) and assume that $\sigma_i = B$. We have that both $Eu(B,v) - Eu(R,v)$ and $Eu(B,v) - Eu(\emptyset,v)$ are increasing in q_i. Therefore, there exists a $x \in [0,1]$ such that both equations are positive and voter i votes for B whenever $q_i \geq x$. Since $q_i \in \left[\frac{1}{2}, 1\right]$ if we define $q_B^+ = \max\left\{\frac{1}{2}, x\right\}$ we have that voter i votes for B whenever $q_i \geq q_B^+$.

Moreover, both $Eu(R,v) - Eu(B,v)$ and $Eu(R,v) - Eu(\emptyset,v)$ are decreasing in q_i. Therefore, there exists a y with $0 \leq y \leq x$ such that both equations are positive and voter i votes for R whenever $q_i < y$. If we define $q_B^- = \max\left\{\frac{1}{2}, y\right\}$ we have that voter i votes for B whenever $q_i < q_B^-$.

The final possibility is that both $Eu(B,v) - Eu(\emptyset,v)$ and $Eu(R,v) - Eu(\emptyset,v)$ are negative, which can happen if and only if $q_i \in [y,x)$ or, in other words, $q_i \in [q_B^-, q_B^+)$. In this case, voter i prefers to abstain.

A similar reasoning when $\sigma_i = R$ leads to the conclusion in the lemma. □

Proof of Theorem 1. **An Equilibrium Exists**

First we demonstrate existence. Given the result in Lemma 1, we know that for any strategy v employed by the other N voters every voter employs a strategy that is characterized by four cutpoints q_B^-, q_B^+, q_R^- and q_R^+. Define the function $\phi : \left[\frac{1}{2}, 1\right]^4 \to \left[\frac{1}{2}, 1\right]^4$ where $\phi(q_B^-, q_B^+, q_R^-, q_R^+)$ is the best response of any voter to a situation where all other N voters employ an strategy characterized the four cutpoints $q_B^-, q_B^+, q_R^-, q_R^+$. We have to prove that ϕ has a fixed point. By the fixed point theorem, since the set $\left[\frac{1}{2}, 1\right]^4$ is convex and compact in the Euclidean space we are left to show that ϕ is continuous.

When N voters are using strategy v characterized by the four cutpoints q_B^-, q_B^+, q_R^- and

q_R^+ we have that

$$\begin{aligned}
\pi_t(v,B) \quad = \quad & \sum_{s_B(B)=0}^{\lfloor \frac{N}{2} \rfloor} \sum_{s_R(B)=0}^{\lceil \frac{N}{2} \rceil - s_B(B)} \sum_{s_B(\emptyset)=0}^{N-2(s_B(B)+s_R(B))} \sum_{s_B(R)=0}^{s_B(B)+s_R(B)} \\
& \frac{N!}{s_B(B)!s_R(B)!s_B(\emptyset)!s_B(R)!(s_B(B)+s_R(B)-s_B(R))!(N-2(s_B(B)+s_R(B))-s_B(\emptyset))!} \\
& \times \left[\int_{q_B^+}^{1} q f(q)\mathrm{d}q\right]^{s_B(B)} \left[\int_{\frac{1}{2}}^{q_R^-} (1-q) f(q)\mathrm{d}q\right]^{s_R(B)} \\
& \times \left[\int_{q_B^-}^{q_B^+} q f(q)\mathrm{d}q\right]^{s_B(\emptyset)} \left[\int_{\frac{1}{2}}^{q_B^-} q f(q)\mathrm{d}q\right]^{s_B(R)} \\
& \times \left[\int_{q_R^+}^{1} (1-q) f(q)\mathrm{d}q\right]^{s_B(B)+s_R(B)-s_B(R)} \left[\int_{q_R^-}^{q_R^+} (1-q) f(q)\mathrm{d}q\right]^{N-2(s_B(B)+s_R(B))-s_B(\emptyset)} \qquad (4)
\end{aligned}$$

Since $F(q) = \int_{\frac{1}{2}}^{q} f(q)\mathrm{d}q$ we have that F is continuous and, because it is a cumulative density function, it is bounded in $[0,1]$. Therefore, F is integrable and moreover continuous with respect to the integration limits. Thus, $\int q f(q)\mathrm{d}(q) = qF(q) - \int F(q)\mathrm{d}q$ is continuous with respect to the integration limits. As a result, $\pi_t(v,B)$ is continuous with respect to the cutpoints q_B^-, q_B^+, q_R^- and q_R^+.

It can be shown in a similar fashion that $\pi_t(v,s), \pi_R(v,s)$ and $\pi_B(v,s)$ are continuous with respect to the cutpoints q_B^-, q_B^+, q_R^- and q_R^+ for all $s \in \{B,R\}$. Hence, we have that $Eu(B,v)-Eu(R,v), Eu(B,v)-Eu(\emptyset,v)$ and $Eu(B,v)-Eu(\emptyset,v)$ are continuous with respect to the cutpoints q_B^-, q_B^+, q_R^- and q_R^+. Thus, ϕ is continuous as we wanted to show.

Equilibrium is of Two Types

Given the result in Lemma 1, any equilibrium is characterized by the four threshold values q_B^-, q_B^+, q_R^- and q_R^+. Assume that $q_R^- > \frac{1}{2}$, then we have that $Eu(B,v) - Eu(R,v) > 0$ and $Eu(B,v) - Eu(\emptyset,v) > 0$ for all i with $\sigma_i = R$ and $q_i \in \left[\frac{1}{2}, q_R^-\right)$, which implies that $Eu(B,v) - Eu(R,v) > 0$ and $Eu(B,v) - Eu(\emptyset,v) > 0$ for all i with $\sigma_i = B$ and $q_i \in \left[\frac{1}{2}, q_R^-\right)$. This means that $q_B^-, q_B^+ = \frac{1}{2}$, which leads to equilibrium of Type 1 in the proposition.

Assume now that $q_R^- = \frac{1}{2}$ and $q_R^+ > \frac{1}{2}$. In this case we have that $Eu(R,v) - Eu(\emptyset,v) < 0$ for all i with $\sigma_i = R$ and $q_i \in \left[\frac{1}{2}, q_R^+\right)$, which implies that $Eu(R,v) - Eu(\emptyset,v) < 0$ for all i with $\sigma_i = B$ and $q_i \in \left[\frac{1}{2}, q_R^+\right)$. This means that $q_B^- = \frac{1}{2}$, which leads to equilibrium of type 2 in the proposition.

Finally, assume that $q_R^- = q_R^+ = \frac{1}{2}$. We proceed by showing that $\pi_t(v,B) + \pi_R(v,B) \geq \pi_t(v,R) + \pi_R(v,R)$. If this were true, and since $q_R^+ = \frac{1}{2}$ implies that $Eu(R,v) - Eu(\emptyset,v) \geq 0$ for all i with $\sigma_i = R$ and $q_i \in \left[\frac{1}{2}, 1\right]$, equation (3) together with the fact that $p \geq \frac{1}{2}$ implies that $\pi_t(v,R)+\pi_R(v,R) \geq \pi_t(v,B)+\pi_R(v,B)$, which would represent a contradiction (unless $q_R^- = q_R^+ = q_B^- = q_B^+ = p = \frac{1}{2}$, which is an equilibrium of either Type in the proposition).

First we show that $\pi_t(v,B) - \pi_t(v,R) \geq 0$ for all $\frac{1}{2} \leq q_B^- \leq q_B^+ \leq 1$. Note that

$$\begin{aligned}
\pi_t(v,B) &= \sum_{j=0}^{\lfloor \frac{N}{2} \rfloor} \sum_{r=0}^{j} \frac{N!}{j!(j-r)!r!(N-2j)!} \\
&\quad \left[\int_{q_B^+}^{1} qf(q)\mathrm{d}q\right]^j \left[\int_{\frac{1}{2}}^{q_B^-} qf(q)\mathrm{d}q\right]^{j-r} \left[\int_{\frac{1}{2}}^{1} (1-q)f(q)\mathrm{d}q\right]^r \left[\int_{q_B^-}^{q_B^+} qf(q)\mathrm{d}q\right]^{N-2j}, \\
\pi_t(v,R) &= \sum_{j=0}^{\lfloor \frac{N}{2} \rfloor} \sum_{r=0}^{j} \frac{N!}{j!(j-r)!r!(N-2j)!} \\
&\quad \left[\int_{q_B^+}^{1} (1-q)f(q)\mathrm{d}q\right]^j \left[\int_{\frac{1}{2}}^{q_B^-} (1-q)f(q)\mathrm{d}q\right]^{j-r} \left[\int_{\frac{1}{2}}^{1} qf(q)\mathrm{d}q\right]^r \left[\int_{q_B^-}^{q_B^+} (1-q)f(q)\mathrm{d}q\right]^{N-2j}.
\end{aligned}$$

