The Swing Voter's Curse in Social Networks*

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Abstract

We study private communication in social networks prior to a majority vote on two alternative policies. Some agents receive a private imperfect signal about which policy is correct. They can, but need not, recommend a policy to their neighbors in the social network prior to the vote. We show theoretically and empirically that communication can undermine efficiency of the vote and hence reduce welfare in a common interest setting. Both efficiency and existence of fully informative equilibria in which vote recommendations are always truthfully given and followed hinge on the structure of the communication network. If some voters have distinctly larger audiences than others, their neighbors should not follow their vote recommendation; however, they may do so in equilibrium. We test the model in a lab experiment and find strong support for the comparative-statics and, more generally, for the importance of the network structure for voting behavior.

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1 Introduction

Motivation. Majority voting is a major form of collective decision making. As such, it is intensely studied in economics. However, the largest part of the literature ignores pre-vote communication, although in reality, people often receive advice before they vote. For instance, family members, neighbors or Facebook friends who are more deeply interested in politics or better informed might try to convince others to vote like them. Vote recommendations seem to be frequent: Approximately 30% of the U.S. population report that they give vote recommendations to their peers often or sometimes (see Carpini et al., 2004, p. 323). Hence, the question arises whether decentralized pre-vote communication is harmless or even desirable, or whether such communication can be harmful. Surprisingly, the effects of (partly) private advice on voting are largely understudied.[1] We show that pre-vote communication in the form of vote recommendations can impede efficient information aggregation even if voters are sophisticated and interests are perfectly aligned. We restrict our analysis to a common-interest setting to take the assumption to the extreme that voters' preferences are sufficiently aligned to allow for truthful communication. Thus, we demonstrate a negative effect of communication that is, other than in the cheap-talk literature, not due to limited degrees of truthfulness, but rather to the exogenous structure of the communication network. Hence, our setting predominantly applies to large elections, involving a high degree of uncertainty, and concerning a "common good" like national security or growth or, in the case of shareholder votes, the future of the company in question. However, we show that our results are robust to the introduction of propaganda by voters with extreme biases.

A negative effect of private pre-vote communication on efficiency can occur if the social network connecting voters who are imperfect experts on the issue at stake with other voters is not sufficiently *balanced*. In insufficiently *balanced* networks, one voter has a somehow larger audience than the other voters without having much better information. Since in some such networks it is an equilibrium strategy to follow the vote recommendations one receives, wrongly informed voters may get too much weight in the vote. Then, the voting outcome is less efficient than it would have been in the absence of pre-vote communication. We show that this result is robust: It even holds true if the number of informed voters goes to infinity.

We conducted two experiments to test our theoretical predictions. The laboratory data validate the comparative statics of our theory and reveal that in the lab, too, truthful communication sometimes impedes efficient information aggregation.

To better understand when pre-vote communication can be harmful and when it is harmless, consider communication networks in which imperfectly informed voters give vote rec-

[1] Under general conditions, it has been shown that *public* communication leads to efficient information aggregation due to deliberation of private signals (Gerardi and Yariv, 2007, and Goeree and Yariv, 2011). However, pre-vote communication need not be public, but can also be – at least partly – *private*, as illustrated by the examples above. To our knowledge, the effects of private pre-vote communication have been only addressed in the contribution of Golub and Jackson (2012). In a setting of naïve learning among non-strategic voters, they show that private communication in homophilous networks can undermine efficient information aggregation in the intermediate term. Outside the literature on information aggregation, Agranov et al. (2017) and Palfrey and Pogorelskiy (2017) study public and private pre-vote communication. In their settings, communication reveals information on preferences or intentions to turnout, which affects actual turnout.

ommendations to their neighbors. Such a communication stage is introduced into a standard common-interest voting game. Nature draws the binary state of the world and the signals that voters receive on the true state. Both states of the world are equally likely. Each informed voter receives only one signal, and signals are independent across voters. Some voters have audiences of one or more other voters and can send one out of two possible messages to their audience or keep silent. Then, a vote takes place to decide which of two possible policies shall be implemented. Only the policy matching the true state of the world generates a strictly positive payoff for all individuals (the other policy generates a zero payoff for everyone). Voters individually and simultaneously decide between voting for one or the other policy and abstaining. Voting is costless.[2] The policy that gets a simple majority of votes is implemented. In case the voting outcome is a tie, the policy to be implemented is randomly drawn, where both policies have equal probability. Voters are *strategic*; i.e., they condition their behavior on pivotality.

