Risk Aversion, Over-Confidence and Private Information as Determinants of Majority Thresholds[1]

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Abstract

We present and experimentally test a theoretical model of majority threshold determination as a function of voters' risk preferences. The experimental results confirm the theoretical prediction of a positive correlation between a voter's risk aversion and the corresponding preferred majority threshold. Furthermore, the experimental results show that a voter's preferred majority threshold negatively relates to the voter's confidence about how others will vote. Moreover, in a treatment in which individuals receive a private signal about others' voting behavior, the confidence-related motivation of behavior loses ground to the signal's strength.

Keywords: majority threshold, risk aversion, (over-)confidence, laboratory experiment.

JEL classification: C91, D72, D81, H11.

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1 Introduction

Voting determines a large number of collective decisions. As a major expression of the democracy of a political system, the design of voting institutions should account, among other things, for citizens' preferences regarding the threshold required in order to determine the winning majority. In this paper, we argue that people's preferences for a given majority threshold depend on their attitudes towards risk as well as other behavioral characteristics. We present both a theoretical framework and experimental evidence that are based on this simple intuition. An agent knows that future common decisions will be made by voting. The decisions may be favorable or unfavorable to her, and the final outcome is uncertain as she does not know how others will vote. Voting becomes a lottery: there is a chance that a favorable majority will form, but also a risk to be tyrannized by an unfavorable majority. The expected value of this lottery crucially depends on the voting rules: for example, less decisive voting rules, such as a high supermajority, reduce the tyranny risk but also the chance to get a favorable outcome. Intuitively, a risk-averse agent is more sensitive to the prospect of falling into a minority than to the chance of ending up into a majority. We expect preference for higher supermajorities and less decisive rules from more risk-averse agents, and vice versa.

Simple majority is less frequent in the real world, than it might be thought. Most countries have *de facto* supermajority requirements because of bicameral legislatures: it is not easy to undo the status-quo if a bill has to pass a two-house majority. Legislation processes are often subject to executive vetoes or other forms of check and balances. International agreements usually require unanimity (WTO), veto power (the UN Security Council), or high supermajorities (the Council of the EU). When corporate boards vote on major actions (mergers and acquisitions, major capital expansions, etc.), high supermajorities are generally required. We claim that this extensive use of supermajorities *de facto* reflects a general aversion towards the risk of being tyrannized. In many cases, the trade-off between protection and decisiveness is solved in favor of protection.

We add a further dimension to our analysis: the agent's priors about how others will vote. The simple intuition is that when an agent thinks of herself as substantially different from the others, then she thinks that the others are less likely to vote as her; thus she assigns a higher probability to the event of being tyrannized. Given her risk attitudes, she demands for stronger protection, i.e. for a higher threshold. With this dimension, we explore how preferences for voting rules depend either on exogenous psychological attitudes, such as subjective confidence, or on the "unbiased" use of objective information about the policy preferences of other people.

Reality shows that those who think of themselves as different from the majority ask for more protectionist rules. This is the case of ethnic minorities, that are usually protected by constitutional provisions that cannot be undone by the majority. In the EU, members may always invoke a conditional veto power when decisions concern their crucial interests (the so-called Luxembourg compromise).

We support theoretical predictions with experimental data. We find a positive and significant correlation between the majority threshold chosen by an agent and her degree of risk aversion as measured by standard experimental techniques. Moreover, agent's preferred majority threshold is negatively and significantly correlated with her subjective over-confidence. However, when agents can observe a private signal on the distribution of voters' preferences over the policies to vote, we find that preferred majority thresholds are fully determined by the signal, rather than by their naive priors.

The rest of the paper is structured as follows. In section 2 we relate our paper to the existing literature on public choice. In section 3 we describe our experimental design. Section 4 draws the main theoretical predictions to test. In section 5, we present experimental results and section 6 concludes.

2 Related Literature

In this study, voting is modeled as a lottery where uncertainty comes from the agent's ignorance about how others will vote. Thus the risk of an unfavorable outcome can be controlled by setting up an appropriate majority threshold.

The idea that the preferences for voting rules reflect the uncertainty about the voting outcome is not new in the literature. Rae (1969) focuses on the uncertainty related to gains or losses generated from the making of a law. He suggests that the bare majority is the only rule that minimizes the expected cost of being part of the minority. This result is formally proved in Taylor (1969). In fact, Rae's result applies to voting contests in which costs and gains are equal and also equally likely to arise from a bill that is opposed to the status quo. Attanasi *et al.* (2013) extend Rae's (1969) setting to a wider range of situations. The most preferred voting rule optimizes the trade-off between the risk of ending up into an unfavorable minority and the chance to be part of the majority. Of course, risk aversion implies stronger preference for more conservative rules. Self-protection from the risk of bad policy decisions is the same reason why in Aghion *et al.* (2004) a representative agent prefers a lower degree of insulation of political leaders. The authors do not specifically consider qualified majorities, but it is easy to see that an executive is less insulated when a higher supermajority is required to pass laws in the Parliament.

The optimal degree of insulation depends on the cost of compensating the losers, the uncertainty about gains and losses, the degree of risk aversion. In Aghion and Bolton (2003), risk derives from ex-ante ignorance about losses or gains from the provision of a public good. In this scenario, if the expected cost of compensating the losing minority raises, then agents prefer a higher qualified majority threshold.

We claim that an individual who is more optimistic about how the others will vote perceives a lower risk of tyranny. As a consequence, she prefers more decisive voting rules. This relationship between confidence and preferences for voting rules is new in the literature. So far, confidence has been directly related to voting preferences rather than to the preferences for voting rules. Seminal papers are Buchanan and Faith (1980, 1981) and Zorn and Martin (1986).

In our experimental setting, uncertainty originates from the random assignment of subjects' favorite alternatives. To the best of our knowledge, there are no experimental works analyzing the choice of majority thresholds at the individual level and relating them to risk aversion and confidence. The experimental literature has paid much more attention to strategic voting, as a situation that arises due to the tension between an individual voter's true preferences and the expected effect of a vote on the final outcome. Specifically, the studies by Fiorina and Plott (1978) and Plott (1991) report experimental results supporting the notion of the core. On the contrary, voting through truthful revelation of voters' preferences has received little, if any, attention because of researchers' lack of interest in the apparently trivial situation in which a voter simply translates her preference into an actual vote. However, our paper shows that truthful voting may still be a fruitful area of research, in the framework of which voters' preferences can be studied over different voting institutions. A number of experimental studies have investigated into the role of majority rules (Fiorina and Plott, 1978) and other alternatives like Borda rule, approval voting (Forsythe *et al.*, 1996) and unanimity (Guarnaschelli *et al.*, 2000) on the observed outcomes. Recently, some experiments have been conducted, such as Hortala-Vallve (2004) and Casella *et al.* (2006, 2008), which explore the behavior of laboratory committees using novel voting methods that allow members to express strength of preference. However, in all these papers the majority rule is *exogenously* imposed by the experimenter while the focus of the studies is on the voting outcomes obtained. Therefore, the emergence of different voting institutions as the result of voters' preferences over them remains unexplored. Furthermore, as we argue in this paper, it is anything but trivial to investigate some of the sources of a voter's preference for a particular majority threshold. Rather than exogenously imposing the threshold as an invariant political institution, we consider voters with different idiosyncratic features which may give rise to different preferences for a higher or a lower majority threshold in a given voting process.

Following the insights of our Expected Utility model, we relate the agent's preferred majority threshold to her subjective degree of risk aversion, i.e. to the curvature of her Bernoullian utility function.[2] We also relate the majority threshold chosen by the agent to her belief about the distribution of votes exogenously assigned to the other voters. Therefore, the kind of "confidence" we are interested in is the one that an agent shows when being asked to evaluate the probability of a random policy outcome, that can get her a gain, a loss, or the status quo. Empirical studies in behavioral finance do not find clear-cut evidence that over-confident investors actually do take more risks (see e.g. Dorn and Huberman, 2005; Menkhoff *et al.*, 2006). Interestingly, the experimental literature has shown that individuals seem to be both overly optimistic about future outcomes and prone to overconfidence (see e.g. Lichtenstein *et al.*, 1982) and that these biases can significantly affect risk taking behavior. In our experiment, we elicit subjects' confidence (unconfidence) in two different situations. In both situations there is no strategic interaction among subjects: each subject truthfully votes for the alternative she has been randomly assigned. In one treatment, subjects are asked to state their beliefs about the exogenous distribution of votes over two alternatives. In this treatment they only know that each subject's vote has the same probability to be assigned to either one or the other of the two alternatives. In another treatment, we ask subjects the same question, after having let them observe a private signal about the votes distribution. Thus, we can estimate the effects of exit polls and pre-voting information on both subjects' beliefs and their preferred threshold. Existing literature has shown that exit polls and pre-voting information affect voting behavior (see e.g. Blais and Bodet, 2006; McAllister and Studlar, 1991; Sudman, 1986). In this paper we check whether and, if so, in which way, pre-voting information affects the preferred threshold.

3 Experimental Design

The experiment consisted of two treatments, the *NO-INFO* and the *INFO* treatment. In the *NO-INFO* treatment, subjects participated in two consecutive phases. Only one of the two phases was used to determine subjects' final payoff. In particular, at the end of the session, we randomly drew the phase to pay by flipping a coin. Instructions were distributed and read aloud at the beginning of each phase.