Given that $q_i \geq \frac{1}{2}$ for all voter i we have that

$$\begin{aligned}
\pi_t(v,B) - \pi_t(v,R) \geq & \sum_{j=0}^{\lfloor \frac{N}{2} \rfloor} \sum_{r=0}^{j} \frac{N!}{j!(j-r)!r!(N-2j)!} \\
& \left(\left[\int_{q_B^+}^{1} qf(q)\mathrm{d}q\right]^j \left[\int_{\frac{1}{2}}^{1} (1-q)f(q)\mathrm{d}q\right]^r \right. \\
& \left. - \left[\int_{q_B^+}^{1} (1-q)f(q)\mathrm{d}q\right]^j \left[\int_{\frac{1}{2}}^{1} qf(q)\mathrm{d}q\right]^r \right).
\end{aligned}$$

Thus, if $q_B^+ = \frac{1}{2}$ or $q_B^+ = 1$ then $\pi_t(v,B) - \pi_t(v,R) \geq 0$. Consider now the cases where $q_B^+ \in \left(\frac{1}{2}, 1\right)$. Using once more that $q_i \geq \frac{1}{2}$ for all i, a necessary condition for $\pi_t(v,B) - \pi_t(v,R) \geq 0$ is that

$$\left[\int_{q_B^+}^{1} qf(q)\mathrm{d}q\right]^r \left[\int_{\frac{1}{2}}^{1} (1-q)f(q)\mathrm{d}q\right]^r \geq \left[\int_{q_B^+}^{1} (1-q)f(q)\mathrm{d}q\right]^r \left[\int_{\frac{1}{2}}^{1} qf(q)\mathrm{d}q\right]^r.$$

This can be written as

$$\begin{aligned}
&\left[\int_{q_B^+}^{1} qf(q)\mathrm{d}q\right] \left[\int_{q_B^+}^{1} (1-q)f(q)\mathrm{d}q + \int_{\frac{1}{2}}^{q_B^+} (1-q)f(q)\mathrm{d}q\right] \geq \\
&\qquad \left[\int_{q_B^+}^{1} (1-q)f(q)\mathrm{d}q\right] \left[\int_{q_B^+}^{1} qf(q)\mathrm{d}q + \int_{\frac{1}{2}}^{q_B^+} qf(q)\mathrm{d}q\right].
\end{aligned}$$

In other words,

$$
\begin{aligned}
\frac{\int_{\frac{1}{2}}^{q_B^+}(1-q)f(q)\mathrm{d}q}{\int_{q_B^+}^{1}(1-q)f(q)\mathrm{d}q} &\geq \frac{\int_{\frac{1}{2}}^{q_B^+} qf(q)\mathrm{d}q}{\int_{q_B^+}^{1} qf(q)\mathrm{d}q}, \\
\frac{\int_{\frac{1}{2}}^{q_B^+}(1-q)f(q)\mathrm{d}q}{\int_{\frac{1}{2}}^{q_B^+} qf(q)\mathrm{d}q} &\geq \frac{\int_{q_B^+}^{1}(1-q)f(q)\mathrm{d}q}{\int_{q_B^+}^{1} qf(q)\mathrm{d}q}, \\
\frac{\int_{\frac{1}{2}}^{q_B^+} f(q)\mathrm{d}q}{\int_{\frac{1}{2}}^{q_B^+} qf(q)\mathrm{d}q} &\geq \frac{\int_{q_B^+}^{1} f(q)\mathrm{d}q}{\int_{q_B^+}^{1} qf(q)\mathrm{d}q}, \\
\frac{\int_{q_B^+}^{1} qf(q)\mathrm{d}q}{\int_{\frac{1}{2}}^{q_B^+} qf(q)\mathrm{d}q} &\geq \frac{\int_{q_B^+}^{1} f(q)\mathrm{d}q}{\int_{\frac{1}{2}}^{q_B^+} f(q)\mathrm{d}q}.
\end{aligned}
$$

Since it is true that

$$
\begin{aligned}
\frac{\int_{q_B^+}^{1} qf(q)\mathrm{d}q}{\int_{\frac{1}{2}}^{q_B^+} qf(q)\mathrm{d}q} &\geq \frac{\int_{q_B^+}^{1} q_B^+ f(q)\mathrm{d}q}{\int_{\frac{1}{2}}^{q_B^+} q_B^+ f(q)\mathrm{d}q} \\
&= \frac{\int_{q_B^+}^{1} f(q)\mathrm{d}q}{\int_{\frac{1}{2}}^{q_B^+} f(q)\mathrm{d}q},
\end{aligned}
$$

we have that $\pi_t(v,B)-\pi_t(v,R)\geq 0$.

Proceeding in a similar fashion, it can be shown that $\pi_R(v,B)-\pi_R(v,R)\geq 0$. Thus, we have that $\pi_t(v,B)-\pi_R(v,B)\geq \pi_i(v,R)-\pi_R(v,R)$ as required.

In Equilibrium of Type 1 $q_R^-\leq p$

We can use the algebra from the previous part of the proof to show that in equilibrium of Type 1 $\pi_t(v,B)-\pi_t(v,R)\leq 0$ and $\pi_B(v,R)-\pi_B(v,B)\geq 0$ for all $\frac{1}{2}\leq q_R^-\leq q_R^+\leq 1$. Hence, equation (2) together with the definition of q_R^- implies $p(1-q_R^-)\geq(1-p)q_R^-$, which in turn implies $q_R^-\leq p$.

In Equilibrium of Type 2 $q_R^+\geq q_B^+$

Next we prove that in any equilibrium of type 2 it must be that $q_R^+\geq q_B^+$. Assume the opposite, $q_B^+ > q_R^+$. Note that in any Type 2 equilibrium we have that

$$\begin{aligned}\pi_t(v,B) &= \sum_{j=0}^{\lfloor \frac{N}{2} \rfloor} \left[\int_{q_B^+}^1 qf(q)\mathrm{d}q\right]^j \left[\int_{q_R^+}^1 (1-q)f(q)\mathrm{d}q\right]^j \\ &\times \sum_{r=0}^{N-2j} \frac{N!}{j!j!r!(N-2j-r)!} \\ &\times \left[\int_{\frac{1}{2}}^{q_B^+} qf(q)\mathrm{d}q\right]^r \left[\int_{\frac{1}{2}}^{q_R^+} (1-q)f(q)\mathrm{d}q\right]^{N-2j-r}.\end{aligned}$$

Thus, it is true that

$$\begin{aligned}\pi_t(v,B) &= \sum_{j=0}^{\lfloor \frac{N}{2} \rfloor} \left[\int_{q_B^+}^1 qf(q)\mathrm{d}q\right]^j \left[\int_{q_R^+}^1 (1-q)f(q)\mathrm{d}q\right]^j \\ &\times \sum_{k=0}^{\lfloor \frac{N-2j}{2} \rfloor} \frac{N!}{j!j!k!(N-2j-k)!} \\ &\times \left[\int_{\frac{1}{2}}^{q_B^+} qf(q)\mathrm{d}q\right]^k \left[\int_{\frac{1}{2}}^{q_R^+} (1-q)f(q)\mathrm{d}q\right]^k \\ &\times \left(\left[\int_{\frac{1}{2}}^{q_B^+} qf(q)\mathrm{d}q\right]^{N-2j-2k} + \left[\int_{\frac{1}{2}}^{q_R^+} (1-q)f(q)\mathrm{d}q\right]^{N-2j-2k}\right), \qquad (5)\\ \pi_t(v,R) &= \sum_{j=0}^{\lfloor \frac{N}{2} \rfloor} \left[\int_{q_B^+}^1 (1-q)f(q)\mathrm{d}q\right]^j \left[\int_{q_R^+}^1 qf(q)\mathrm{d}q\right]^j \\ &\times \sum_{k=0}^{\lfloor \frac{N-2j}{2} \rfloor} \frac{N!}{j!j!k!(N-2j-k)!} \\ &\times \left[\int_{\frac{1}{2}}^{q_B^+} (1-q)f(q)\mathrm{d}q\right]^k \left[\int_{\frac{1}{2}}^{q_R^+} qf(q)\mathrm{d}q\right]^k \\ &\times \left(\left[\int_{\frac{1}{2}}^{q_B^+} (1-q)f(q)\mathrm{d}q\right]^{N-2j-2k} + \left[\int_{\frac{1}{2}}^{q_R^+} qf(q)\mathrm{d}q\right]^{N-2j-2k}\right). \qquad (6)\end{aligned}$$