A focal stragegy in this setting is to truthfully transmit one's own signal to one's neighbours in the social network and to vote according to one's updated belief about the "correct" policy. We call this strategy *sincere* behavior and investigate when it is an equilibrium and when efficient. Consider an informed voter whose audience – consisting of her neighbors – is a substantial part of the voting population and follows (only) her vote recommendation; i.e., this voter is an opinion leader. Being pivotal with a vote that follows the opinion leader's recommendation implies that many voters from the rest of the population voted for the opposite, which implies, in turn, that they had information contradicting the opinion leader's recommendation. Hence, conditioning on pivotality, it is more likely that the vote recommendation of the opinion leader is wrong rather than correct. More generally, in highly *unbalanced* networks in which the power to influence opinions is insufficiently justified by the expertise of the opinion leaders, sincere behavior is neither informationally efficient nor equilibrium behavior. However, we state as a main result that for mildly *unbalanced* communication networks sincere behavior is both an equilibrium and informationally inefficient; and neither existence nor inefficiency vanish in the limit.

An important feature of our model is that the exogenously given network structure only determines the system of communication channels that can potentially be used, while there is always an equilibrium without communication. Indeed, there is an alternative focal strategy: Voters who are better informed than others vote for the policy indicated by their signal and the others abstain. In line with the literature, we call this strategy "*let the experts decide*" (henceforth: LTED). Importantly, we show that LTED is always efficient in the limit, i.e., if the number of voters converge to infinity, independent of the network structure. Hence, in a class of mildly *unbalanced* networks the problem of efficiency becomes one of equilibrium selection between sincere behavior and LTED, which is essentially an empirical question.

Testing our theoretical predictions in two lab experiments, we find that (i) individually, uninformed voters are indeed more inclined to abstain when they listen to an overly powerful

[2] With costs of voting, the pivot probability which might change across equilibria in different networks would affect the willingness to abstain. Since we want to isolate the effects of communication on voting behavior, we abstract from voting costs. In the lab, costless voting makes the "willingness to delegate to the expert" harder to find and hence more surprising.

opinion leader, that (ii) collectively, LTED is more often chosen over sincere behavior if the network becomes more *unbalanced*, but that (iii) sincere behavior still occurs frequently even in highly unbalanced networks, causing a loss in efficiency, compared to more balanced networks. (iv) Informed voters tend to pass on their signals to their audience whenever they feel well informed but become more reluctant to do so when they are in the position of an overly powerful opinion leader *and* feel not too well informed.

In the experiments, the loss in informational efficiency is the larger, the more unbalanced the communication network becomes. Intuitively, the more unbalanced the network structure, the less balanced is the power to influence opinions such that the final outcome is determined by the messages of a few agents, in contrast to the Marquis de Condorcet's original idea of aggregating information in the entire collective (De Caritat, 1785).

Related literature. Condorcet's argument that majority voting among independently informed voters efficiently aggregates private signals, i.e., his "Jury Theorem," is a cornerstone of the justification of the majority rule, and, even more generally, of making collective decisions by voting. His argument has been seriously challenged by Austen-Smith and Banks (1996) and Feddersen and Pesendorfer (1996, 1997, 1998) who study voters as strategic actors. As they show, to vote in line with one's private information, i.e., to "sincerely" cast the vote for the alternative that maximizes unconditional expected utility, is not automatically an optimal decision. When restricting attention to the cases in which one's own vote is decisive, the resulting conditional expected utility may be different. Hence, we assume strategic voting when solving our model, but also address the question when sincere and strategic voting lead to the same behavior.

In the absence of communication, Feddersen and Pesendorfer (1996) find that it is optimal for rational voters with common interests to abstain if they are uninformed and to vote in line with their independent private signal if they are informed.[3,4] This LTED behavior not only forms an equilibrium, but also exhibits informational efficiency. In their experimental study of the model of Feddersen and Pesendorfer (1996), Battaglini et al. (2010) find that this equilibrium provides a good prediction for real behavior. Morton and Tyran (2011) have extended the model of Feddersen and Pesendorfer (1996) to include heterogeneity in information quality among the informed voters and find that less well informed voters generally tend to abstain and delegate the collective decision to the better informed voters. Hence, the tendency to "delegate to the expert" seems quite strong in the lab. This suggests that the LTED equilibrium might be a good prediction even in more general models of information aggregation by majority votes. Accordingly, we consider it to be a benchmark equilibrium in our model, too.