In the first phase, subjects participated in a variant of the Holt and Laury's mechanism to elicit subjects' risk aversion (Holt and Laury, 2002). Subjects were presented with a battery of 19 pairs of lotteries numbered from (line) $L1$ to (line) $L19$ and a last (empty) line $L20$. Each pair described two lotteries called A and B. Each lottery presented two possible monetary outcomes, a favorable and an unfavorable outcome, as well as their attached probabilities. Probabilities were framed by means of an urn that contained twenty tickets, numbered from 1 to 20. The structure of the battery had two main characteristics. First, within each pair, lottery A and lottery B had the same probability structure but different monetary outcomes. In particular, the favorable and the unfavorable outcome of lottery A were 12.00 and 10.00 euros respectively, while they were set to 22.00 and 0.50 euros for lottery B. Second, across pairs, while we kept constant the monetary outcomes of the corresponding lotteries, we varied the probabilities of the favorable and unfavorable outcomes. In particular, while in $L1$ the probabilities of the favorable and unfavorable outcome where $1/20$ and $19/20$ respectively, they were gradually and monotonically changed across pairs in such a way that in $L19$ they ended up with $19/20$ and $1/20$ respectively. Given the battery, each subject was asked to choose the line (pair of lotteries) starting from which she preferred lottery B to lottery A. Thus, for all pairs of lotteries above her choice, a subject preferred lottery A to lottery B, while starting from the pair on the chosen line and for all the pairs below, she preferred lottery B to lottery A. A subject preferring lottery A to lottery B for all the 19 pairs selected the last (empty) line $L20$. Participants knew that, if the first phase of the experiment was drawn (by flipping the coin) to determine their final earnings, the computer would randomly select a pair of lotteries for each participant. Given her choice and according to the pair selected by the computer, each subject participated in the preferred lottery. Then, an experimenter randomly drew one of the twenty tickets contained in the urn. The ticket drawn by the experimenter was used to determine the outcome of the preferred lottery and the corresponding payoff for each participant.

We will use a subject's choice in the first phase of the experiment as a proxy of her degree of risk aversion. Given the structure of the battery, the higher the number of the line chosen by the subject, the higher her degree of risk aversion. Note that, differently from the original setting proposed by Holt and Laury (2002), in our experiment we imposed consistency. Indeed, rather than offering further evidence on (in-)consistency of risk preferences, in this paper we are interested in measuring the correlation between risk aversion and the preferred majority threshold.[3]

The second phase of the experiment consisted of two consecutive parts. Again, the instructions of each decisional task were distributed and read aloud at the beginning of each part.

In part 1 of the second phase, each subject was asked to choose a majority threshold included between the simple majority and the unanimity, that she wanted to apply in a voting procedure between two alternatives, X and Y. At the beginning of the phase, the computer randomly assigned to each subject and with equal probability one of two types, x or y. Given her type, a subject's vote was automatically assigned by the computer to the corresponding alternative, such that $x-$type voters supported alternative X while $y-$type voters supported alternative Y. Subjects were informed that, if at the end of the experiment the second phase was drawn to be paid, the payoff of each subject from part 1 was determined by comparing her preferred majority threshold with the distribution of $x-$type voters and $y-$type voters in that session. In particular, if the majority threshold stated by a subject was equal to or smaller than the number of subjects of her own type, then she earned 22.00 euros; while, if it was equal to or smaller than the number of subjects of the other type, she earned nothing. Finally, if neither the number of subjects of her own type nor that of the other type were greater than or equal to her stated majority threshold, then the subject earned 11.00 euros.

In part 2 of the second phase, each subject was asked to guess the distribution of $x-$type and $y-$type voters in that session. If at the end of the experiment the second phase was drawn to be paid and her guess was correct, then 3.00 euros were added to the subject's earnings from part 1 of this phase.

The only difference between the *NO-INFO* and the *INFO* treatment was that in the latter, at the beginning of the second phase, each subject privately observed a signal about the distribution of $x-$type and $y-$type voters in that session. In particular, for each subject the computer randomly and independently selected a subset of 7 participants. Then, each subject was presented with the distribution of $x-$type and $y-$type voters in the correspondent subset. After that, each subject was asked to choose a majority threshold (part 1) and to guess the distribution of $x-$type and $y-$type voters in that session (part 2), as in the *NO-INFO* treatment.

Overall, we run three sessions of the *NO-INFO* treatment and two sessions of the *INFO* treatment. Each session of the *NO-INFO* treatment involved 31 subjects, while each session of the *INFO* treatment involved 35 subjects. Each subject could only participate in one of these sessions. The sessions were run at the EELAB, University of Milan - Bicocca, in 2008 and at the Bocconi University, Milan, in 2009. Each session lasted around one hour and subjects earned on average 12.59 euros plus 3.00 euros of show-up fee. The experiment was computerized using the z-Tree software (Fischbacher, 2007).

4 Theoretical Predictions

In political choices, the agent faces a certain amount of risk if she does not know how others will vote. In this section, we present a simple theoretical model in which the majority threshold preferred by an agent depends on her degree of risk aversion and her priors about how others will vote. Coherently with our experimental design, we propose a discrete model for a "small" number of agents, $n+1$, with n being even.[4]

Consider agent j. Her voting prospect can be represented as a non-degenerate lottery in the following way. Let $N = \{1, ..., n, j\}$ be the set of $n+1$ agents who play a majority voting game where q is the majority threshold and agents have one vote each. Thus the sum of votes is $n+1$. Assume that the threshold must be at least the simple majority, i.e. $q \in \left\{\frac{n}{2}+1, ..., n+1\right\}$ given the discreteness of the setting.

Let $u_j(\cdot)$ be j's utility function. The argument of u_j is a policy outcome. Assume that two alternative policy reforms, W and L, are opposed one to another within a legislature. Either reform passes only if it reaches the required majority threshold. From j's perspective, W is better than the status quo, and L is worse: $u_j(W) > u_j(S) > u_j(L)$. We say that j "wins" if her most preferred policy alternative, W, reaches the required majority in voting. Agent j "loses" when this happens for the least preferred alternative, L. The status quo S remains if no alternative reaches the required majority threshold. In other words, agent j wins only if, in addition to her, a coalition T_W that commands at least $q-1$ votes forms. She loses if an adverse coalition T_L of voters who favor L collects at least q votes. We are interested in the probability that either T_W, or T_L or no winning coalition form, and in how these chances depend on the majority threshold.

Let us assume that agent j thinks that any other agent i (where $i = 1, .., n$) will cast her vote in favor of W with subjective probability p, and will vote for L with probability $(1-p)$.[5] One may say that p captures j's degree of confidence regarding how the other n agents will vote. Thus, the probabilities of winning and losing originate from two binomial distributions with parameters (n, p) and $(n, 1-p)$, respectively. More precisely, the others' votes behave as n independent Bernoulli random variables, Z, where $Z = 1$ with probability p, and $Z = 0$ with probability $(1-p)$. As a consequence, j's probability of winning, i.e. the probability that T_W forms, is given by the probability that the sum of those variables is at least $q-1$:

$$\Pr\{W\} = \sum_{k=q-1}^{n} \binom{n}{k} p^k (1-p)^{n-k} \ . \tag{1}$$

Conversely, j's subjective probability of falling into the minority (the probability that T_L forms) is

$$\Pr\{L\} = \sum_{k=q}^{n} \binom{n}{k} (1-p)^k p^{n-k} \ . \tag{2}$$

Finally, j's subjective probability that the status quo prevails (the probability that neither T_W nor T_L reach the required majority) is

$$\Pr\{S\} = 1 - \Pr\{W\} - \Pr\{L\} \ . \tag{3}$$

Thus, from agent j's viewpoint, voting can be described as a lottery with three possible outcomes and attached subjective probabilities, as defined in (1-3); i.e. as $\Lambda = (W, \Pr\{W\}; L, \Pr\{L\}; S, \Pr\{S\})$. Observe that all probabilities in Λ depend, among other things, on the majority threshold, q. For example, with the simple majority, $\Pr\{S\}$ is close to zero, whereas with unanimity, the status quo is "almost" certain.

Therefore, agent j's expected utility from the voting lottery

$$EU_j(\Lambda) = \Pr\{W\} \cdot u_j(W) + \Pr\{L\} \cdot u_j(L) + \Pr\{S\} \cdot u_j(S) \tag{4}$$

depends on the majority threshold q. Call q^* the threshold that maximizes EU_j. Below, we show that q^* is positively related to j's degree of risk aversion, and negatively related to her degree of confidence.

For simplicity, let us normalize the status quo utility to zero. Thus, for any majority threshold q, we can write:

$$\frac{EU_j(q)}{u_j(W)} = \sum_{k=q-1}^{n} \binom{n}{k} p^k (1-p)^{n-k} - R_j \sum_{k=q}^{n} \binom{n}{k} (1-p)^k p^{n-k} \tag{5}$$

where

$$R_j \equiv \frac{u_j(S) - u_j(L)}{u_j(W) - u_j(S)} > 0 \ . \tag{6}$$

From (5) it is clear that the agent balances the impact of q on the expected benefit of belonging to the majority with the impact of q on the expected loss of falling into the minority. Call R_j in (6) the ratio between agent j's benefits of not being tyrannized by an undesired majority, $u_j(S) - u_j(L)$, and her benefits of being part of a favorable winning majority, $u_j(W) - u_j(S)$. Basically, R_j is positively related to j's degree of risk aversion, i.e. to the curvature of her utility function. In fact, all lotteries over three fixed prizes can be represented in the 2-dimensional Marschak-Machina triangle. The slope of indifference curves on this domain is exactly R_j and, indeed, the more risk-averse agent j is, the steeper the indifference curves are.[6] The idea is that, for given policy outcomes W, L and S, a more risk-averse agent "weights" the advantage of avoiding the tyranny of an adverse majority (the numerator) more than the advantage of being part of a favorable majority (the denominator). We will come back to this point below.

Let us call $\Delta(q) \equiv \frac{q}{n+1-q}\left(\frac{p}{1-p}\right)^{2q-n-1}$. Notice that the first-order difference of $\frac{EU_j(q)}{u_j(W)}$ has the same sign of $R_j - \Delta(q)$. Therefore,

$$\begin{aligned} EU_j(q+1) < EU_j(q) \quad \text{iff} \quad \Delta(q) > R_j \ , \\ EU_j(q+1) > EU_j(q) \quad \text{iff} \quad \Delta(q) < R_j \ . \end{aligned} \tag{7}$$

According to the conditions above, we can distinguish three cases for the preferred majority threshold q^*, in terms of j's priors about how others will vote. The following definition identifies the three subsets of priors.