We now show that $\pi_t(v,B) - \pi_t(v,R) \geq 0$ in three steps. First, we have that $q_B^+ > q_R^+$ implies

$$\left[\int_{q_B^+}^1 qf(q)\mathrm{d}q\right]^j \left[\int_{q_R^+}^1 (1-q)f(q)\mathrm{d}q\right]^j \geq \left[\int_{q_B^+}^1 (1-q)f(q)\mathrm{d}q\right]^j \left[\int_{q_R^+}^1 qf(q)\mathrm{d}q\right]^j \qquad (7)$$

for all $j \in \{0, 1, \dots\}$ if and only if

$$\int_{q_B^+}^{1} qf(q)\mathrm{d}q \left[\int_{q_B^+}^{1}(1-q)f(q)\mathrm{d}q + \int_{q_R^+}^{q_B^+}(1-q)f(q)\mathrm{d}q\right] \geq \int_{q_B^+}^{1}(1-q)f(q)\mathrm{d}q \left[\int_{q_B^+}^{1} qf(q)\mathrm{d}q + \int_{q_R^+}^{q_B^+} qf(q)\mathrm{d}q\right].$$

which can be rewritten as

$$\begin{aligned}
\int_{q_B^+}^{1} qf(q)\mathrm{d}q \int_{q_R^+}^{q_B^+}(1-q)f(q)\mathrm{d}q &\geq \int_{q_B^+}^{1}(1-q)f(q)\mathrm{d}q \int_{q_R^+}^{q_B^+} qf(q)\mathrm{d}q, \\
\frac{\int_{q_R^+}^{q_B^+}(1-q)f(q)\mathrm{d}q}{\int_{q_R^+}^{q_B^+} qf(q)\mathrm{d}q} &\geq \frac{\int_{q_B^+}^{1}(1-q)f(q)\mathrm{d}q}{\int_{q_B^+}^{1} qf(q)\mathrm{d}q}, \\
\frac{\int_{q_R^+}^{q_B^+} f(q)\mathrm{d}q}{\int_{q_R^+}^{q_B^+} qf(q)\mathrm{d}q} &\geq \frac{\int_{q_B^+}^{1} f(q)\mathrm{d}q}{\int_{q_B^+}^{1} qf(q)\mathrm{d}q}, \\
\frac{\int_{q_B^+}^{1} qf(q)\mathrm{d}q}{\int_{q_R^+}^{q_B^+} qf(q)\mathrm{d}q} &\geq \frac{\int_{q_B^+}^{1} f(q)\mathrm{d}q}{\int_{q_R^+}^{q_B^+} f(q)\mathrm{d}q},
\end{aligned}$$

which given that

$$\begin{aligned}
\frac{\int_{q_B^+}^{1} qf(q)\mathrm{d}q}{\int_{q_R^+}^{q_B^+} qf(q)\mathrm{d}q} &\geq \frac{\int_{q_B^+}^{1} q_B^+ f(q)\mathrm{d}q}{\int_{q_R^+}^{q_B^+} q_B^+ f(q)\mathrm{d}q}, \\
&= \frac{\int_{q_B^+}^{1} f(q)\mathrm{d}q}{\int_{q_R^+}^{q_B^+} f(q)\mathrm{d}q},
\end{aligned}$$

proves that equation (7) holds true when $q_B^+ > q_R^+$.

Second, we have that $q_B^+ > q_R^+$ implies

$$\left[\int_{\frac{1}{2}}^{q_B^+} qf(q)\mathrm{d}q\right]^k \left[\int_{\frac{1}{2}}^{q_R^+}(1-q)f(q)\mathrm{d}q\right]^k \geq \left[\int_{\frac{1}{2}}^{q_B^+}(1-q)f(q)\mathrm{d}q\right]^k \left[\int_{\frac{1}{2}}^{q_R^+} qf(q)\mathrm{d}q\right]^k \quad (8)$$

for all $k \in \{0, 1, \ldots\}$ if and only if

$$
\begin{aligned}
\frac{\int_{\frac{1}{2}}^{q_R^+} f(q)\mathrm{d}q}{\int_{\frac{1}{2}}^{q_B^+} f(q)\mathrm{d}q} &\geq \frac{\int_{\frac{1}{2}}^{q_R^+} qf(q)\mathrm{d}q}{\int_{\frac{1}{2}}^{q_B^+} qf(q)\mathrm{d}q}, \\
\frac{\int_{\frac{1}{2}}^{q_B^+} qf(q)\mathrm{d}q}{\int_{\frac{1}{2}}^{q_R^+} qf(q)\mathrm{d}q} &\geq \frac{\int_{\frac{1}{2}}^{q_B^+} f(q)\mathrm{d}q}{\int_{\frac{1}{2}}^{q_R^+} f(q)\mathrm{d}q}, \\
\frac{\int_{q_R^+}^{q_B^+} qf(q)\mathrm{d}q}{\int_{\frac{1}{2}}^{q_R^+} qf(q)\mathrm{d}q} &\geq \frac{\int_{q_R^+}^{q_B^+} f(q)\mathrm{d}q}{\int_{\frac{1}{2}}^{q_R^+} f(q)\mathrm{d}q},
\end{aligned}
$$

which given that

$$
\begin{aligned}
\frac{\int_{q_R^+}^{q_B^+} qf(q)\mathrm{d}q}{\int_{\frac{1}{2}}^{q_R^+} qf(q)\mathrm{d}q} &\geq \frac{\int_{q_R^+}^{q_B^+} q_R^+ f(q)\mathrm{d}q}{\int_{\frac{1}{2}}^{q_R^+} q_R^+ f(q)\mathrm{d}q}, \\
&= \frac{\int_{q_R^+}^{q_B^+} f(q)\mathrm{d}q}{\int_{\frac{1}{2}}^{q_R^+} f(q)\mathrm{d}q},
\end{aligned}
$$

proves that equation (8) holds true when $q_B^+ > q_R^+$.

Third, we have that $q_B^+ > q_R^+$ implies

$$
\begin{aligned}
&\left[\int_{\frac{1}{2}}^{q_B^+} qf(q)\mathrm{d}q\right]^m + \left[\int_{\frac{1}{2}}^{q_R^+} (1-q)f(q)\mathrm{d}q\right]^m \geq \\
&\left[\int_{\frac{1}{2}}^{q_B^+} (1-q)f(q)\mathrm{d}q\right]^m + \left[\int_{\frac{1}{2}}^{q_R^+} qf(q)\mathrm{d}q\right]^m
\end{aligned}
\tag{9}
$$

for all $m \in \{0, 1, \ldots\}$ if and only if

$$
\begin{aligned}
&\left[\int_{\frac{1}{2}}^{q_R^+} qf(q)\mathrm{d}q + \int_{q_R^+}^{q_B^+} qf(q)\mathrm{d}q\right]^m - \left[\int_{\frac{1}{2}}^{q_R^+} qf(q)\mathrm{d}q\right]^m \geq \\
&\left[\int_{\frac{1}{2}}^{q_R^+} (1-q)f(q)\mathrm{d}q + \int_{q_R^+}^{q_B^+} (1-q)f(q)\mathrm{d}q\right]^m - \left[\int_{\frac{1}{2}}^{q_R^+} (1-q)f(q)\mathrm{d}q\right]^m
\end{aligned}
$$

which is always true for $m = 0$ and true for $m \in \{1, 2, \ldots\}$ if and only if

$$
\begin{aligned}
&\sum_{l=1}^{m} \binom{m}{l} \left[\int_{\frac{1}{2}}^{q_R^+} qf(q)\mathrm{d}q\right]^{m-l} \left[\int_{q_R^+}^{q_B^+} qf(q)\mathrm{d}q\right]^l \geq \\
&\sum_{l=1}^{m} \binom{m}{l} \left[\int_{\frac{1}{2}}^{q_R^+} (1-q)f(q)\mathrm{d}q\right]^{m-l} \left[\int_{q_R^+}^{q_B^+} (1-q)f(q)\mathrm{d}q\right]^l.
\end{aligned}
$$

Since the expression above is true we have that $q_B^+ > q_R^+$ implies equation (9) as required.

Therefore, we have shown that $q_B^+ > q_R^+$ implies equations (7), (8) and (9) are true. Hence, from equations (5) and (6) we have that $q_B^+ > q_R^+$ implies $\pi_t(v,B) - \pi_t(v,R) \geq 0$.