[3]Since Feddersen's and Pesendorfer's ingenious contribution, the finding that uninformed voters in a common interest setting are better off abstaining from the vote has been dubbed the swing voter's curse. More generally, a voter is "cursed" if his optimal strategy conditional on his pivotality differs from what he would deem optimal if he did not condition his strategy on being pivotal, i.e., what he would choose as a dictator. We adopt this way of speaking.

[4]If one deviates from the assumption of common interests by introducing a number of "partisans" who always vote into a pre-specified direction, then abstention does no longer need to be the optimal strategy of the uninformed voters.

However, the selection of this equilibrium hinges on the assumption that all participating voters enter the majority vote with *independent private* pieces of information – which is fulfilled in the standard model of common interest voting.[5] But the picture becomes more complicated when a mechanism is introduced that leads to *correlated* information among voters, despite their private independent signals. To our knowledge, the existing literature on common interest voting has considered two such mechanisms: Public communication (deliberation), and additional public signals.[6] Coughlan (2000) and Austen-Smith and Feddersen (2006) find that deliberation under the majority rule fosters efficiency. Gerardi and Yariv (2007) show that introducing public communication prior to the vote admits the same set of (sequential) equilibria for a whole set of voting rules. Intuitively, the information aggregation that the vote has to achieve in the standard model is shifted up the game tree and is now obtained in the communication stage already. Goeree and Yariv (2011) validate this insight experimentally and document that public communication fosters informational efficiency under general conditions. By contrast, introducing a public signal on the state of the world prior to the vote changes the picture dramatically. Kawamura and Vlaseros (2016) find that the presence of a public signal generates a new class of equilibria in which voters discard their private information in favor of the public signal and information aggregation is inefficient, *even if* voters condition their strategy on their pivotality.[7]

We introduce a third way of correlating voters' information into the standard model of common interest voting: private communication between voters. To our knowledge, private communication before voting has so far only been modeled as naïve exchange among voters who do not condition on pivotality (Golub and Jackson, 2012).[8] In contrast, we study strategic voters who are Bayesian learners. We show that the way in which private communication affects information aggregation is different from the effects of public communication: Although efficient equilibria always exist (in particular, the LTED equilibrium), there are also equilibria (in particular, the sincere equilibrium) in which information is inefficiently aggregated. The latter equilibria and their corresponding "sincere" strategies are more frequently played in the lab than the former such that private communication indeed undermines informational efficiency if some voters are too powerful communicators. Our general model

[5] Levy and Razin (2015) provide a model on informed voting which includes heterogeneous preferences among voters, different sources of information for each voter and voters who neglect the correlation between their information sources. They show that correlation neglect may improve the informational efficiency of the vote since it makes voters put more weight on information than on the conflict of interest.

[6] In a recent theory paper, Battaglini (2016) allows for communication between citizens in separate audiences so that information becomes correlated among the citizens in one audience. However, in his model, citizens cannot vote on policies directly but coordinate on public protest instead, potentially signing a petition against the policy maker's default policy. Battaglini shows that communication in social media can improve information aggregation and transmission via public protests.

[7] Somewhat relatedly, the literature on hidden profiles reports that in group discussions prior to group decisions, information shared with other group members gets too much weight compared to unique private information. See, e.g., the meta-study by Lu et al. (2012).

[8] For a society of naïve learners, it is known that information aggregation is inefficient in the long term when some agents are overly powerful (Golub and Jackson, 2010). In their application of the homophily theory to voting, Golub and Jackson (2012) assume that every voter has the same expected number of links and is hence equally influential. Then information aggregation is efficient in the limit, but not necessarily in the intermediate term: They show that inefficiency can arise, when there are multiple groups with more links within group than across groups (i.e. homophily) and when the signals are not distributed equally across groups.

incorporates both private communication and public communication as a special case, and hence builds a bridge between the two.

Organization of the paper. The remainder of the paper is organized as follows: In the next section, we introduce a simple model of vote recommendations, restricting our analysis to a specific subset of communication networks and to homogeneous signal qualities. We characterize conditions on the network structure under which the two focal strategy profiles, i.e., sincere behavior and LTED, are equilibria and compare them to the conditions under which they are efficient. In section 3, we present the design of the laboratory experiments and in section 4, we report the experimental results. In section 5, we conclude. In Appendix A.1, we study the general model with arbitrary networks and heterogeneous signal precisions. We report that our main results are robust in the general model and also hold true in the limit. All propositions of section 2 are generalized and proven in their general version in Appendix A.1. We provide supplementary mathematical results in online Appendix B and supplementary experimental material including the instructions in online Appendix C.