Definition 1 *An agent is* ***unbiased*** *with respect to how others will vote if her prior on ending up into a majority matches the probability inferred from the objective information at her disposal. She is* ***over-confident (unconfident)*** *if her prior of ending up into a majority is higher (lower) than the probability inferred from the objective information at her disposal.*

The analysis below is implemented for the *NO-INFO* treatment, where all subjects are publicly given the following objective information about the distribution of votes: each subject is randomly and with equal probability assigned one of two policy alternatives. The results below can be easily extended to the *INFO* treatment, as it will be discussed at the end of this section.

Case 1. Suppose that j is *unbiased* with respect to how others will vote. Thus, in the *NO-INFO* treatment, she thinks that a favorable majority and an unfavorable one are equally likely to form ($p = 0.5$). Given her vote, she thinks that her alternative will receive $\frac{n}{2}+1$ votes. In this case, $\Delta(q) = \frac{q}{n+1-q}$, increasing in q and larger than 1 for every possible thresholds $q \geq \frac{n}{2}+1$.

Case 1.a. If $R_j \in (0,1]$, then $EU_j(q)$ is decreasing in q for every possible $q \geq \frac{n}{2}+1$ and j prefers the simple majority.

Case 1.b. If $R_j \in (1,+\infty)$, if n and R_j are sufficiently small, then $\Delta(\frac{n}{2}+1) = 1+\frac{2}{n} > R_j$, and j prefers the simple majority. If R_j is sufficiently large, then $\Delta(n) = n \leq R_j$ and j prefers unanimity. For intermediate R, the preferred threshold is an internal supermajority.

Recalling that R_j is positively related to j's degree of risk aversion, the following lemma can be stated.

Lemma 1 *The preferred majority threshold of an unbiased agent depends positively on her degree of risk aversion.*

Case 2. Suppose that j is *over-confident* with respect to how others will vote. Thus, in the *NO-INFO* treatment, she thinks that the probability of a favorable majority is higher than an unfavorable one, i.e. $p > 0.5$. Given her vote, she thinks that her alternative will always receive more than $\frac{n}{2}+1$ votes. In that case, $\Delta(q)$ is increasing in q and it is larger than 1 for all possible $q \geq \frac{n}{2}+1$.

Case 2.a. If $R_j \in (0,1]$, given (7), the most preferred threshold is the simple majority $q^s = \frac{n}{2}+1$. The interpretation of this result is trivial. The agent has two good perspectives from voting: on the one hand, winning is always more likely; on the other hand, losing is (weakly) less costly than winning. In this case, she wants to increase the chance of winning by choosing the lowest possible threshold, even though this will also increase the chance of losing.

Case 2.b. If $R_j \in (1,+\infty)$, then EU_j is possibly not monotonic in q. Thus there might be several local maxima for EU_j; among them j will choose the global one. Observe that in the simple majority $\Delta(\frac{n}{2}+1) = \left(1+\frac{2}{n}\right)\frac{p}{1-p}$. Given that $p > 0.5$, it is $\Delta(\frac{n}{2}+1) > 1$; however, if n and R_j are sufficiently large such that $\left(1+\frac{2}{n}\right)\frac{p}{1-p} \leq R_j$, then $EU_j(q)$ is increasing when q is the simple majority. Moreover, $\Delta(n) = n\left(\frac{p}{1-p}\right)^{n-1}$. For large n, $R_j < \Delta(n)$, then EU_j decreases when q approaches unanimity. Therefore, if n is sufficiently large, the first-order difference of $EU_j(q)$ is positive in the simple majority and negative in unanimity. This implies that the global maximum is an interior supermajority. If instead $R_j \geq \Delta(n)$ then unanimity is the preferred threshold. This means that the over-confident agent prefers either a supermajority $q^S \in \left\{\frac{n}{2}+2,...,n\right\}$, or unanimity $q^S = n+1$, if the gains of winning $(u_j(W) - u_j(S))$ are lower than the gains from not losing $(u_j(S) - u_j(L))$. The intuition is clear: j thinks that winning is more likely than losing. However, she has little advantages in winning, compared to the disadvantage of losing. Thus, she tends to protect herself with a supermajority. To some extent, the positive prospect that winning is more likely than losing is mitigated by the higher cost of falling into a minority.

The analysis in case 2, compared to the analysis in case 1, leads to the following lemma.

Lemma 2 *The preferred majority threshold of an over-confident agent depends positively on her degree of risk aversion. Moreover, for the same degree of risk aversion, an over-confident agent prefers a lower majority threshold than the one preferred by an unbiased agent.*

Case 3. Now consider the case in which agent j is *unconfident* with respect to how others will vote. Thus, in the *NO-INFO* treatment, she thinks that the probability of a favorable majority is lower than an unfavorable one, i.e. $p < 0.5$. Despite her vote, she thinks that her alternative will always receive less than $\frac{n}{2}+1$ votes. In that case, $\Delta(q)$ is smaller than 1 for all possible $q \geq \frac{n}{2}+1$.

Case 3.a. If $R_j \in (0,1)$, we can examine the shape of $EU_j(q)$ by studying the sign of $\Delta(q)-\Delta(q+1)$. If it is positive then possibly $\Delta(q) > R_j$ holds for low thresholds and $\Delta(q) < R_j$ holds for high thresholds; i.e. $EU_j(q)$ is convex. Of course, this is not always the case. Observe, however that

$$\Delta(q)-\Delta(q+1) = \left(\frac{p}{1-p}\right)^{2q-n}\left[\frac{q}{n-q} - \frac{q+1}{n-q-1}\left(\frac{p}{1-p}\right)^2\right].$$

In the right-hand side the first term is positive. The second term is decreasing in p and increasing in q.

If p is high, then $\Delta(q)$ is high and increasing in q for every $q \geq \frac{n}{2}+1$. Thus, if $R \to 0^+$, then $\Delta(q) > R_j$ for every q and the most preferred threshold is the simple majority. As R increases, it is $\Delta(q) < R_j$ for low q and $\Delta(q) > R_j$ for high q and the most preferred threshold is an internal supermajority.

If p is low, then $\Delta(q)$ is low and decreasing in q for every $q \geq \frac{n}{2}+1$. Thus, if $R \to 1^-$, it is $\Delta(q) < R_j$ for every q and the most preferred threshold is unanimity. As R decreases, it is $\Delta(q) > R_j$ for low q and $\Delta(q) < R_j$ for high q and the most preferred threshold can be unanimity or simple majority depending on the comparison between $EU_j(n)$ and $EU_j(\frac{n}{2}+1)$. In particular, the more R decreases, the more likely that simple majority is preferred to unanimity.[7]

For intermediate p, then $\Delta(q)$ is decreasing in q for low q, and is increasing in q for high q. For $R \to 0^+$ and $R \to 1^-$ the preferred threshold is the simple majority and unanimity respectively. For intermediate R, given that $\Delta(q)$ is convex, EU_j is possibly not monotonic in q. Thus there might be several local maxima for EU_j; among them j will choose the global one. In that case, the most preferred threshold can be simple majority, an internal supermajority or unanimity, depending on p and on R. Therefore, for intermediate values of R, an unconfident agent could prefer a simple majority if p is not too low, i.e. if the ratio between winning and losing probabilities under the simple majority is higher than the relative advantage of the status quo. For lower p, she prefers to protect herself against the tyranny of an adverse majority through a supermajority threshold. Notice that if the expected loss of falling into the minority is at least equal to the the expected benefit of belonging to the majority, an unconfident agent prefers unanimity as threshold whatever her $p < 0.5$.

Case 3.b. If $R_j \in [1, +\infty)$, given (7), the most preferred threshold is unanimity.

The intuition is clear: for an unconfident agent, winning is always less likely than losing; moreover, a R_j greater than one implies that losing is relatively more costly than winning. The voting lottery presents a double disadvantage: tyranny is highly likely and highly costly. This is the worst situation; thus, not surprisingly, the agent prefers the highest protection from the risk of being tyrannized. This kind of protection is provided by unanimity.

The analysis in case 3, compared to the analysis in case 1, leads to the following lemma.

Lemma 3 *The preferred majority threshold of an unconfident agent depends positively on her degree of risk aversion. Moreover, for the same degree of risk aversion, an unconfident agent prefers a higher majority threshold than the one preferred by an unbiased agent.*

Considering together the three lemmas above, a general result can be stated about the relation between an agent's preferred majority threshold and her degree of risk aversion, and between the former and the agent's confidence about how the other agents will vote. This result is formally presented in Proposition 1.

Proposition 1 *In the voting lottery Λ, an agent's preferred majority threshold depends positively on her degree of risk aversion and negatively on her confidence about how the other agents will vote.*

Proposition 1 provides the two main theoretical predictions that we want to test on subjects' decisions in our experiment.

First, once elicited the subject's degree of risk aversion in the first phase of the experiment, we expect to find that the higher the subject's degree of risk aversion, the higher the majority threshold she would select in part 1 of the second phase of the experiment. In fact, a risk-averse subject weights the sure payoff in the status quo more than the uncertain payoff of the voting. Thus, the higher her degree of risk aversion, the stronger the protection demanded, the higher her preferred majority threshold.