Equations (2) and (3) together with the fact that $q_B^+ > q_R^+$ and $p \geq \frac{1}{2}$ imply that

$$\begin{aligned} q_B^+ \left(\pi_t(v,B) + \pi_B(v,B)\right) &\leq (1-q_B^+)\left(\pi_t(v,R) + \pi_B(v,R)\right), \\ q_B^+ \left(\pi_t(v,R) + \pi_R(v,R)\right) &> (1-q_B^+)\left(\pi_t(v,B) + \pi_R(v,B)\right). \end{aligned}$$

Given that, as we have just shown, $q_B^+ > q_R^+$ implies $\pi_t(v,B) - \pi_t(v,R) \geq 0$, the two expressions above imply

$$(1-q_B^+)\left(\pi_B(v,R) - \pi_R(v,B)\right) > q_B^+\left(\pi_B(v,B) - \pi_R(v,R)\right). \tag{10}$$

Note now that

$$\begin{aligned} \pi_R(v,B) &= \sum_{j=1}^{\lceil \frac{N}{2} \rceil} \left[\int_{q_B^+}^1 q f(q)\mathrm{d}q\right]^j \left[\int_{q_R^+}^1 (1-q) f(q)\mathrm{d}q\right]^{j-1} \\ &\times \sum_{k=0}^{\lfloor \frac{N-2j+1}{2} \rfloor} \frac{N!}{j!j!k!(N-2j+1-k)!} \\ &\times \left[\int_{\frac{1}{2}}^{q_B^+} q f(q)\mathrm{d}q\right]^k \left[\int_{\frac{1}{2}}^{q_R^+} (1-q) f(q)\mathrm{d}q\right]^k \\ &\times \left(\left[\int_{\frac{1}{2}}^{q_B^+} q f(q)\mathrm{d}q\right]^{N-2j+1-2k} + \left[\int_{\frac{1}{2}}^{q_R^+} (1-q) f(q)\mathrm{d}q\right]^{N-2j+1-2k}\right), \\ \pi_B(v,R) &= \sum_{j=1}^{\lceil \frac{N}{2} \rceil} \left[\int_{q_B^+}^1 (1-q) f(q)\mathrm{d}q\right]^{j-1} \left[\int_{q_R^+}^1 q f(q)\mathrm{d}q\right]^j \\ &\times \sum_{k=0}^{\lfloor \frac{N-2j+1}{2} \rfloor} \frac{N!}{j!j!k!(N-2j+1-k)!} \\ &\times \left[\int_{\frac{1}{2}}^{q_B^+} (1-q) f(q)\mathrm{d}q\right]^k \left[\int_{\frac{1}{2}}^{q_R^+} q f(q)\mathrm{d}q\right]^k \\ &\times \left(\left[\int_{\frac{1}{2}}^{q_B^+} (1-q) f(q)\mathrm{d}q\right]^{N-2j+1-2k} + \left[\int_{\frac{1}{2}}^{q_R^+} q f(q)\mathrm{d}q\right]^{N-2j+1-2k}\right), \end{aligned}$$

and similarly for $\pi_B(v,B)$ and $\pi_R(v,R)$. Define

$$
\begin{aligned}
K_B &= \sum_{k=0}^{\lfloor \frac{N-2j+1}{2} \rfloor} \frac{N!}{j!j!k!(N-2j-k+1)!} \\
&\quad \times \left[\int_{\frac{1}{2}}^{q_B^+} qf(q)\mathrm{d}q\right]^k \left[\int_{\frac{1}{2}}^{q_R^+} (1-q)f(q)\mathrm{d}q\right]^k \\
&\quad \times \left(\left[\int_{\frac{1}{2}}^{q_B^+} qf(q)\mathrm{d}q\right]^{N-2j+1-2k} + \left[\int_{\frac{1}{2}}^{q_R^+} (1-q)f(q)\mathrm{d}q\right]^{N-2j+1-2k}\right), \\
K_R &= \sum_{k=0}^{\lfloor \frac{N-2j+1}{2} \rfloor} \frac{N!}{j!j!k!(N-2j-k+1)!} \\
&\quad \times \left[\int_{\frac{1}{2}}^{q_B^+} (1-q)f(q)\mathrm{d}q\right]^k \left[\int_{\frac{1}{2}}^{q_R^+} qf(q)\mathrm{d}q\right]^k \\
&\quad \times \left(\left[\int_{\frac{1}{2}}^{q_B^+} (1-q)f(q)\mathrm{d}q\right]^{N-2j+1-2k} + \left[\int_{\frac{1}{2}}^{q_R^+} qf(q)\mathrm{d}q\right]^{N-2j+1-2k}\right).
\end{aligned}
$$

Then, equations (8) and (9) imply $K_B \geq K_R$. Moreover, as $q_B^+ > q_R^+$ implies equation (7), we have that

$$
\begin{aligned}
(1-q_B^+)\left(\pi_B(v,R)-\pi_R(v,B)\right) &\leq (1-q_B^+)\left(\int_{q_R^+}^1 qf(q)\mathrm{d}q - \int_{q_B^+}^1 qf(q)\mathrm{d}q\right) K_R, \\
q_B^+\left(\pi_B(v,B)-\pi_R(v,R)\right) &\geq q_B^+\left(\int_{q_R^+}^1 (1-q)f(q)\mathrm{d}q - \int_{q_B^+}^1 (1-q)f(q)\mathrm{d}q\right) K_B.
\end{aligned}
$$

This means that equation (10) holds only if

$$
\begin{aligned}
(1-q_B^+)\left(\int_{q_R^+}^1 qf(q)\mathrm{d}q - \int_{q_B^+}^1 qf(q)\mathrm{d}q\right) K_R &\geq q_B^+\left(\int_{q_R^+}^1 (1-q)f(q)\mathrm{d}q - \int_{q_B^+}^1 (1-q)f(q)\mathrm{d}q\right) K_B, \\
(1-q_B^+)\left(\int_{q_R^+}^{q_B^+} qf(q)\mathrm{d}q\right) &\geq q_B^+\left(\int_{q_R^+}^{q_B^+} (1-q)f(q)\mathrm{d}q\right), \\
\left(\int_{q_R^+}^{q_B^+} qf(q)\mathrm{d}q\right) &\geq \left(\int_{q_R^+}^{q_B^+} q_B^+ f(q)\mathrm{d}q\right),
\end{aligned}
$$

holds. However, given that $q_B^+ > q_R^+$ the expression above is false. This leads to a contradiction, which means that the claim $q_B^+ > q_R^+$ is false as required. □

The following Lemma from Feddersen and Pessendorfer (1996) is used in the proof of the Theorem 2.

Lemma 2 (Lemma 0 in Feddersen and Pessendorfer (1996)). *Let $(a_N, b_N, c_N)_{N=1}^{\infty}$ a sequence that satisfies $(a_N, b_N, c_N) \in [0,1]^3$ and $a_N < b_N - \delta$ and $\delta < c_N$ for all N and some $\delta > 0$. Then, for $i = 0, 1$ as $N \to \infty$*

$$\frac{\sum_{j=0}^{\frac{N}{2}-i} \frac{N!}{(j+i)!j!(N-2j-i)!} c_N^{N-2j-i} a_N^j}{\sum_{j=0}^{\frac{N}{2}-i} \frac{N!}{(j+i)!j!(N-2j-i)!} c_N^{N-2j-i} b_N^j} \quad \to \quad 0.$$

Proof of Theorem 2. **Equilibrium of Type 1**

Define γ_{xy} as the proportion of voters who vote for $x \in \{B, R, \emptyset\}$ when the state is $y \in \{B, R\}$.

First we show that as $N \to \infty$ the equilibrium of Type 1 is such that $\int_{\frac{1}{2}}^{q_R^+} f(q)\mathrm{d}q \to 0$. Assume for now that there exists a $\rho > 0$ such that $\int_{q_R^+}^{1} f(q)\mathrm{d}q > \rho$ for all N and consider an equilibrium of Type 1 and assume that there exists a $\varepsilon > 0$ such that either $\int_{\frac{1}{2}}^{q_R^-} f(q)\mathrm{d}q \geq \varepsilon$ or $\int_{q_R^-}^{q_R^+} f(q)\mathrm{d}q \geq \varepsilon$ for all N. We have that there exists a $\delta_1 > 0$ such that $\gamma_{RR}\gamma_{BR} - \delta_1 > \gamma_{BB}\gamma_{RB}$ if and only if

$$\begin{gathered}
\int_{q_R^+}^{1} qf(q)\mathrm{d}q \left(\int_{\frac{1}{2}}^{1} (1-q)f(q)\mathrm{d}q + \int_{\frac{1}{2}}^{q_R^-} qf(q)\mathrm{d}q \right) - \delta_1 > \\
\int_{q_R^+}^{1} (1-q)f(q)\mathrm{d}q \left(\int_{\frac{1}{2}}^{1} qf(q)\mathrm{d}q + \int_{\frac{1}{2}}^{q_R^-} (1-q)f(q)\mathrm{d}q \right), \\
\int_{q_R^+}^{1} qf(q)\mathrm{d}q \left(\int_{q_R^-}^{1} (1-q)f(q)\mathrm{d}q + \int_{\frac{1}{2}}^{q_R^-} f(q)\mathrm{d}q \right) - \delta_1 > \\
\int_{q_R^+}^{1} (1-q)f(q)\mathrm{d}q \left(\int_{q_R^-}^{1} qf(q)\mathrm{d}q + \int_{\frac{1}{2}}^{q_R^-} f(q)\mathrm{d}q \right), \\
\int_{q_R^+}^{1} qf(q)\mathrm{d}q \left(\int_{q_R^-}^{q_R^+} (1-q)f(q)\mathrm{d}q + \int_{\frac{1}{2}}^{q_R^-} f(q)\mathrm{d}q \right) - \delta_1 > \\
\int_{q_R^+}^{1} (1-q)f(q)\mathrm{d}q \left(\int_{q_R^-}^{q_R^+} qf(q)\mathrm{d}q + \int_{\frac{1}{2}}^{q_R^-} f(q)\mathrm{d}q \right).
\end{gathered}$$