2 A Simple Model of Vote Recommendations

2.1 Set-Up

Nature draws one state of the world, ω, which has two possible realizations, A and B, that occur with equal probability and are not directly observable. There is a finite set of agents partitioned into a group of *experts* M and a group of *non-experts* N. Experts $j \in M$ receive a private independent signal $s_j \in \{A^*, B^*\}$ about the true state of the world. The signal is imperfectly informative with quality $p_j = \Pr\{s_j = A^* \mid \omega = A\} = \Pr\{s_j = B^* \mid \omega = B\} \in \left(\frac{1}{2}, 1\right)$. We preliminarily assume that $p_i = p \; \forall j \in M$ and that non-experts $i \in N$ do not receive a signal, but can potentially receive a message from an expert. A graph g represents the communication structure between non-experts and experts. We preliminarily assume that g is bipartite, consisting of links $(i, j) \subseteq N \times M$ only. Degree d_i is the number of links of agent i. An expert j with $d_j \geq 1$ is called sender and all non-experts linked to j are called the "audience of j." Our final preliminary assumption is that different audiences do not overlap, i.e., the degree of each non-expert is at most one, such that no agent can access more than one piece of information.[9] We will drop our preliminary assumptions in section 4.

After receiving the signal, each sender may send message "A" or message "B" or an empty message $\emptyset$ to her audience. Then, all agents participate in a majority vote the outcome of which determines which of two alternative policies, P_A or P_B, shall be implemented. Voters simultaneously vote for one of the two policies or abstain. If one policy obtains a simple majority, i.e. a plurality, of votes, it is implemented; otherwise, the policy to be chosen is randomly drawn with equal probability from the two alternatives.

[9]This assumption assures that information aggregation can only take place in the voting stage but not in the communication stage and hence is the natural counterpart to public communication and deliberation.

All experts and non-experts are assumed to be unbiased in the sense that they want the policy to match the state of the world. More precisely, their utility is represented by $u(P_A|A) = u(P_B|B) = 1$ and $u(P_B|A) = u(P_A|B) = 0$.[10,11]

The sequence of actions is as follows. First, nature draws the state of the world and the signals of the experts. Second, each sender decides which message to communicate to her audience, if any. Third, all agents vote or abstain and the outcome is determined by the simple majority rule. The full description of the game including the network structure is common knowledge.[12]

Strategies are defined as follows: A communication and voting strategy σ_j of a sender $j \in M$ defines which message to send and whether and how to vote for each signal received, i.e., $\sigma_j : \{A^*, B^*\} \to \{A, B, \emptyset\} \times \{A, B, \emptyset\}$ if $d_j \geq 1$ and $\sigma_j : \{A^*, B^*\} \to \{A, B, \emptyset\}$ if $d_j = 0$. We can abstract from the timing of these two actions (communication and voting) here. A voting strategy of a non-expert $i \in N$ with a link is a mapping from the set of messages into the voting action $\sigma_i : \{A, B, \emptyset\} \to \{A, B, \emptyset\}$, and a voting strategy of an agent $i \in N$ without a link is simply a voting action $\sigma_i \in \{A, B, \emptyset\}$. A strategy profile σ consists of all experts' and all non-experts' strategies.

We analyze this model using the concept of perfect Bayesian equilibrium, i.e., agents use sequentially rational strategies, given their beliefs, and beliefs are updated according to Bayes' rule whenever possible. We focus on two strategy profiles, one with information transmission ("sincere") and one without information transmission ("let the experts decide", in short: LTED). These are the two strategy profiles predominantly discussed in the literature on voting. Still, social networks generally give rise to a multiplicity of equilibria, and focality of strategies is ultimately an empirical question. We address this question in our laboratory experiments. It turns out that exactly the two strategy profiles that we focus on are the only relevant ones in the lab.

Note that if all non-experts in a given audience choose not to condition their voting action on the message received, then the outcome of the game is as if communication was not possible at all ("babbling equilibrium"). Similarly, if all non-experts in a given audience vote B if the message is A and vote A if the message is B, then the outcome of the game is as if their sender had chosen another communication strategy, where messages A and B are permuted ("mirror equilibria"). We will not differentiate between mirror equilibria, i.e., on the basis of the syntax of information transmission. Instead, we will identify equilibria via the semantics of information transmission, i.e., on the basis of the meanings that messages acquire in equilibrium.[13]

A desirable property of an equilibrium is *informational efficiency* which is defined as follows.