Proposition 1 also provides a prediction about the role of the subject's degree of confidence about how the other subjects will vote (elicited in part 2 of the second phase of the experiment). In this case, the intuition provided by the theoretical model is straightforward. Higher confidence means that the subject considers winning relatively more likely; thus, other things being equal, she fears losing less and prefers lower protection. In this case, she wants to facilitate majority formation, because, for any majority threshold, a favorable majority has become more likely;

thus, she wants a lower threshold. We test the negative effect of subjects' confidence on the preferred majority thresholds in two different settings. In the first treatment (*NO-INFO*), we measure confidence by simply asking subjects to state their naive priors about the distribution of others' votes over the two alternatives. In this treatment, the only information available to subjects is about the process of random draw of votes, but they know nothing about the realizations of these draws for the other subjects in the session. In the second treatment (*INFO*), we study how the effects of confidence change when subjects, before stating their preferred majority thresholds, privately observe a signal about these realizations, i.e. about the (exogenous) distribution of votes over policies.

A final theoretical prediction to be validated concerns the independency of the effect of risk aversion and of confidence on the preferred threshold (this is assumed in our model). Our model predicts that given two subjects with the same prior, the one with the lowest degree of risk aversion should select the lowest majority threshold. Moreover, if an over-confident subject and an unconfident subject have the same degree of risk aversion, the preferred threshold of the former cannot be higher than the preferred threshold of the latter.

All theoretical predictions above will be directly verified through an analysis of the determinants of a subject's preferred majority threshold in the *NO-INFO* treatment. The *INFO* treatment has been introduced with the goal of extending our analysis to the case where an informative signal is sent to a subject before she declares her preferred majority threshold. This can be interpreted as a robustness test of our theoretical model.

Indeed, although an explicit theoretical analysis of the *INFO* treatment is not provided in this section, it is easy to predict that, under the assumption of independence between risk attitude and confidence on how the others will vote, a positive dependence of the preferred majority threshold on the subject's degree of risk aversion should be found also in the *INFO* treatment.

Moreover, as in the *NO-INFO* treatment, the subject's preferred majority threshold in the *INFO* treatment should depend negatively on her degree of confidence. However, here the generalization of Proposition 1 is anything but trivial, since the definition itself of confidence provided above (Definition 1) should account for a variety of private signals.

In the *NO-INFO* treatment, each subject only possesses the same ex-ante information about the random process determining the other voters' types: each subject has the same objective probability of being a $x-$type or a $y-$type voter. Hence, according to Definition 1, an unbiased subject should report that both types of voters are equally likely among other subjects. Indeed, this is also the modal outcome of the binomial distribution over types of voters.

Although this ex-ante information is provided also in the *INFO* treatment, here each subject receives an additional private signal, and none of the private signals she may receive entails equiprobable types.[8] As the latter signal conveys information on the realizations of the random process,[9] our behavioral assumption is that a subject *totally* adapts her beliefs to the ex-post private signal rather than to the ex-ante information about the underlying distribution of voters in the whole population.

Therefore, we take the private signal as reference point for measuring confidence in the *INFO* treatment. According to Definition 1, we define as *unbiased* in this treatment a subject who rescales the distribution of types in the signal she privately received to the size of the subject pool. Then, an index of confidence is defined as the difference between the number of voters a subject expects to have her own type and the predicted number obtained by rescaling the private signal she received. For an over-confident (unconfident) subject the sign of the index of confidence is positive (negative). The behavioral assumption on the dominance of the private over the public signal in the *INFO* treatment is tested by comparing the percentage of unbiased subjects in the *NO-INFO* and in the *INFO* treatment. A significantly higher percentage of such subjects in the latter treatment would provide support to a prevalent role of the private signal in determining a subject's prior about how others will vote. If this is the case, then we expect the private signal to have a significant effect over the preferred majority threshold in the *INFO* treatment.

Notice that our strict definition of *unbiasedness* in the *INFO* treatment requires that subjects use their private information from 7 observations to form their beliefs on the larger sample of 35. Thus, deviations from the resulting linear extrapolation are considered biased, even if they could be the result of a more sophisticated use of statistics.[10] Thus, our definition might lead to an overestimation of biased subjects (although in the next section we show that an opposite result applies). At the same time, it is the most objective and straightforward way of determining an unbiased guess.

Lastly, the role of the private signal over the preferred majority threshold in the *INFO* treatment requires a thorough discussion. The percentage of votes disclosed through the private signal (20%) is non-negligible with the respect to the whole population of voters. Hence, different private signals might lead to different preferred thresholds (also) because their realization influences the number of favorable votes needed – in the remaining part of the population – to form a majority given the preferred threshold. We discuss this point in Appendix B, through an extension of the theoretical model provided in this section. In particular, we show that the theoretical predictions in Proposition 1 hold also in the extended version of the model.

We also show that, *ceteris paribus*, the preferred majority threshold is non-increasing in the number of favorable votes contained in the signal. This can be interpreted as further theoretical support for the importance of the private signal in determining the preferred majority threshold in our voting lottery.

5 Experimental Results

5.1 Risk Attitude

Table 1 reports the distribution of subjects' choices in the first phase of the experiment in both treatments.

In the *NO-INFO* treatment, more than 78% of subjects choose a pair of lotteries included between the 11th and the 20th line, thereby showing risk aversion. The median choice is the 16th line (revealing a high degree of risk aversion).[11] Similarly to the *NO-INFO* treatment, in the *INFO* treatment the median choice is the 16th line. More than 84% of subjects exhibit risk aversion.

Thus, as in other experiments, we observe the majority of subjects exhibiting risk aversion, and among these many are highly-risk-averse.[12] In addition, we do not find any significant difference between treatments in the distribution of the risk parameter (Wilcoxon-Mann-Whitney test, *p-value* = 0.607). Therefore, subjects' samples in the two treatments are comparable in terms of risk attitudes.

[Table 1 about here]

5.2 Guess about Distribution of Voters

Moving to the second phase of the experiment, we start from analyzing subjects' guesses about the distribution between $x-$type and $y-$type voters.[13]

In the *NO-INFO* treatment, both types have the same objective probability in each draw and the random draws of the type are independent for all subjects. As anticipated in section 4, according to Definition 1 a subject with *unbiased* expectations about the distribution of voters should expect the rest of the population to be equally split over the two alternatives (modal, average and median voting outcome). Thus, knowing her type, she should expect the probability of winning to be moderately higher than the probability of losing ($n/2+1$ subjects in her session, including herself, should be of her type). An *over-confident* subject should state a distribution of the other subjects' votes that is biased in favour of her type. Such subject would expect that more than $n/2+1$ subjects in her session, including herself, are of her type. Conversely, an *unconfident* subject should state a distribution of the other subjects' votes that is biased in favour of the other type. Such subject would expect that less than $n/2+1$ subjects in her session, including herself, are of her type.

Therefore, Definition 1 allows to split the subjects in the *NO-INFO* treatment into three subsets – unbiased, over-confident and unconfident ones – according to their guess in the second phase of the experiment. We built for each subject an index of confidence defined as the difference between the number of voters she expects to have her own type and $n/2+1$. This index is negative for unconfident subjects, null for unbiased subjects, and positive for over-confident ones. The distribution of the index of confidence is shown in Figure 1.

Observe that the modal guess is unbiased (12% of subjects report a guess equal to $n/2+1$), whereas around 58% of subjects exhibit over-confidence. A binomial test strongly rejects the null hypothesis of equal distribution between over-confident and unconfident subjects (*p-value* < 0.01). According to a Spearman correlation test, we find no significant correlation between a subject's risk attitude (as proxied by the subject's choice in the first phase) and her confidence on how other subjects will vote. This holds both by considering the index of confidence introduced above ($\rho = 0.082$, *p-value* $= 0.432$) and by using a dummy variable that assumes value one if the subject is over-confident ($\rho = 0.090$, *p-value* $= 0.389$). Therefore, the main assumption of our theoretical model – independence between a subject's degree of risk aversion and her level of confidence – is verified in the *NO-INFO* treatment.

[Figure 1 about here]

Result 1. *In the NO-INFO treatment, the majority of subjects exhibit risk aversion and report over-confident guesses. There is not significant correlation between the degree of risk aversion and confidence.*

The following analysis is dedicated to subjects' guesses in the *INFO* treatment. Recall that in this treatment, before choosing the majority threshold and stating her guess, each subject observed the distribution of $x-$type and $y-$type voters in a subset of seven subjects. Again relying on Definition 1, in order to disentangle unbiased, over-confident and unconfident subjects in the *INFO* treatment, we combine subjects' stated guesses with the informative content of their private signal. For an unbiased subject the private signal she receives crowds out her naive prior, whatever this prior is. Therefore, she reports as guess about the number of $x-$type and $y-$type voters in her session the distribution inferred from the subset of seven subjects she observed.

More specifically, for each subject in the *INFO* treatment, we built a theoretical distribution by rescaling the number of $x-$type and $y-$type voters in the private signal to the size of the subject pool. Then, we built an index of confidence defined as the difference between the number of voters a subject expects to have her own type and the predicted number obtained by rescaling the private signal she received. If this difference is null, than the subject is classified as *unbiased* in the *INFO* treatment. Consequently, if this difference is positive (negative), the subject is classified as *over-confident* (*unconfident*) in the *INFO* treatment. Figure 2 reports the distribution of the index of confidence in the *INFO* treatment.

[Figure 2 about here]

As shown by the graph, 36% of subjects reported unbiased guesses, a percentage that is significantly higher than in the *NO-INFO* treatment (*p-value* < 0.001 according to a test for the null hypothesis of equality of proportions of unbiased guesses between treatments). This result supports our behavioral assumption of relevance of the private signal in determining a subject's prior about how others will vote in the *INFO* treatment.

However, the group of subjects exhibiting over-confidence (41%) is still the most numerous in the sample. One can think that this may depend on the signal observed. The set of signals that subjects observe in the *INFO* treatment can be divided in two groups: favorable and unfavorable ones. On a subset of seven subjects, a *favorable signal* reveals at least four votes of the same type as the subject receiving the signal. An *unfavorable signal* shows only three or less votes of the same type as the subject receiving the signal.