B necessary condition for this is

$$\begin{aligned}
\int_{q_R^+}^{1} (q - q_R^+)f(q)\mathrm{d}q \int_{q_R^-}^{q_R^+} f(q)\mathrm{d}q + \int_{q_R^+}^{1} (2q-1)f(q)\mathrm{d}q \int_{\frac{1}{2}}^{q_R^-} f(q)\mathrm{d}q - \delta_1 &> 0, \\
\int_{q_R^+}^{1} (q - q_R^+)f(q)\mathrm{d}q \int_{q_R^-}^{q_R^+} f(q)\mathrm{d}q + (2q_R^- - 1) \int_{q_R^+}^{1} f(q)\mathrm{d}q \int_{\frac{1}{2}}^{q_R^-} f(q)\mathrm{d}q - \delta_1 &> 0.
\end{aligned}$$

By assumption $\int_{q_R^+}^{1} f(q)\mathrm{d}q > \rho$ for some $\rho > 0$. Therefore, if $\int_{\frac{1}{2}}^{q_R^-} f(q)\mathrm{d}q \geq \varepsilon$ then $q_R^- \geq F^{-1}(\varepsilon)$ and the expression above is true for any $\delta_1 \in (0, (2F^{-1}(\varepsilon) - 1)\rho\varepsilon)$.[9]

[9] F^{-1} exists because f is integrable and, hence, F is continuous.

Assume $\int_{\frac{1}{2}}^{q_R^-} f(q)\mathrm{d}q < \varepsilon$, which implies that $\int_{q_R^-}^{q_R^+} f(q)\mathrm{d}q \geq \varepsilon$. Note that $\int_{q_R^+}^{1} f(q)\mathrm{d}q > \rho$ for some $\rho > 0$ implies that for all $\bar{\rho} \in (0, \rho)$ there exists a $\beta > 0$ such that $\int_{q_R^+ + \beta}^{1} f(q)\mathrm{d}q > \bar{\rho}$, fix such ρ and consider its corresponding β. Thus, a necessary condition for $\gamma_{RR}\gamma_{BR} - \delta_1 > \gamma_{BB}\gamma_{RB}$ is

$$\begin{aligned}
\int_{q_R^+}^{1} (q - q_R^+) f(q)\mathrm{d}q \int_{q_R^-}^{q_R^+} f(q)\mathrm{d}q - \delta_1 &> 0, \\
\int_{q_R^+ + \beta}^{1} \beta f(q)\mathrm{d}q \int_{q_R^-}^{q_R^+} f(q)\mathrm{d}q - \delta_1 &> 0, \\
\beta\bar{\rho} \int_{q_R^-}^{q_R^+} f(q)\mathrm{d}q - \delta_1 &> 0, \\
\beta\bar{\rho}\varepsilon - \delta_1 &> 0.
\end{aligned}$$

Hence, for any $\delta_1 \in (0, \min\{(2F^{-1}(\varepsilon) - 1)\rho\varepsilon, \beta\bar{\rho}\varepsilon\})$ we have that $\gamma_{RR}\gamma_{BR} - \delta_1 > \gamma_{BB}\gamma_{RB}$.

If $\int_{q_R^-}^{q_R^+} f(q)\mathrm{d}q < \varepsilon$ for all $\varepsilon > 0$ then $\gamma_{\emptyset s} \to 0$. Since $\gamma_{RR}\gamma_{BR} - \delta_1 > \gamma_{BB}\gamma_{RB}$ implies

$$\lim_{N\to\infty} \frac{(\gamma_{BB}\gamma_{RB})^{\frac{N}{2}-i}}{(\gamma_{RR}\gamma_{BR})^{\frac{N}{2}-i}} \to 0$$

for $i = 0, 1$, we have $\frac{\pi_t(v,B)}{\pi_t(v,R)} \to 0$ and, if $\int_{q_R^-}^{q_R^+} f(q)\mathrm{d}q \neq 0$, also that $\frac{\pi_B(v,B)}{\pi_B(v,R)} \to 0$ and $\frac{\pi_R(v,B)}{\pi_R(v,R)} \to 0$. If $\int_{q_R^-}^{q_R^+} f(q)\mathrm{d}q = 0$ then $\pi_B(v,B) = \pi_B(v,R) = \pi_R(v,B) = \pi_R(v,R) = 0$.

On the other hand, if $\int_{q_R^-}^{q_R^+} f(q)\mathrm{d}q \geq \varepsilon$ then there exists a $\delta_2 > 0$ such that $\gamma_{\emptyset s} > \delta_2$. Define $\delta = \min\{\delta_1, \delta_2\}$. By Lemma 2 we have that as N grows large $\frac{\pi_t(v,B)}{\pi_t(v,R)} \to 0$, $\frac{\pi_B(v,B)}{\pi_B(v,R)} \to 0$ and $\frac{\pi_R(v,B)}{\pi_R(v,R)} \to 0$.

Therefore, equations (2) and (3) then imply $q_R^- \to \frac{1}{2}$ and $q_R^+ \to \frac{1}{2}$ which in turn implies $\int_{\frac{1}{2}}^{q_R^-} f(q)\mathrm{d}q \to 0$ and $\int_{q_R^-}^{q_R^+} f(q)\mathrm{d}q \to 0$, which contradicts the fact that either $\int_{\frac{1}{2}}^{q_R^-} f(q)\mathrm{d}q \geq \varepsilon$ or $\int_{q_R^-}^{q_R^+} f(q)\mathrm{d}q \geq \varepsilon$ for a fixed ε.

Assume now that for all $\rho > 0$ there exists an $\bar{N}$ such that for all $N \geq \bar{N}$, we have $\int_{q_R^+}^{1} f(q)\mathrm{d}q \leq \rho$. Fix a $\rho \in \left(0, \frac{1}{2}\right)$ and the corresponding $\bar{N}$. This means that at most a fraction ρ of voters vote for R for any $N \geq \bar{N}$. In equilibrium of Type 1, $q_B^+ = \frac{1}{2}$ and all voters who receive signal B vote for B. Hence, if a voter is pivotal it must be that at most a fraction ρ of voters plus one received signal B. Since ρ can be chosen as small as desired and N as large as desired, we have that if a voter is pivotal then the fraction of voters who received signal B is negligible compared to the fraction of voters who received signal R and, hence, the probability that the state of nature is R converges to one when a voter is pivotal by law of large numbers. By equation (3) this implies $q_R^+ \to \frac{1}{2}$ which contradicts the fact that $\int_{q_R^+}^{1} f(q)\mathrm{d}q \leq \rho$.

Equilibrium of Type 2

We prove next that in an equilibrium of Type 2 we must have $\int_{q_B^+}^{q_R^+} f(q)\mathrm{d}q \to 0$. Assume for now that there exists a $\rho > 0$ such that $\int_{q_R^+}^1 f(q)\mathrm{d}q > \rho$ for all N. Consider an equilibrium of Type 2 and suppose there exists a $\varepsilon > 0$ such that $\int_{q_B^+}^{q_R^+} f(q)\mathrm{d}q \geq \varepsilon$ for all N. We have that a necessary condition for there to be a $\delta_1 > 0$ such that $\gamma_{RR}\gamma_{BR} - \delta_1 > \gamma_{BB}\gamma_{RB}$ is

$$\begin{aligned}
\int_{q_B^+}^1 qf(q)\mathrm{d}q \int_{q_R^+}^1 (1-q)f(q)\mathrm{d}q - \delta_1 &> \int_{q_B^+}^1 (1-q)f(q)\mathrm{d}q \int_{q_R^+}^1 qf(q)\mathrm{d}q, \\
\int_{q_B^+}^1 qf(q)\mathrm{d}q \int_{q_R^+}^1 f(q)\mathrm{d}q - \delta_1 &> \int_{q_B^+}^1 f(q)\mathrm{d}q \int_{q_R^+}^1 qf(q)\mathrm{d}q, \\
\int_{q_R^+}^1 qf(q)\mathrm{d}q \int_{q_B^+}^{q_R^+} f(q)\mathrm{d}q - \delta_1 &> \int_{q_R^+}^1 f(q)\mathrm{d}q \int_{q_B^+}^{q_R^+} qf(q)\mathrm{d}q, \\
\int_{q_R^+}^1 (q-q_R^+)f(q)\mathrm{d}q \int_{q_B^+}^{q_R^+} f(q)\mathrm{d}q &> \delta_1.
\end{aligned}$$

Since $\int_{q_R^+}^1 f(q)\mathrm{d}q > \rho$ for some $\rho > 0$ then for all $\bar{\rho} \in (0,\rho)$ there exists a $\beta > 0$ such that $\int_{q_R^+ + \beta}^1 f(q)\mathrm{d}q > \bar{\rho}$, fix such ρ and consider its corresponding β. Moreover, by assumption $\int_{q_B^+}^{q_R^+} f(q)\mathrm{d}q \geq \varepsilon$. Thus, if we choose any $\delta_1 \in (0, \beta\hat{\rho}\varepsilon)$ then $\gamma_{RR}\gamma_{BR} - \delta_1 > \gamma_{BB}\gamma_{RB}$.