Definition 2.1. *A strategy profile σ is* ***efficient*** *if it maximizes the ex ante probability of*

[10]Here, we follow the convention to define cardinal utility levels, although this assumption is not necessary.

[11]An extended model with heterogeneous preferences, in particular with biased agents who always favor one of the two alternatives, is studied in online Appendix B.1.

[12]Knowing the network structure prevents potential inefficiencies due to imperfect information about the network structure.

[13]This is standard in the cheap talk literature starting with Crawford and Sobel (1982).

the implemented policy matching the true state of the world.

Observe that an efficient strategy profile σ maximizes the sum of ex ante expected utilities of all experts and non-experts since they are unbiased. Given efficient strategy profiles, the probability of matching the true state is maximized but not equal to one because it might always happen by chance that many experts receive the wrong signal. Letting the number of experts grow, this probability approaches one as in Condorcet's Jury Theorem. Observe also that in this simple setting an efficient strategy profile is characterized by always implementing the policy indicated by the signal that has been received by most experts, which we call the *majority signal*. For convenience, we let the number of experts $m := |M|$ be odd such that there is always a unique majority signal indicating the policy that *should* be implemented.[14]

While the definition of informational efficiency above is binary, strategy profiles can also be ranked according to their informational efficiency by comparing their corresponding ex ante probabilities of matching the true state.

Hereafter, we will slightly misuse notation by using "A" and "B" to denote the corresponding state of the world, message content, and policy, whenever the context prevents confusion.

2.2 "Let the Experts Decide"

One important feature of this simple model is that informational efficiency can always be obtained in equilibrium, regardless of the network structure. Consider for instance the strategy profile σ^* in which all experts vote in line with their signal and all non-experts abstain. Under the simple majority rule this LTED strategy profile σ^* is efficient since for any draw of nature the signal received by a majority of experts is implemented. Moreover, because preferences are homogeneous, efficient strategy profiles do not only maximize the sum of utilities, but also each individual agent's utility. Thus, there is no room for improvement, as already argued in McLennan (1998).

Proposition 2.1. *There exist efficient equilibria for any network structure. For instance, the LTED strategy profile σ^* is efficient and an equilibrium for any network structure.*

Importantly, while efficient strategies constitute an equilibrium, the reverse does not hold true: Existence of an equilibrium does not imply that it is efficient. On the contrary, there are (trivial and non-trivial) inefficient equilibria of the game. One non-trivial inefficient equilibrium will be discussed as Example 3 below.

Among the efficient equilibria, we consider the LTED equilibrium σ^* focal for two reasons. First, it is simple: All experts use the same type of strategy and all non-experts use the same type of strategy. Second, it is intuitive to abstain as a non-expert and to vote in line with one's signal as an expert, as already argued by, e.g., Feddersen and Pesendorfer (1996) and experimentally shown by Morton and Tyran (2011). However, since it is also intuitive for experts to send informative messages and for receivers to vote according to their messages, it may nonetheless be difficult to coordinate on σ^*. In particular, consider the strategy profile

[14] Admitting an even number of experts would not change the results qualitatively, but it would make the analysis cumbersome because more cases would have to be distinguished.

$\hat{\sigma}$ in which experts communicate and vote for the policy indicated by their signal and non-experts vote in line with their message and abstain if they did not receive any information. This strategy profile $\hat{\sigma}$ is *sincere* in the sense that each agent communicates and votes for the alternative that she considers as most likely given her private information.[15] We now proceed by investigating the sincere strategy profile.

2.3 Sincere Voting

Balanced networks. To characterize under which conditions on the network structure the sincere strategy profile $\hat{\sigma}$ is an equilibrium, we define two intimately related balancedness requirements. Both the content and the purpose of the following definition will be explained with the help of simple examples below.

Definition 2.2 (Balancedness). *(a) Let $M' \subset M$ denote the set of the $m' = \frac{m+1}{2}$ experts with the lowest degree.*[16] *A network is called* "strongly balanced" *if this set is involved in at least half of all links, i.e. $\sum_{j \in M'} d_j \geq \sum_{k \in M \setminus M'} d_k$.*

(b) For an expert $j \in M$, let $\mathcal{M}_j$ be the set of expert sets $M'' \subseteq M$ that contain expert j and form a slight majority when adding their audiences of non-experts, i.e. $\sum_{k \in M''}(d_k + 1) - \sum_{l \in M \setminus M''}(d_l + 1) \in \{0, 1, 2\}$. A network is called "weakly balanced " *if for every expert $j \in M$, non-emptiness of this set, i.e. $\mathcal{M}_j \neq \emptyset$, implies that there is at least one element consisting of a weak majority of experts, i.e. $\exists M'' \in \mathcal{M}_j$ such that $m'' \geq \frac{m+1}{2}$.*

To illustrate strong and weak balancedness, we use the following two examples.