In Table 2, we report the reactions in terms of stated confidence by subjects in the *INFO* treatment, disentangled by the sign of the signal (positive if favorable and negative otherwise). We controlled for the sign of the signal: the population is equally split between those observing a favorable signal and those receiving an unfavorable one. Despite that, a binomial test rejects the null hypothesis of an equal distribution between over-confident and unconfident subjects (*p-value* $= 0.072$). Recall that in this treatment an unbiased subject should rescale the distribution of types in the signal she privately received to the size of the subject pool. Therefore, if she receives a favorable (unfavorable) signal she should report a guess on the number of voters of her type greater (smaller) than $n/2 + 1$, exactly equal to five times the number of votes observed in the signal.[14]

By considering only subjects observing an unfavorable signal, there is a clear tendency towards over-confidence (20 subjects out of 35 report over-confident guesses, while only 3 report unconfident guesses), confirming the tendency in the *NO-INFO* treatment. Interestingly, a different picture emerges when we focus on those observing a favorable signal. In this case, the proportion of over-confident subjects is slightly smaller than both the unbiased and the unconfident ones (9 vs 13): most subjects receiving a favorable signal either believe this signal or interpret it as too positive. However, the proportion of unbiased subjects is almost the same that we find when the signal is unfavorable.

[Table 2 about here]

We have an intuitive interpretation for this evidence. Suppose that, when asked to state her prior without observing any private signal, a subject is genuinely over-confident (i.e. over-confident according to the index defined for *NO-INFO*). If we let this subject observe a favorable private signal, then she finds confirmation of her over-confidence and shows herself as unbiased with respect to the signal (i.e., according to the index defined for *INFO*). If instead she observes an unfavorable signal, her genuine over-confidence prevails. Although the opposite happens for genuinely unconfident subjects, this effect is less evident, given the relative small number of these subjects.

Furthermore, similarly to the *NO-INFO* treatment, confidence is not significantly correlated to risk aversion. This is true both if we consider the index of confidence introduced for the *INFO* treatment ($\rho = 0.122$, *p-value* $= 0.315$) and by using a dummy variable with value one when a subject exhibits over-confidence ($\rho = 0.164$, *p-value* $= 0.279$). Thus, the assumption of independence between a subject's degree of risk aversion and her level of confidence is also verified in the *INFO* treatment.

Result 2. *Result 1 holds in the INFO treatment, although the number of over-confident subjects is significantly lower. In particular, more than one third of subjects reports a guess about the others' types that is unbiased with respect to the private signal. However, a slightly larger proportion of subjects exhibit over-confidence with respect to the private signal.*

5.3 Preferred Majority Threshold

This section presents and discusses the preferred majority thresholds in the two treatments. Table 3 reports the distribution of subjects' choices about thresholds in the second phase of the experiment in the *NO-INFO* and *INFO* treatment respectively. Notice that, due to the different number of subjects in *NO-INFO* sessions (31 in each of the three sessions) and *INFO* sessions (35 in each of the two sessions), the set of possible majority thresholds slightly differ between the two treatments: it is

$\{16, 17, ..., 31\}$ in *NO-INFO* and $\{18, 19, ..., 35\}$ in *INFO*. In order to provide a visual comparison of the distributions of majority thresholds in the two treatments, Table 3 reports them as fraction of required votes over the total number of voters. In particular, "normalized" supermajority thresholds $q/n \in (50\%, 100\%)$ are grouped in five different intervals of similar size. The remaining two categories are the simple majority and unanimity.

In the *NO-INFO* treatment, the median preferred threshold is around 77% (24 votes over 31). In the *INFO* treatment it is slightly lower, around 74% (26 votes over 35). In both treatments, the modal threshold is unanimity. In the *NO-INFO* treatment, simple majority is the second most preferred threshold. However, by comparing the observed distributions of normalized majority thresholds in the two treatments through a two-sample Kolmogorov-Smirnov test, we cannot reject the null hypothesis that the two distributions are different (*p-value* $= 0.400$).

[Table 3 about here]

Before moving to the discussion of the determinants of a subject's preferred majority threshold in the two treatments, it is worth controlling whether there has been a hedging effect across part 1 and part 2 of the second phase. Indeed, given the preferred majority threshold (part 1), a subject might state a guess "against" this threshold (part 2) so as to have a positive probability to get this guess paid in the case an unfavorable majority would emerge given this threshold. In Table C.1 in Appendix C, we report – for each treatment separately and by considering the same intervals of "normalized" majority thresholds used in Table 3 – the number of subjects stating a guess "against" the preferred threshold and the number of subjects stating a guess such that the preferred threshold protects them against the possibility of falling into a minority. In the former category, we include all subjects reporting in part 2 a guess of the number of unfavorable votes higher than or equal to the majority threshold chosen in part 1. In the latter category, we report the remaining subjects. A two-sample binomial test (two-tailed) shows that, in each treatment, the number of subjects stating a guess "against" the preferred threshold is negligible in the whole sample (5/93 in the *NO-INFO* treatment, 7/70 in the *INFO* treatment, *p-value* $= 0.000$ in both treatments). In the *NO-INFO* treatment, it is negligible in each interval of preferred majority thresholds used in Table 3, while in the *INFO* treatment it is negligible in all but two of these intervals (with *p-value* $= 0.157$ and *p-value* $= 0.103$ in these two intervals, respectively).

Given the absence of a hedging effect in a subject's guess of about how others will vote, we consider (also) this variable in the following discussion, which focuses on the determinants of a subject's preferred majority threshold. The analysis under the *NO-INFO* treatment provides a direct test of our theoretical predictions. Comparative analysis under the *INFO* treatment provides a robustness test of our theoretical model when an informative signal – potentially influencing a subject's prior about the voting outcome – is sent to a subject before she declares her preferred majority threshold. Table 4 reports the results of these analyses.

[Table 4 about here]

The first column of Table 4 reports results from a Tobit model in which the chosen majority thresholds in the *NO-INFO* treatment are regressed on individual degrees of risk aversion and two dummies for the guesses, one for *Unbiasedness* and the other for *Over-confidence*. The majority thresholds are positively and highly correlated with subjects' degree of risk aversion (the estimated coefficient of *Risk Aversion* is 0.499 and it is significant at the 1% level). This result is confirmed by non-parametric tests. Indeed, according to a Wilcoxon-Mann-Whitney test, the majority thresholds chosen by subjects exhibiting risk aversion are significantly higher than those chosen by risk-loving subjects (*p-value* = 0.012). As for the guesses about how others will vote, the coefficients of both dummies are negative and only the one reflecting *Over-confidence* is highly significant.

Thus, after controlling for the degree of risk aversion, over-confident subjects choose majority thresholds that are significantly lower than the thresholds chosen by the unconfident ones. This evidence and the non-significant correlation between confidence and risk aversion discussed above support the theoretical insights of our model. In fact – under the assumption that risk aversion and confidence are independent idiosyncratic features – the theoretical model predicts that an over-confident subject with a given degree of risk aversion will never choose a higher threshold than an unconfident one with same degree of risk aversion.

Result 3. *In the NO-INFO treatment, subjects prefer supermajority thresholds. Subjects' preferences strongly depend on specific idiosyncratic features: majority thresholds are positively correlated with risk aversion and negatively correlated with confidence.*

In the second column of Table 4, we present results from a Tobit model that regresses the majority thresholds chosen by subjects in the *INFO* treatment on the same set of explanatory variables used for the *NO-INFO* treatment and on *Net Favorable Signal*. This variable is defined, given the signal that a subject receives, as the difference between the number of voters of her own type and the number of voters of the other type in her observed subset of seven subjects. As before, the estimated coefficient of *Risk Aversion* is positive and highly significant. Interestingly, neither *Over-Confidence* nor *Unbiasedness* are significant, while *Net Favorable Signal* is highly significant. Thus, the private signal tends to replace (or at least has a stronger impact than) subject's over-confidence in determining the preferred majority threshold. Indeed, the private signal in the *INFO* treatment has a significant negative impact on the preferred majority threshold, as *Over-Confidence* in the *NO-INFO* treatment.

Result 4 *In the INFO treatment, subjects prefer supermajority thresholds. There is a positive and highly significant correlation between a subject's preferred majority threshold and her degree of risk aversion. A favorable private signal has a significant negative effect on the preferred threshold: the (over-)confidence determinant of a subject's preferred majority threshold loses ground in the presence of a favorable private signal.*

6 Conclusion

In this paper, we argue that the fear of being subject to a majority tyranny leads an individual to prefer higher majority thresholds. In accordance to the theoretical prediction, our experimental results show that the level of the preferred majority threshold depends on the voter's risk aversion and on subjective priors about how others will vote. Therefore, a more risk-averse and a less confident agent may fear more being tyrannized by an unfavorable majority, thus asking for higher supermajorities.

First of all, these findings have important implications for the design of the optimal voting system, which have been neglected by the literature so far.[15] As a major expression of a system's democracy, the design of voting institutions should account, among other things, for citizens' preferences regarding the threshold required in order to determine the winning majority.

It is also worth observing that, while risk aversion is intrinsically related to an individual's perception of private gains and losses, lack of confidence reflects an individual's perception about how own preferences may differ from the others'. Lack of confidence may be caused by the feeling of being different in ideology, needs, desires, vision of the world. This is particularly important in collective situations, such as voting. An unconfident individual may think that the majority is different from herself and consequently she does not want the majority to easily make decisions that will affect her. Thus, over-confidence is a behavioral distortion that possibly affects a voter's preferences on the threshold. In fact, we find that naively over-confident individuals significantly prefer lower thresholds. As soon as agents receive a private signal according to which others are more likely to vote in a favorable way, naive over-confidence is replaced by the signal. Thus, the preferred thresholds are fully determined by the signal, rather than by voters' naive priors. Our findings are in line with the existing literature on the role of exit polls and pre-voting information on agents' choice. However, while previous experimental works focus on the role of exit polls on voting behavior, our paper sheds light on their relevance for agents' preferences on the voting rules.