Given that $\int_{q_B^+}^{q_R^+} f(q)\mathrm{d}q \geq \varepsilon$ it is true that $\int_{\frac{1}{2}}^{q_R^+} f(q)\mathrm{d}q \geq \varepsilon$ and, hence, there exists a $\delta_2 > 0$ such that $\gamma_{\emptyset s} > \delta_2$. Define $\delta = \min\{\delta_1, \delta_2\}$. Then by Lemma 2 we have then that as N grows large $\frac{\pi_t(v,B)}{\pi_t(v,R)} \to 0$, $\frac{\pi_B(v,B)}{\pi_B(v,R)} \to 0$ and $\frac{\pi_R(v,B)}{\pi_R(v,R)} \to 0$. Equations (2) and (3) then imply $q_R^+ \to \frac{1}{2}$ which in turn implies $\int_{q_B^+}^{q_R^+} f(q)\mathrm{d}q \to 0$, this contradicts the fact that $\int_{q_B^+}^{q_R^+} f(q)\mathrm{d}q > \varepsilon$ for a fixed ε.

Assume now that for all $\rho > 0$ there exists an $\bar{N}$ such that for all $N \geq \bar{N}$, we have $\int_{q_R^+}^1 f(q)\mathrm{d}q \leq \rho$. Fix a $\rho \in \left(0, \frac{1}{2}\right)$ and the corresponding $\bar{N}$. This means that at most a fraction ρ of voters vote for R for any $N \geq \bar{N}$. In equilibrium of Type 2, $q_R^- = \frac{1}{2}$ and we have two possibilities. If for all $\rho > 0$ there exists an N such that for all $N \geq \bar{N}$ we have $\int_{q_B^+}^1 f(q)\mathrm{d}q \leq \rho$, then $\int_{q_B^+}^{q_R^+} f(q)\mathrm{d}q \leq \rho$ which is what the result in the Theorem states. If, on the other hand, there exists a $\varepsilon > 0$ such that $\int_{q_B^+}^1 f(q)\mathrm{d}q \geq \varepsilon$ for all N, then at least a fraction ε of voters who receive signal B vote for B. If a voter is pivotal, it must be because at most a fraction ρ of voters plus one receive signal B. However, since ρ can be chosen as small as desired and $N+1$ as large as desired, the fraction of voters who receive signal B must be arbitrarily small as otherwise a fraction ε of them vote for B against the fraction ρ that vote for R and the voter is not pivotal. Therefore, the probability that the state of nature is R converges to one when a voter is pivotal by law of large numbers. By equation (3) this implies $q_R^+ \to \frac{1}{2}$ which contradicts the fact that $\int_{q_R^+}^1 f(q)\mathrm{d}q \leq \rho$. $\square$

Proof of Proposition 1. Using the proof of Theorem 2 we have that either $\int_{\frac{1}{2}}^{q_R^+} f(q)\mathrm{d}q \to 0$ or $\int_{q_B^+}^{q_R^+} f(q)\mathrm{d}q \to 0$. Assume first that $\int_{\frac{1}{2}}^{q_R^+} f(q)\mathrm{d}q \to 0$. In this case almost all voters vote for the candidate that coincides with their signal (for all $\delta > 0$ there exists a N for which the proportion of voters who do not is smaller than δ). Therefore, by law of large numbers the proportion of voters who vote for the candidate that coincides with the state of nature is μ while the proportion of voters who vote for the other candidate is $1-\mu$. Since $\mu > \frac{1}{2}$ implies that there exists a $\varepsilon > 0$ such that $\mu - \varepsilon > \frac{1}{2}$, we have that most voters vote for the candidate that coincides with the state of nature which gives the desired result.

Assume now $\int_{q_B^+}^{q_R^+} f(q)\mathrm{d}q \to 0$. In this case all voters who do not abstain vote for the candidate that coincides with their signal and, furthermore, the decision on whether to vote or not is independent on the signal received (for all $\delta > 0$ there exists a N for which the number of voters choose whether to abstain or not depending on their signal is smaller than δ). Therefore, by law of large numbers the proportion of voters who vote for the candidate that coincides with the state of nature is $(N+1)\int_{q_R^+}^{1} qf(q)\mathrm{d}q$ while the proportion of voters who vote for the other candidate is $(N+1)\int_{q_R^+}^{1}(1-q)f(q)\mathrm{d}q$. If there exists a $\rho > 0$ such that $\int_{q_R^+}^{1} f(q)\mathrm{d}q > \rho$ for all $N+1$ then for all $\bar{\rho} \in (0,\rho)$ there exists a $\beta > 0$ such that $\int_{q_R^+ + \beta}^{1} f(q)\mathrm{d}q > \bar{\rho}$ we have

$$\begin{aligned}
\int_{q_R^+}^{1} qf(q)\mathrm{d}q - \int_{q_R^+}^{1}(1-q)f(q)\mathrm{d}q &= \int_{q_R^+}^{1}(2q-1)f(q)\mathrm{d}q \\
&\geq \int_{q_R^+ + \beta}^{1}(2q-1)f(q)\mathrm{d}q \\
&\geq 2\beta\int_{q_R^+ + \beta}^{1} f(q)\mathrm{d}q \\
&> 2\beta\bar{\rho}.
\end{aligned}$$

Thus, most voters vote for the candidate that coincides with the state of nature as we wanted to show.

Consider now the case where for all $\rho > 0$ there exists a $\bar{N}$ such that $\int_{q_R^+}^{1} f(q)\mathrm{d}q \leq \rho$ for all $n > \bar{N}$. By monotonicity of F and the fact that $\int_{q_B^+}^{q_R^+} f(q)\mathrm{d}q \to 0$ we have $q_B^+ \to q_R^+ \to 1$. Moreover,

$$\begin{aligned}
\lim_{q_R^+ \to 1} \frac{\gamma_{BR}}{\gamma_{RR}} &= \lim_{q_R^+ \to 1} \frac{\int_{q_R^+}^{1}(1-q)f(q)\mathrm{d}q}{\int_{q_R^+}^{1} qf(q)\mathrm{d}q}, \\
&= \lim_{q_R^+ \to 1} \frac{(1-q_R^+)f(q_R^+)}{q_R^+ f(q_R^+)}, \\
&= \lim_{q_R^+ \to 1} \frac{1}{q_R^+} - 1, \\
&= 0,
\end{aligned}$$

and similarly $\lim_{q_B^+ \to 1} \frac{\gamma_{RB}}{\gamma_{BB}} = 0$, where we have used L'Hôpital's rule for computing the limit above. That is, the probability that a random voter votes for the candidate that does not match the state of nature is insignificant compared to the probability that a random voter votes for the candidate that does, which implies $P(V = S) \to 1$. $\square$

B Appendix: Experimental Instructions

Welcome! You are about to participate in a decision making experiment. If you follow the instructions carefully, you can earn a considerable amount of money depending on your decisions and the decisions of the other participants. Your earnings will be paid to you in cash at the end of the experiment

This set of instructions is for your private use only. During the experiment you are not allowed to communicate with anybody. In case of questions, please raise your hand. Then we will come to your seat and answer your questions. Any violation of this rule excludes you immediately from the experiment and all payments.

For your participation you will receive a show-up fee 3 pounds. You can earn additional amounts of money. Below we will describe how. All your decisions will be treated confidentially both during the experiment and after the experiment. This means that none of the other participants will know which decisions you made.