Example 1. *Let $n = 4$, $m = 5$, and the degree distribution of experts $(d_1, d_2, d_3, d_4, d_5) = (1, 1, 1, 1, 0)$ as illustrated in the left panel of Figure 1. This network is strongly balanced since $d_3 + d_4 + d_5 \geq d_1 + d_2$; and it is weakly balanced since every slight majority of voters in which a given expert $j \in \{j_1, j_2, j_3, j_4, j_5\}$ partakes comprises a weak majority of experts, too.*

Example 2. *Let $n = 4$, $m = 5$, and the degree distribution of experts $(d_1, d_2, d_3, d_4, d_5) = (4, 0, 0, 0, 0)$ as illustrated in the right panel of Figure 1. This network violates weak balancedness. Indeed, $\mathcal{M}_1 = \{\{j_1\}\}$ such that there is no $M'' \in \mathcal{M}_1$ with $m'' \geq \frac{m+1}{2} = 3$. Put differently, expert 1 can partake in a slight majority of voters that contains only a minority of experts (himself).*

In general, strong balancedness requires that even the majority of experts with the smallest degrees, which is called M' in the definition, is involved in at least half of all links. This simply means that *every* majority of experts is involved in at least half of all links, which requires a rather even degree distribution. Weak balancedness restricts a related requirement

[15] The LTED strategy profile σ^*, in contrast, is not "fully sincere" for the following reason. The aspect that information is not transmitted either means that senders do not communicate their signal or that receivers do not follow their message.

[16] If there are several of these sets, we can choose any one. If m was even, we would require $m' = \frac{m+2}{2}$ in this definition.

to certain sets of experts $\mathcal{M}_j$. Indeed, strong balancedness always *implies* weak balancedness (since it implies for all j and all $M'' \in \mathcal{M}_j$ that $m'' \geq \frac{m+1}{2}$). Networks violating weak balancedness also violate strong balancedness and will be called *unbalanced* hereafter.

The two properties capture some kind of balance between a group's *expertise* (which depends on the number of signals) and its *power* (which depends on the size of the audiences). For instance, in Example 1, experts are equally powerful, whereas in Example 2, expert 1 is overly powerful, compared to the other experts.[17]

Proposition 2.2. *The sincere strategy profile $\hat{\sigma}$ is* efficient *if and only if the network is strongly balanced. The sincere strategy profile $\hat{\sigma}$ is an equilibrium* if *(a) the network is strongly balanced, and* only if *(b) the network is weakly balanced.*

Applied to our two examples, Proposition 2.2 implies that the sincere strategy profile $\hat{\sigma}$ is efficient and an equilibrium in Example 1 but neither efficient nor an equilibrium in Example 2. The intuition of Proposition 2.2 can be illustrated with these two examples.[18]

Consider first strong balancedness in Example 1. Observe that under the sincere strategy profile $\hat{\sigma}$ any three experts who vote and communicate the same alternative determine the final outcome. Thus, for any draw of nature the policy indicated by the majority signal is implemented, which means that information is aggregated efficiently and hence $\hat{\sigma}$ is an equilibrium. Likewise, in any strongly balanced network the majority signal receives a majority of votes since the set of experts who have received this signal has a majority of votes when considering their own votes and the votes of their audiences.

Consider now weak balancedness, which is violated in Example 2. To see why $\hat{\sigma}$ is inefficient in Example 2, consider a draw of nature by which the most powerful expert, i.e., the expert j_1 with the highest degree, receives the minority signal. Assume now, for the sake of argument, that the sincere strategy profile $\hat{\sigma}$ is played. In this case the minority signal determines which policy is implemented; information is hence aggregated inefficiently. To see why $\hat{\sigma}$ is not an equilibrium, consider the following two deviation incentives. First, the most powerful expert would want to deviate to not communicating, but still voting for, the policy indicated by her signal. This would lead to an efficient strategy profile that is outcome-equivalent to LTED since the non-experts then abstain. Second, the non-experts, too, can improve by deviating. In particular, consider a non-expert receiving message A. His posterior belief that A is true is $p_i(A|A) = p > \frac{1}{2}$. However, his posterior belief that A is true, given that he is pivotal, is $p_i(A|A, piv) < \frac{1}{2}$ because in this simple example pivotality only occurs when all other experts have received signal B^*. Thus, abstention or voting the opposite of the message is a strict improvement for any non-expert.