Of course, protection comes at the cost of lower chance to overcome the status quo in a favorable way. One might argue that this individual trade-off between risk of tyranny and chance of being part of a favorable majority reflects the trade-off at collective level between decisiveness of the voting rules and the need of protecting minorities. In this paper we have not answered the question of which threshold will be chosen at the constitutional level, and whether it is "socially" optimal or not. We think, however, that our findings contribute to answering important normative issues such as: How voting rules reflect the risk attitudes of citizens? What kind of protection do agents demand when they belong to an ethnic minority or when they think that their policy preferences are different from the bulk of the population? What degree of conflict on decisional rules should we expect within a constituency whose members have diversified preferences? How many supermajority thresholds should a statute include, and for which issues?

Finally, from a purely experimental point of view, our paper provides a methodological contribution to the literature on risk aversion elicitation. Indeed, our findings relate to the previous literature about how a specific risk-aversion measurement in the laboratory correlates with behavior in other risk-related tasks within the same experiment.

As has been pointed out recently, by García-Gallego *et al.* (2012) and Crosetto and Filippin (2013), the external validity of risk elicitation tasks has very rarely been addressed. For example, in very few occasions[16] a risk elicitation procedure has been useful to explain the behavior in a strategic context through subjects' externally elicited risk attitudes. In that sense, although the Holt and Laury (2002) procedure has been adopted more frequently than other tasks as a risk elicitation device, there is still no conclusive evidence on whether the test reasonably predicts the behavior of a subject in a different, even risk-related task. Exceptionally, Crosetto and Filippin (2013) compared their Bomb Risk Elicitation Task with three alternative risk elicitation procedures[17] finding significant differences in the results and the classification of subjects emerging from these four procedures. Yet, although a negative answer seems to be implied, the question whether risk attitudes correlate across tests was not explicitly addressed. Therefore, the results presented in our paper also contribute with a clear positive finding concerning the correlation of risk attitudes across different tasks which becomes even more interesting if we take into account that the Holt and Laury (2002) procedure and our threshold-setting experiment adopt two very different framings.

Footnotes

[1]We thank Olivier Armantier, Antonio Nicolò, Valentina Rotondi, Viola Saredi, Robert Sugden, Unal Zenginobuz, and participants at the PET 2008 in Seoul, at the PET 2009 in Lyon, at the seminar series at Catholic University of Milan, and at the 3^{rd} Annual Xiamen University International Workshop on Experimental Economics and Finance (2012), for useful comments and suggestions. G. Attanasi gratefully acknowledges financial support by the Foundation for an Industrial Safety Culture (Fondation pour une Culture de Sécuruté Industrielle, *FONCSI*) and by the European Research Council (*ERC* Starting Grant DU 283953). N. Georgantzís gratefully acknowledges financial support by the Ministerio de Economia y Competitividad (ECO 2011-23634).

[2]For an analysis of policy alternatives as lotteries in a Prospect Theory framework, see Passarelli (2012). He particularly focuses on the status quo bias induced by loss aversion.

[3]Andersen *et al.* (2006) use a similar mechanism. See Dohmen *et al.* (2010) for an alternative design that imposes consistency.

[4]The number of participants in our experimental sessions is 31 (i.e. $n = 30$) in the *NO-INFO* treatment and 35 (i.e. $n = 34$) in the *INFO* treatment.

[5]To save notation, we do not index j's subjective probability p by j. The reader should keep in mind that p and all other variables that depend on p are conditional to j.

[6]See Machina (1987) for details.

[7]This is because $EU_j(q)$ in (5) depends negatively on R_j, with $EU_j(\frac{n}{2}+1)$ increasing more than $EU_j(n)$ for a similar decrease in R.

[8]The signal observed by a subject in the *INFO* treatment can be favorable or unfavorable. On a subset of seven subjects, a favorable signal reveals at least four votes of the same type as the subject receiving the signal. An unfavorable signal shows only three or less votes of the same type as the subject receiving the signal.

[9]The private signal reveals 20% of the realizations of the random draws of subjects' types.

[10]For example, using a Chi-Squared test one can build confidence bands around the unbiased expected guess accounting for the fact that a "3-4" sample and a "18-17" guess are both not significantly different from the 50%-50% theoretical expectation based on the binomial distribution. Also, a more sophisticated subject would form a guess, keeping the 7-observation signal and applying the binomial distribution to the remaining 28 observations. Again, intervals should be used to define significantly biased guesses.

[11]See Holt and Laury (2002).

[12]See Carlsson *et al.* (2002) and Harrison and Rutström (2008).

[13]In designing the guessing task, we have followed an existing economic literature that implements similar experimental settings to study and measure subjects' optimism (see, for instance, Muren 2012).

[14]Differently from the *NO-INFO* treatment, where all unbiased subjects must report a probability of winning slightly higher than the probability of losing (i.e. $(n/2+1)/n$), here an unbiased subject may report a probability of winning lower than the probability of losing. This happens when she has received an unfavorable signal.

[15]With one notable exception by Procaccia and Segal (2003) analyzing how a constitution is drafted by people that behave according to Prospect Theory (Kahneman and Tversky, 1979).

[16]See for example, Sabater-Grande and Georgantzís (2002) and Charness and Villeval (2009) on the connection between risk taking and cooperation or Heinemann *et al.* (2009) on uncertainty and coordination.

[17]The procedures introduced in Holt and Laury (2002), Eckel and Grossman (2002) and Gneezy and Potters (1997).

Appendix A. Tables and Figures

Table 1. Distribution of Risk Preferences

	Category	*NO-INFO*	*INFO*
$r \leq -2.863$	$L1$	0.01	0.01
	$L2$	0.00	0.00
	$L3$	0.00	0.00
	$L4$	0.01	0.01
	$L5$	0.00	0.00
	$L6$	0.03	0.00
	$L7$	0.00	0.01
	$L8$	0.02	0.03
	$L9$	0.05	0.01
$-0.112 \leq r \leq 0.038$	$L10$	0.09	0.07
	$L11$	0.02	0.13
	$L12$	0.01	0.01
	$L13$	0.05	0.06
	$L14$	0.05	0.03
	$L15$	0.11	0.13
	$L16$	0.21	0.20
	$L17$	0.14	0.12
	$L18$	0.06	0.03
	$L19$	0.09	0.08
$r \geq 1.613$	$L20$	0.05	0.07

Note. This table reports the distribution of subjects' risk preferences in *NO-INFO* and *INFO*. For a given choice, r refers to the estimated interval of the risk aversion parameter as obtained by using a *CRRA* utility function.

Figure 1. Index of Confidence in *NO-INFO*.

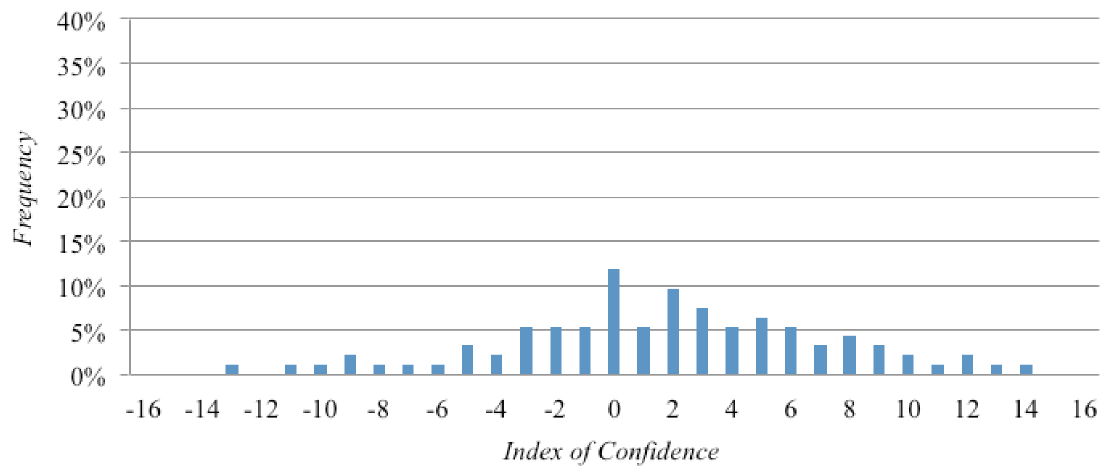

Figure 2. Index of Confidence in *INFO*.

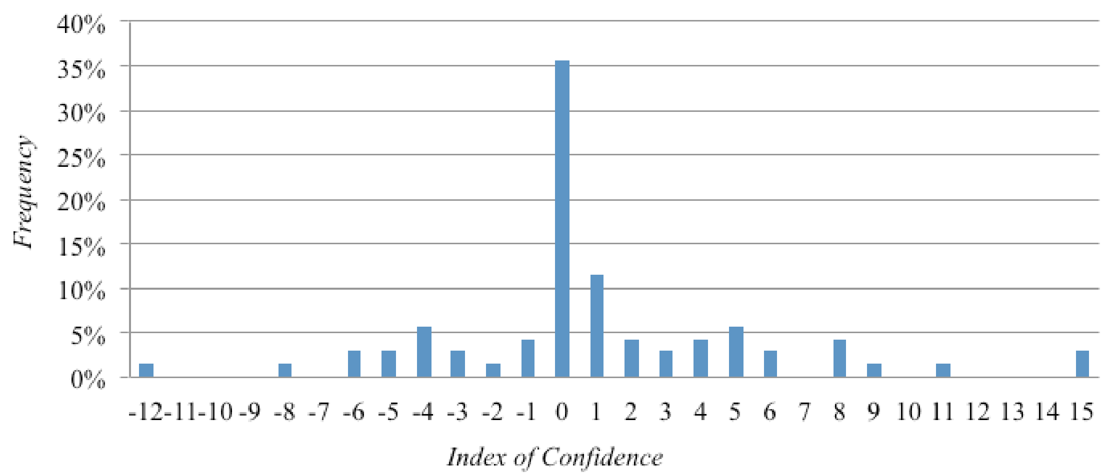

Table 2. Over-Confident, Unbiased and Unconfident subjects in *INFO*.