Experimental Instructions The experiment will last for 30 rounds. In each round you will be matched randomly in groups of four participants. Remember that the groups change in each round, so the participants you play with in one round are most likely different from those you played with the round before. At the beginning of each round of the experiment the computer randomly draws one of two colours RED or BLUE. We call the colour that was drawn "the state". BLUE is much more likely than RED to be drawn. In particular there is a 95% chance that BLUE is drawn and only a 5% chance that RED is drawn. *Remember that the state is drawn anew in each round, i.e. it can be different in each round. The state is the same, though, for all group members in each round.*

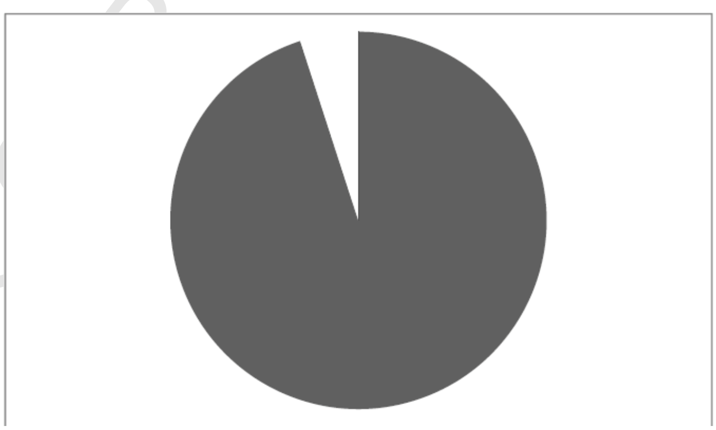

Figure 6: The state is BLUE with a 95% chance, i.e. a chance of 95 in 100.

Goal of the experiment: You will be asked to guess whether the state is RED or BLUE. Your goal is to guess correctly as a group. Hence it will not matter whether you guess correctly yourself. The only thing that matters is whether the majority of your group guesses correctly. We will explain now what additional information each group member gets before making a guess, what guesses you can make and how your payments are computed.

Information you receive: Each group member receives a "signal" about whether the state is BLUE or RED before they submit their guess. A signal is a ball drawn randomly from a box containing RED and BLUE balls. All balls in a box are equally likely to be drawn.

There are however, two boxes for each player and you don't know which one the ball is drawn from. If the state is BLUE the ball will be drawn from your BLUE box. (Remember that this is the case with a 95% chance). If the state is RED, the ball will be drawn from your RED box. (This is the case with a 5% chance). Hence if you knew the box you would know the state. This is true for all participants.

There are always at least as many BLUE balls in your BLUE box as there are in your RED box. Hence, if both boxes were equally likely, a BLUE ball is more likely to come from a BLUE box and a RED ball is more likely to come from a RED box.

How much more likely will depend on the exact composition of the boxes. In each round you will be shown the composition of your boxes. You will also be shown the colour of the ball drawn.

It is important to note that the composition of boxes can be different for different group members. In particular, for each participant, the number of BLUE balls in their BLUE box is randomly drawn from anything between half the balls being BLUE to all balls being BLUE. The number of RED balls in a participant's RED box always equals the number of BLUE balls in their BLUE box[10]

Things to remember about signals:

- You will see a ball drawn from either your RED or your BLUE box.
- If the state is BLUE the ball will be drawn from the BLUE box. If the state is RED it will be drawn from the RED box.

[10]In **ASYM-COARSE** and **SYM-COARSE** the version of this paragraph reads "It is important to note that the composition of boxes can be different for different group members. In particular, for each participant, the number of BLUE balls in their BLUE box is randomly drawn from anything between half the balls being BLUE to three quarters of the balls being BLUE. The number of RED balls in a participant's RED box always equals the number of BLUE balls in their BLUE box"

- You will also see how many RED and BLUE balls your RED and BLUE boxes contain.
- All other group members will also see a ball drawn from one of their boxes.
- Remember, though, that their boxes can have a different composition.
- Boxes change in each round for each participant.

Making a guess: After all group members have received their signals, all will make a guess simultaneously. You have three options. You either guess RED, BLUE or you can ABSTAIN. Remember that the goal is to guess correctly as a group.

Your payment: Apart from the show up fee you receive, one round is drawn for payment and you receive

- 10 additional pounds if the group guesses correctly in that round and
- 2 additional pounds if the group is not correct in that round.

When is the group correct? The group is correct if the majority of group members who do not abstain indicate the correct state.

Hence, if the state is BLUE then the group is correct if

- at least 3 group members vote BLUE,
- at least 2 group members vote BLUE and at least one abstains,
- at least 1 group member votes BLUE and all others abstain.

Similarly, if the state is RED then the group is correct if

- at least 3 group members vote RED,
- at least 2 group members vote RED and at least one abstains,
- at least 1 group member votes RED and all others abstain.

If the same number of group members vote RED and BLUE, then there is a tie and whether the group's guess is considered correct is determined by the flip of a coin.

Control Questions: Are the following statements TRUE or FALSE? If you have any questions please raise your hand.

1. My group members change from round to round.
2. All group members receive a ball from the same box.
3. The composition of the box of my group members can be different from the composition of my box.
4. If I vote RED, one group member abstains and two vote BLUE, I receive 2 pounds if the state is RED and 10 pounds if the state is BLUE.
5. If I vote BLUE, one group member abstains and two vote BLUE, I receive 2 pounds if the state is RED and 10 pounds if the state is BLUE.
6. Only one round is randomly drawn for payment.

ENJOY THE EXPERIMENT !!

C Appendix: Additional Tables and Figures

This Appendix collects additional tables and figures. Figure 7 shows a screenshot of how the signal and signal accuracy were communicated during the experiment.

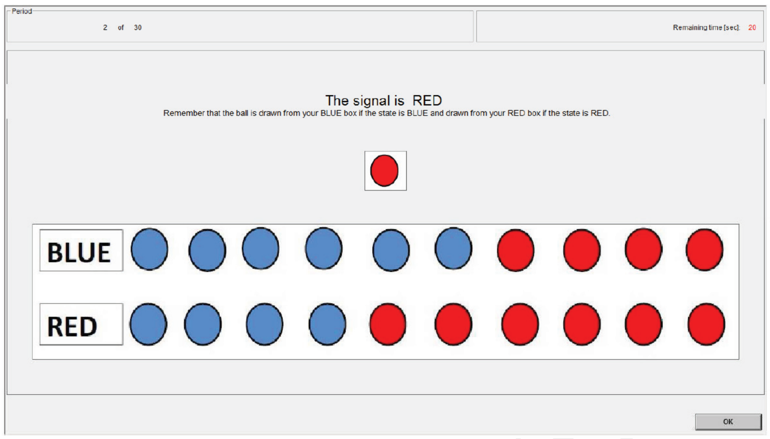

Figure 7: Screenshot of how the signal drawn was communicated.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
		RED signal				*BLUE signal*		
	SYM	SYM-COARSE	ASYM	ASYM COARSE	SYM	SYM-COARSE	ASYM	ASYM COARSE
Vote with signal								
Abstain								
q	-8.640***	-5.034***	6.130***	2.629*	-9.251***	-9.946***	-4.854***	-3.344**
	(0.863)	(1.839)	(0.976)	(1.958)	(0.968)	(1.532)	(1.060)	(1.474)
Constant	4.754***	1.505	-2.865***	-5.082***	4.687***	3.936***	0.561	-0.098
	(0.552)	(1.082)	(0.663)	(1.816)	(0.591)	(0.913)	(0.704)	(0.913)
Vote against signal								
q	-1.634**	-1.093	-0.382	1.159	-3.677***	-9.917***	-3.020*	-3.357
	(0.719)	(1.360)	(0.905)	(1.816)	(0.995)	(1.819)	(1.690)	(3.563)
Constant	0.076	-0.091	-0.541	-1.936*	0.487	3.524***	-1.715	-1.957
	(0.523)	(0.831)	(0.582)	(1.074)	(0.673)	(1.080)	(1.173)	(2.202)
Observations	739	719	471	350	701	721	969	970

Standard Errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 7: Multinomial logit regression on voting outcomes categorized as "voting with the signal", "abstaining" or "voting against the signal".