Example 2 provides a simple illustration of the swing voter's curse. The argument, however, is much more general. Assume that all agents play according to the sincere strategy profile $\hat{\sigma}$ and consider the receivers who belong to a large audience. These receivers know

[17] A formal definition of power is given in online Appendix B.5. It relies on the cooperative framework of simple games, in which individual power is measured by the Shapley-Shubik index or the Banzhaf index, which both count the number of "swings" a voter has (cf., e.g., Roth, 1988).

[18] Note that Proposition 2.2 provides one sufficient and one necessary condition for the sincere strategy profile $\hat{\sigma}$ to be an equilibrium, but no condition that is both sufficient and necessary. For such a condition see Proposition B.4 in online Appendix B.2.

Figure 1

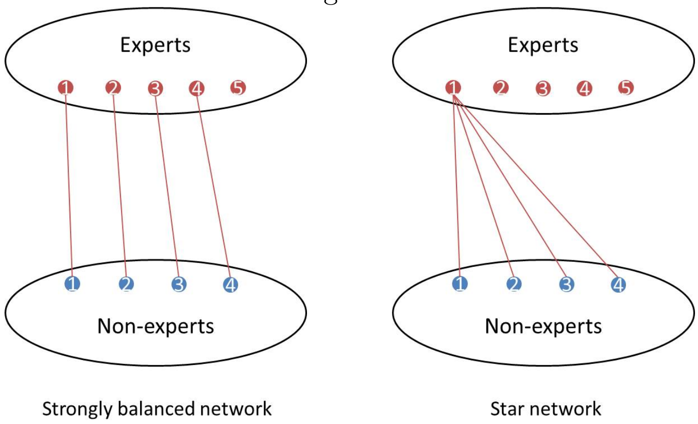


Figure 1: Left: Example 1, which is a network satisfying strong balancedness. Right: Example 2, the star network, which is an unbalanced network.

that their sender is very powerful. Hence, if they are pivotal in the vote, this implies that a considerable number among the other experts must have got a signal that contradicts the message they received. Thus, if following the message has any effect on the outcome, it has most likely a detrimental effect. If a receiver realizes that he is "cursed" in this sense, he wants to deviate from the *sincere* strategy and prefers to abstain or to vote the opposite.

Inefficient equilibria. For networks that satisfy the necessary condition (weak balancedness), but violate the sufficient condition (strong balancedness) the sincere strategy profile $\hat{\sigma}$ is inefficient but potentially still an equilibrium. More generally, the question arises whether there are equilibria with information transmission prior to the vote that are inefficient.

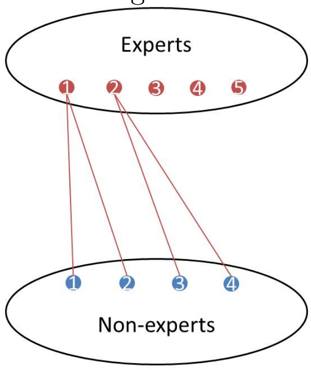
Proposition 2.3. *There are networks in which the sincere strategy profile $\hat{\sigma}$ is both an equilibrium and exhibits informational inefficiency.*

One example demonstrating the above proposition is given below.

Example 3 (weakly balanced)**.** *Let $n = 4$, $m = 5$, and the degree distribution of experts $(d_1, ..., d_5) = (2, 2, 0, 0, 0)$ as illustrated in Figure 2. In this network the sincere strategy profile $\hat{\sigma}$ is inefficient because the network violates strong balancedness. However, the sincere strategy profile $\hat{\sigma}$ is an equilibrium in this network (see proof of Proposition A.3 in Appendix A.1).*

Overall, we can conclude that communication need not, but can impair information aggregation in equilibrium, depending on the balancedness of the network structure. In strongly balanced networks (such as in Example 1), $\hat{\sigma}$ is both efficient and an equilibrium. In weakly balanced networks that are no longer strongly balanced (such as in Example 3), $\hat{\sigma}$ can still be an equilibrium, but is always informationally inefficient. Finally, in unbalanced networks (such as in Example 2) neither property holds. There the swing voter's curse occurs such that non-experts can profitably deviate from $\hat{\sigma}$ by not following their message.