	Sign of Signal		
Index of Confidence	> 0	< 0	N
> 0	9	20	29
$= 0$	13	12	25
< 0	13	3	16
N	35	35	70
p-value^a	0.175	0.000	0.000
p-value^b	0.523	0.000	0.072

Note. This table reports the distribution of over-confident, unbiased and unconfident subjects in the *INFO* treatment, cross-tabulated with the information contained in their signals. The table also reports results from a binomial test for the null hypothesis of an equal distribution between confident and unconfident subjects either by including (a) or by excluding (b) from the first category those reporting unbiased guesses.

Table 3. Distribution of Majority Thresholds

Majority Threshold	*NO-INFO*	*INFO*
$(q/n) = 50\%$	0.09	0.13
$(q/n) \in (50\%, 60\%)$	0.08	0.10
$(q/n) \in [60\%, 70\%)$	0.10	0.16
$(q/n) \in [70\%, 80\%)$	0.27	0.20
$(q/n) \in [80\%, 90\%)$	0.21	0.16
$(q/n) \in [90\%, 100\%)$	0.07	0.08
$(q/n) = 100\%$	0.18	0.17

Note. This table reports the distribution of the majority thresholds chosen by subjects in part 1 of the second phase of *NO-INFO* and *INFO*.

Table 4. Tobit Models in *NO-INFO* and *INFO*.

Dependent Variable:	(1)	(2)
Majority Threshold		
Explanatory Variables:		
Risk Aversion	0.499***	1.027***
	(0.164)	(0.218)
Unbiasedness	−2.409	−1.522
	(3.014)	(1.971)
Over-Confidence	−2.742**	−1.183
	(1.313)	(1.894)
Net Favorable Signal		−0.803**
		(0.356)
Constant	19.185***	13.132***
	(2.555)	(3.416)
N. Obs.	93	70
Log-pseudolikelihood	−242.946	−182.396
F-test	4.38	6.96
Prob>F	0.006	0.000

Note. This table reports coefficient estimates (robust standard errors in parentheses) from Tobit models for both the *NO-INFO* and *INFO* treatment. The dependent variable is given by the majority thresholds chosen by subjects in part 1 of the second phase of the experiment. *Risk Aversion* is given by subjects' choices in the first phase of the experiment. *Unbiasedness* and *Over-Confidence* are dummies assuming value one if, in part 2 of the second phase of the experiment, a subject reported unbiased or over-confident guesses respectively. For a given signal received by a subject in the second phase of the *INFO* treatment, *Net Favorable Signal* is the difference between the number of voters of her own type and the number of voters of the other type in her observed subset of seven subjects. *, ** and *** denote statistical significance at 0.1, 0.05 and 0.01 level, respectively.

Appendix B. Extension of the Theoretical Model

Define with f the number of favorable votes in the private signal, with $f \in \{0, 1, ..., \bar{f}\}$, where $\bar{f}$ is the size of the signal, and so the highest possible number of favorable (or unfavorable) votes. Notice that $\bar{f}$ is fixed and set to 0 (*NO-INFO*) or 7 (*INFO*) in our experiment. By construction, it is $\bar{f} < \frac{n}{2} + 1$, so that, regardless of the outcome f of the signal and the majority threshold q, the agent is left with some uncertainty about the probability of winning (losing) the voting lottery.

We can rewrite the probability of winning the voting lottery in (1) as

$$\Pr\{W\} = \sum_{k=q-f}^{n+1-\bar{f}} \binom{n+1-\bar{f}}{k} p^k (1-p)^{n+1-\bar{f}-k}$$

where also j's vote has to be taken into account, given that it can be randomly included in the signal.

Accordingly, the probability of losing the voting lottery in (2) becomes

$$\Pr\{L\} = \sum_{k=q-(\bar{f}-f)}^{n+1-\bar{f}} \binom{n+1-\bar{f}}{k} (1-p)^k p^{n+1-\bar{f}-k} \ .$$

Notice that $\Pr\{W\}$ is increasing in f, while $\Pr\{L\}$ is decreasing in f. Indeed, given the threshold q, the minimum number of favorable (unfavorable) votes needed to form the majority (fall into the minority) is decreasing (increasing) in the number of favorable votes in the signal.

By plugging the extended formulas of $\Pr\{W\}$ and $\Pr\{L\}$ into (4), we obtain agent j's normalized expected utility from the voting lottery after having received a private signal of size $\bar{f}$ containing f favorable votes:

$$\frac{EU_j(q)}{u_j(W)} = \sum_{k=q-f}^{n+1-\bar{f}} \binom{n+1-\bar{f}}{k} p^k (1-p)^{n+1-\bar{f}-k} - R_j \sum_{k=q-\bar{f}+f}^{n+1-\bar{f}} \binom{n+1-\bar{f}}{k} (1-p)^k p^{n+1-\bar{f}-k} \tag{8}$$

where R_j is as in (6).

Then, the first-order difference of $\frac{EU_j(q)}{u_j(W)}$ in (8) has the same sign of $R_j - \Delta(q_f)$, where

$$\Delta(q_f) \equiv \frac{(q-\bar{f}+f)!(n+1-q-f)!}{(q-f)!(n+1-q-\bar{f}+f)!} \left(\frac{p}{1-p}\right)^{2q-n-1} \ .$$

Four remarks about the expression of $\Delta(q_f)$ are worth introducing.

Remark 1. Regardless of the size $\bar{f}$ of the signal, if the difference between the number of favorable votes and the number of unfavorable ones is equal to 1, then $\Delta(q_f)$ reduces to $\Delta(q)$, as defined in the basic version of the model presented in the main text.

Remark 2. $\Delta(q_f)$ is increasing in f. In fact, the first-order difference of $\Delta(q_f)$ with respect to f has the same sign of

$$[q+f-(\bar{f}-1)](q-f)-[q+f-(n+1)][q-f-(n+1-\bar{f})] \ ,$$

which is positive for every triple $(q,\bar{f},f)$, given that $\bar{f} < \frac{n}{2}+1$ by construction. Hence, the higher f, the smaller the difference $R_j - \Delta(q_f)$.

Remark 3. The first-order difference of the ratio $\frac{(q-\bar{f}+f)!(n+1-q-f)!}{(q-f)!(n+1-q-\bar{f}+f)!}$ with respect to q in $\Delta(q_f)$ has the same sign of

$$(q+1-\bar{f}+f)(n+1-q-\bar{f}+f)-(n+1-q-f)(q+1-f) \ ,$$

which is positive iff the signal is favorable, i.e. $f \geq \frac{\bar{f}}{2}+1$, and negative otherwise.

Remark 4. Given that $q \geq \frac{n}{2}+1$ by construction, if the signal is favorable, then the ratio $\frac{(q-\bar{f}+f)!(n+1-q-f)!}{(q-f)!(n+1-q-\bar{f}+f)!}$ is greater (smaller) than 1.

Extension of Case 1 in the main text. Suppose that the agent is *unbiased* with respect to the private signal she receives. Hence (see Definition 1 in the main text), if the signal is favorable ($f \geq \frac{\bar{f}}{2}+1$), then $p=\frac{f}{\bar{f}} \geq 0.5$ and, by Remarks 3 and 4, $\Delta(q_f)$ is increasing in q and greater than 1 for every possible threshold $q \geq \frac{n}{2}+1$. If instead the signal is unfavorable ($f < \frac{\bar{f}}{2}+1$), then $p=\frac{f}{\bar{f}} < 0.5$ and, by Remarks 3 and 4, $\Delta(q_f)$ is decreasing in q and smaller than 1 for every possible threshold $q \geq \frac{n}{2}+1$.

Consider two signals $f^{'} < f^{''}$. Then, by Remark 2, it is always $\Delta(q_{f'}) < \Delta(q_{f''})$ and, for any R_j, it is $R_j - \Delta(q_{f'}) > R_j - \Delta(q_{f''})$.

Case 1f (favorable). The two signals are favorable, i.e. $\frac{\bar{f}}{2}+1 \leq f^{'} < f^{''}$.

Case 1f.a. If $R_j \in (0,1]$, it is $0 > R_j - \Delta(q_{f'}) > R_j - \Delta(q_{f''})$ for every possible q. Then, $EU_j(q)$ is decreasing in q for every possible $q \geq \frac{n}{2}+1$ and j prefers the simple majority whatever the favorable signal.

Case 1f.b. If $R_j \in (1,+\infty)$, there are four main subcases.

For sufficiently low R_j, it is $0 > R_j - \Delta(\frac{n}{2}+1|f^{'}) > R_j - \Delta(\frac{n}{2}+1|f^{''})$ and the same result of case 1f.a applies.

For higher R_j, it is $R_j - \Delta(\frac{n}{2}+1|f^{'}) > 0 > R_j - \Delta(\frac{n}{2}+1|f^{''})$. By Remark 3, the higher the threshold q, the lower the difference $R_j - \Delta(q_f)$. Hence, it is $R_j - \Delta(q_{f'}) > 0 > R_j - \Delta(q_{f''})$ for sufficiently low q and $0 > R_j - \Delta(q_{f'}) > R_j - \Delta(q_{f''})$ for higher q. Hence, $EU_j(q_{f'})$ is increasing in q for sufficiently low q and decreasing otherwise; $EU_j(q_{f''})$ is decreasing in q for every $q \geq \frac{n}{2}+1$. This means that j prefers a (internal) supermajority for $f = f^{'}$ and the simple majority for $f = f^{''}$, i.e. $n+1 > q^*_{f'} > q^*_{f''} = \frac{n}{2}+1$.