Table 8 addresses the potential concern in the asymmetric treatments, that the frequency of receiving RED signals is low making learning difficult. Empirically this frequency ranges between $16 - 53\%$ in the asymmetric treatments. Table 8 linearly controls for the frequency with which a RED signal was seen by a participant and shows that results are qualitatively robust.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	RED signal				*BLUE signal*			
	SYM	SYM-COARSE	ASYM	ASYM COARSE	SYM	SYM-COARSE	ASYM	ASYM COARSE
Vote with signal								
Abstain								
q	-8.641***	-4.797***	5.076***	2.627***	-9.203***	-9.995***	-5.675***	-3.403**
	(0.863)	(1.853)	(1.948)	(0.976)	(0.971)	(1.532)	(1.060)	(1.479)
Constant	4.575***	2.616**	-6.239***	-2.763***	6.106***	4.053***	-2.722***	0.954
	(0.785)	(1.226)	(1.347)	(1.816)	(0.823)	(1.009)	(0.909)	(0.962)
Vote against signal								
q	-1.632**	-1.170	-0.351	1.158	-3.686***	-9.879***	-3.091*	-3.352
	(0.720)	(1.360)	(0.905)	(1.827)	(0.996)	(1.820)	(1.699)	(3.563)
Constant	-0.083	-0.470	-1.611**	-1.615*	0.075	3.139***	-2.066	-0.157
	(0.737)	(0.944)	(0.757)	(1.201)	(0.982)	(1.201)	(1.415)	(2.275)
Observations	739	719	471	350	701	721	969	970

Standard Errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 8: Multinomial logit regression on voting outcomes categorized as "voting with the signal", "abstaining" or "voting against the signal" including linear controls for the frequency with which participants saw a red signal across the 30 rounds.

$$\begin{aligned} y_{it} &= \alpha_i + \beta_0 q_{it} + \beta_1 \textbf{SYM-COARSE} + \beta_2 \textbf{ASYM} + \beta_3 \textbf{ASYM-COARSE} \qquad (11) \\ &+ \beta_{10} * (q_{it} * \textbf{ASYM}) + \beta_{20} * (q_{it} * \textbf{ASYM}) + \beta_{30} * (q_{it} * \textbf{ASYM-COARSE}) + \epsilon_{it} \end{aligned}$$

Table 9 shows the results of running regression (11) in our sample using as binary outcome y_{it} whether or not a participant i voted against her signal in period t. Columns (1) and (2) include the whole sample, columns (3) and (4) only the second half of the experiment after potentially some learning has occurred. Columns (1) and (3) focus on participants who received a RED signal. The estimates show that in the baseline (treatment **SYM**) participants rarely vote against their signal. They do so more often in **ASYM** and **ASYM-COARSE** if the signal is RED, i.e. goes against the prior and less often if it is BLUE, i.e. consistent with the prior. Interestingly, in **SYM-COARSE** they tend to vote more often against a BLUE signal compared to **SYM**. Signal accuracy decreases the propensity to vote against the signal across all treatments, albeit not always significantly so.

Table 10 shows the results of running regression (11) in our sample using as binary outcome y_{it} whether or not a participant i abstained in period t. Irrespective of the signal, participants abstain less often in **SYM-COARSE**, **ASYM** and **ASYM-COARSE** compared to **SYM**. An increased signal accuracy decreases the propensity to abstain in **SYM** and to a lesser extent in **SYM-COARSE**, but not in **ASYM** and **ASYM-COARSE**, where especially with RED signals participants decide to abstain rather than voting against the signal.

Vote against signal if it is:	(1) RED	(2) BLUE	(3) RED 15-30	(4) BLUE 15-30
q	0.129	-0.119**	0.120	-0.021
	(0.102)	(0.0509)	(0.128)	(0.0705)
SYM-COARSE	0.212	0.248***	0.099	0.219**
	(0.167)	(0.067)	(0.215)	(0.088)
ASYM	0.550***	-0.117**	0.794***	-0.0689
	(0.132)	(0.052)	(0.160)	(0.069)
ASYM-COARSE	1.041***	-0.123*	0.858***	-0.075
	(0.187)	(0.068)	(0.236)	(0.089)
SYM-COARSE$\times q$	-0.188	-0.449***	0.0312	-0.423***
	(0.255)	(0.101)	(0.328)	(0.134)
ASYM$\times q$	-0.254	0.0680	-0.514**	-0.024
	(0.181)	(0.068)	(0.219)	(0.093)
ASYM-COARSE$\times q$	-0.962***	0.060	-0.562	-0.021
	(0.296)	(0.102)	(0.378)	(0.135)
Constant	0.097	0.175***	0.076	0.114**
	(0.081)	(0.037)	(0.101)	(0.050)
Observations	1,979	3,661	1,052	1,768

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 9: Random Effects OLS regressions: Voting against one's signal when it indicates the low prior (column (1)) or high prior (column (2)) state. Columns (3) and (4) only consider data from the last 15 periods.

Table 11 corresponds to Table 4 in the main text, but includes linear time trends (and treatment interactions).

Table 12 corresponds to Table 6 in the main text, but linearly controls for the frequency with which a RED signal was seen by a participant and shows that results are qualitatively robust.

Abstain if signal is	(1) RED	(2) BLUE	(3) RED 15-30	(4) BLUE 15-30
q	-1.195***	-1.142***	-1.292***	-1.187***
	(0.0879)	(0.068)	(0.120)	(0.096)
SYM-COARSE	-0.601***	-0.374***	-0.414**	-0.349***
	(0.145)	(0.093)	(0.201)	(0.124)
ASYM	-0.633***	-0.706***	-0.892***	-0.805***
	(0.115)	(0.072)	(0.149)	(0.098)
ASYM-COARSE	-0.944***	-0.705***	-0.936***	-0.857***
	(0.162)	(0.093)	(0.221)	(0.125)
SYM-COARSE$\times q$	0.672***	0.329**	0.359	0.271
	(0.220)	(0.135)	(0.307)	(0.183)
ASYM$\times q$	0.919***	0.849***	1.330***	0.921***
	(0.157)	(0.091)	(0.205)	(0.128)
ASYM-COARSE$\times q$	1.332***	0.856***	1.288***	1.066***
	(0.255)	(0.136)	(0.354)	(0.185)
Constant	1.058***	0.982***	1.142***	1.031***
	(0.070)	(0.052)	(0.094)	(0.071)
Observations	1,979	3,661	1,052	1,768

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 10: Random Effects OLS regressions: Abstaining when the signal indicates the low prior (column (1)) or high prior (column (2)) state. Columns (3) and (4) only consider data from the last 15 periods.

VARIABLES	(1) All periods	(2) periods 1-5	(3) periods 26-30
period	0.003***	-0.079***	0.027
	(0.001)	(0.016)	(0.024)
SYM-COARSE(β_1)	-0.076**	-0.404***	1.117***
	(0.037)	(0.086)	(0.384)
ASYM(β_2)	0.342***	0.100	-0.600***
	(0.022)	(0.069)	(0.231)
ASYM-COARSE(β_3)	0.180**	0.056	1.328**
	(0.075)	(0.067)	(0.540)
SYM-COARSE×period (γ_1)	-0.007***	0.079***	0.022***
	(0.001)	(0.016)	(0.008)
ASYM×period (γ_2)	0.001	0.040	-0.040**
	(0.003)	(0.025)	(0.019)
ASYM-COARSE×period (γ_3)	-0.002	0.121***	-0.043***
	(0.001)	(0.010)	(0.013)
Constant	0.649***	0.850***	0.012
	(0.013)	(0.058)	(0.700)
$\beta_2 - \beta_3$	0.162**	0.044	-1.928***
p-value	0.0464	0.3657	<0.0001
$\gamma_2 - \gamma_3$	-0.001***	-0.081**	-0.083***
p-value	0.0006	0.0272	<0.0001
Observations	5,640	940	940
Number of id	188	188	188

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 11: Random effects OLS regression of efficiency on treatment dummies including linear time trends. Standard errors are clustered at the matching group level.

	Asymmetric Prior treatments							
	ASYM				**ASYM-COARSE**			
	Abstention		Switching		Abstention		Switching	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
q	-0.423***	-0.423***	-0.071	-0.078	-0.344**	-0.335**	0.072	0.064
	(0.102)	(0.101)	(0.095)	(0.088)	(0.120)	(0.113)	(0.149)	(0.151)
Majority wrong$_{t-1}$	-0.005	-0.005	-0.002	-0.002	-0.019**	-0.017**	0.009	0.007
	(0.003)	(0.003)	(0.006)	(0.006)	(0.005)	(0.005)	(0.008)	(0.008)
i wrong$_{t-1}$	0.064***	0.063*	0.497***	0.443***	0.303***	0.345***	0.369***	0.326***
	(0.015)	(0.031)	(0.065)	(0.074)	(0.070)	(0.080)	(0.041)	(0.053)
i (pivotal$\wedge$wrong)$_{t-1}$		0.002		0.170**		-0.148*		0.152*
		(0.050)		(0.043)		(0.059)		(0.071)
Frequency RED signals	0.687*	0.687*	0.409*	0.409*	-0.236	-0.224	0.339	0.327
	(0.322)	(0.322)	(0.176)	(0.176)	(0.285)	(0.272)	(0.339)	(0.345)
Constant	0.135	0.136	0.078	0.084	0.153	0.165	0.106	0.093
	(0.086)	(0.086)	(0.110)	(0.107)	(0.134)	(0.120)	(0.165)	(0.164)
Observations	1,392	1,392	1,392	1,392	1,276	1,276	1,276	1,276
R-squared	0.073	0.073	0.211	0.217	0.149	0.158	0.149	0.155

Robust standard errors in parentheses

*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 12: Simple Heuristics in asymmetric Prior treatment with linear controls for the frequency with which a red signal was observed across the 30 rounds. Abstention and Switching regressed on signal accuracy and three dummies indicating whether (i) the majority vote in the past period was incorrect (i.e. not coinciding with the state), (ii) participant i's vote was incorrect and (iii) whether participant i was pivotal and incorrect.