For even higher R_j, it is $R_j - \Delta(q_{f'}) > R_j - \Delta(q_{f''}) > 0$ for sufficiently low q and $R_j - \Delta(q_{f'}) > 0 > R_j - \Delta(q_{f''})$ for higher q. Then, for $f = f^{'}$, j prefers a higher supermajority (eventually, unanimity) than for $f = f^{''}$, i.e. $n+1 \geq q^*_{f'} > q^*_{f''} > \frac{n}{2}+1$.

For extremely high R_j, it is $q^*_f = n+1$, regardless of the favorable signal.

Case 1u (unfavorable). The two signals are unfavorable, i.e. $f^{'} < f^{''} < \frac{\bar{f}}{2}+1$.

Case 1u.a. If $R_j \in (0,1]$, there are three main subcases.

For sufficiently low R_j, it is $0 > R_j - \Delta(q_{f'}) > R_j - \Delta(q_{f''})$ for low q and $R_j - \Delta(q_{f'}) > 0 > R_j - \Delta(q_{f''})$ for high q. Hence: $EU_j(q_{f'})$ is decreasing for low q and increasing for high q (i.e. $EU_j(q_{f'})$ is convex in q) and the preferred threshold is either the simple majority or unanimity, i.e. $q^*_{f'} \in \{\frac{n}{2}+1, n+1\}$; $EU_j(q_{f''})$ is decreasing in q for every $q \geq \frac{n}{2}+1$ and the preferred threshold is simple majority, i.e. $q^*_{f''} = \frac{n}{2}+1$.

For higher R_j, it is $R_j - \Delta(q_{f'}) > 0 > R_j - \Delta(q_{f''})$ for low q and $R_j - \Delta(q_{f'}) > R_j - \Delta(q_{f''}) > 0$ for high q. Hence: $EU_j(q_{f'})$ is increasing in q for every $q \geq \frac{n}{2}+1$ and the preferred threshold is unanimity, i.e. $q^*_{f'} = \frac{n}{2}+1$; $EU_j(q_{f''})$ is decreasing for low q and increasing for high q (i.e. $EU_j(q_{f''})$ is convex in q) and the preferred threshold is either the simple majority or unanimity, i.e. $q^*_{f''} \in \{\frac{n}{2}+1, n+1\}$.

For even higher R_j, it is $R_j - \Delta(n+1|f^{'}) > R_j - \Delta(n+1|f^{''}) > 0$, hence the preferred threshold is unanimity whatever the unfavorable signal, i.e. $q^*_{f'} = q^*_{f''} = n+1$.

Case 1u.b. If $R_j \in (1, +\infty)$, it is $R_j - \Delta(q_{f'}) > R_j - \Delta(q_{f''}) > 0$ for every threshold q. Then, $EU_j(q)$ is increasing in q for every possible $q \geq \frac{n}{2}+1$ and j prefers unanimity whatever the unfavorable signal.

Case 1uf. One signal is unfavorable ($f^{'}$) and the other is favorable ($f^{''}$), i.e. $f^{'} < \frac{\bar{f}}{2}+1 \leq f^{''}$.

By combining the results of case 1f and case 1u, one can easily get that q^*_f is increasing in R_j also in this case and that, given R_j, it is always $q^*_{f'} \geq q^*_{f''}$.

Recalling that R_j is positively related to j's degree of risk aversion, Lemma 1 can be extended in the following way.

Lemma 4 *In the INFO treatment, the preferred majority threshold of an unbiased agent depends positively on her degree of risk aversion and negatively on the numbers of favorable votes in the private signal.*

Extension of Case 2 in the main text. Suppose that the agent is *over-confident* with respect to the private signal she receives. Hence (see Definition 1 in the main text), $p > \frac{f}{\bar{f}}$.

If the signal is favorable, then $p > \frac{f}{\bar{f}} > 0.5$. Then, results of case 1f about the role of R_j and f on q_f^* apply *a fortiori*. Moreover, since $\Delta(q_f)$ is increasing in p, then, given R_j and f, $R_j - \Delta(q_f)$ is lower for an over-confident agent than for an unbiased one. This leads to a lower q_f^* for the over-confident agent.

If the signal is unfavorable, then $p > \frac{f}{\bar{f}}$, with $\frac{f}{\bar{f}} < 0.5$. Hence, p can be greater than, equal to, or smaller than 0.5. Regardless of p, results of case 1u about the role of R_j and f on q_f^* still apply. Furthermore, if $p < 0.5$, by replicating the analysis of case 1u and since, for given R_j and f, $\Delta(q_f)$ is increasing in p, an over-confident agent selects a lower q_f^* than an unbiased one. If $p \geq 0.5$, the first-order difference of $\Delta(q_f)$ with respect to q has the same sign of

$$\left(\frac{p}{1-p}\right)^2 - \frac{(q+1-f)(n+1-q-f)}{(q+1-\bar{f}+f)(n+1-q-\bar{f}+f)} \ ,$$

where both the first and the second term are greater than 1. If p is sufficiently low, $\Delta(q_f)$ is decreasing in q, as occurs for the unbiased agent. Hence, by replicating the analysis of case 1u and since, for given R_j and f, $\Delta(q_f)$ is increasing in p, an over-confident agent selects a lower q_f^* than an unbiased one. If p is sufficiently high, $\Delta(q_f)$ is increasing in q and so, given R_j and f, $R_j - \Delta(q_f)$ is lower for an over-confident agent than for an unbiased one. Then, regardless of p, q_f^* is lower for the over-confident agent.

Therefore, Lemma 2 can be extended in the following way.

Lemma 5 *In the INFO treatment, the preferred majority threshold of an over-confident agent depends positively on her degree of risk aversion and negatively on the number of favorable votes in the private signal. Moreover, for the same degree of risk aversion and the same number of favorable votes in the private signal, an over-confident agent prefers a lower majority threshold than the one preferred by an unbiased agent.*

Extension of Case 3 in the main text. Suppose that the agent is *unconfident* with respect to the private signal she receives. Hence (see Definition 1 in the main text), $p < \frac{f}{\bar{f}}$.

If the signal is favorable, then $p < \frac{f}{\bar{f}}$, with $\frac{f}{\bar{f}} > 0.5$. Hence, p can be greater than, equal to, or smaller than 0.5. Regardless of p, results of case 1f about the role of R_j and f on q_f^* still apply. Furthermore, if $p \geq 0.5$, by replicating the analysis of case 1f and since, for given R_j and f, $\Delta(q_f)$ is increasing in p, an unconfident agent selects a higher q_f^* than an unbiased one. If $p < 0.5$, the first-order difference of $\Delta(q_f)$ with respect to q has the same sign of

$$\left(\frac{p}{1-p}\right)^2 - \frac{(q+1-f)(n+1-q-f)}{(q+1-\bar{f}+f)(n+1-q-\bar{f}+f)} \ ,$$

where both the first and the second term are smaller than 1. If p is sufficiently high, $\Delta(q_f)$ is increasing in q, as occurs for the unbiased agent. Hence, by replicating the analysis of case 1f and since, for given R_j and f, $\Delta(q_f)$ is increasing in p, an unconfident agent selects a higher q_f^* than an unbiased one. If p is sufficiently low, $\Delta(q_f)$ is decreasing in q and so, given R_j and f, $R_j - \Delta(q_f)$ is higher for an unconfident agent than for an unbiased one. Then, regardless of p, q_f^* is higher for the unconfident agent.

If the signal is unfavorable, then $p < \frac{f}{\bar{f}} < 0.5$. Then, results of case 1u about the role of R_j and f on q_f^* apply *a fortiori*. Moreover, since $\Delta(q_f)$ is increasing in p, then, given R_j and f, $R_j - \Delta(q_f)$ is higher for an unconfident agent than for an unbiased one. This leads to a higher q_f^* for the unconfident agent.

Therefore, Lemma 3 can be extended in the following way.

Lemma 6 *In the INFO treatment, the preferred majority threshold of an unconfident agent depends positively on her degree of risk aversion and negatively on the number of favorable votes in the private signal. Moreover, for the same degree of risk aversion and the same number of favorable votes in the private signal, an unconfident agent prefers a higher majority threshold than the one preferred by an unbiased agent.*

Considering together the three lemmas above, Proposition 1 can be extended in the following way.

Proposition 2 *In the voting lottery Λ of the INFO treatment, an agent's preferred majority threshold depends positively on her degree of risk aversion and negatively on the number of favorable votes in the private signal and on her confidence about the private signal.*

Appendix C

Table C.1. Majority thresholds and Guesses of the number of unfavorable votes (# *unf*).

	NO-INFO			*INFO*		
Majority Threshold	$\#unf \geq q$	$\#unf < q$	*p-value*	$\#unf \geq q$	$\#unf < q$	*p-value*
$(q/n) = 50\%$	0	8	0.000	3	6	0.157
$(q/n) \in (50\%, 60\%)$	3	12	0.001	4	8	0.103
$(q/n) \in [60\%, 70\%)$	0	9	0.000	1	14	0.000
$(q/n) \in [70\%, 80\%)$	1	24	0.000	1	13	0.000
$(q/n) \in [80\%, 90\%)$	0	20	0.000	1	10	0.000
$(q/n) \in [90\%, 100\%)$	1	6	0.008	0	6	0.000
$(q/n) = 100\%$	0	17	0.000	0	12	0.000
overall	5	88	0.000	7	63	0.000

Note. This table reports, for both the *NO-INFO* and the *INFO* treatment: the number of subjects indicating in part 2 of the second phase a guess of the number of unfavorable votes (# *unf*) higher than or equal to the majority threshold chosen in part 1 of the second phase (q); all the remaining subjects; results of a (two-tailed) proportion test for the null hypothesis of an equal distribution between the two categories identified in the considered treatment.

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