Figure 2



Weakly balanced network

Figure 2: Example 3, a network in which the sincere strategy profile $\hat{\sigma}$ is both inefficient and an equilibrium.

2.4 Robustness in General Model and in the Limit

In Appendix A.1, we generalize the above model in two ways. First, we assume that every agent i receives a signal with idiosyncratic signal quality $p_i \in [\frac{1}{2}, 1)$. Second, we admit arbitrary network structures. Hence, agents can receive multiple messages. We show in the appendix that our theoretical results (Propositions 2.1-2.3) are robust in the following sense.

In all networks, there exists a LTED equilibrium (with "expert" re-defined as an agent with a signal quality above an arbitrary cut-off that leads to an odd number of experts). We provide a sufficient and necessary condition under which it is efficient and show that, even if this condition is not fulfilled, the LTED equilibrium is asymptotically efficient if the size of the electorate goes to infinity (Proposition A.1). We generalize the definition of the sincere strategy profile (voters report their signal to their neighborhood, update their beliefs according to Bayes' rule, and vote for the policy that is more likely to be optimal, given their updated beliefs). We also generalize the definitions of strong and weak balancedness and re-state our result that the sincere strategy profile is an equilibrium if the network is strongly balanced and only if it is weakly balanced (Proposition A.2). We then demonstrate our main general result which states that the inefficiency of (some) sincere-strategy equilibria subsists in the limit (Proposition A.3).

2.5 Equilibrium Selection

Whether real people, both individually and collectively, account for the swing voter's curse in unbalanced networks is an empirical question. Therefore, it may be helpful to bring the theory to the lab and find out how experimental subjects play the game in various networks that differ in the balancedness of their degree distribution. Hence, one purpose of the laboratory experiment is to test the comparative-statics of our theory. The other, equally important, purpose is to empirically study equilibrium selection. In particular, in the case of weakly balanced networks that are not strongly balanced the quality of information aggregation depends on whether the agents manage to coordinate on the efficient LTED equilibrium or whether they coordinate on the inefficient sincere equilibrium, or on other potential equilibria. This question is hard to answer theoretically, since both the LTED strategy profile σ^* and the sincere strategy profile $\hat{\sigma}$ are intuitive and seem focal.

To theoretically prepare experimental equilibrium selection, we address the question of additional, non-focal equilibria. We extend the equilibrium analysis of our Examples 1, 2, and 3, which is particularly useful since these examples are also implemented in our experiment. In online Appendix B.3, we give a full characterization of all equilibria conforming to four selection criteria (Purity, Symmetry, Monotonicity, and Neutrality). It shows that one more strategy than considered so far contributes to equilibrium formation, namely a *delegation* strategy according to which experts with an audience delegate their vote to their audience by revealing their signal and abstaining themselves. Moreover, there are equilibria in which experts who are never pivotal abstain from voting without delegating their vote. However, there are no additional strategies that arise as composites of equilibria in these examples. All equilibria conforming to our selection criteria are composites of the LTED strategy profile, the sincere voting profile, and the delegation or abstention strategies of experts. Which of these equilibria are indeed focal will be assessed by the empirical frequency with which each of them is played in the laboratory experiments.

3 Experimental Design

We conducted two experimental studies. In Study I, we implement the empty network, in which communication is precluded, and the three examples – Example 1, 2, and 3 – analyzed above. The empty network serves as a benchmark, since the sincere strategy profile $\hat{\sigma}$ is impossible to play in the empty network because there are no communication channels. Hence, the LTED equilibrium is the only focal equilibrium in the empty network. The other three networks differ in the way described in section 2.3. Hence, Study I directly tests our simple model.

In Study II, we again implement the empty network as a baseline, but add three other examples in order to study different network structures. Moreover, Study II tests a version of our model which includes some biased senders. The consequences for equilibrium analysis are negligible (as we show in online Appendix B.1), but behaviorally the presence of biased agents may make a difference. The four networks differ in the following respects: Network 1 is the *empty network*. Network 2 is the *weakly balanced network* and is the unique network among the four in which the sincere strategy profile $\hat{\sigma}$ is both an equilibrium and inefficient, as demonstrated in the proof of Proposition B.3 in online Appendix A.1. Network 3, which we call the *unbalanced network*, makes sender 1 too powerful compared to the other sender, and the strategy profile $\hat{\sigma}$, which is again inefficient, is no longer an equilibrium, though possible to play. The same holds true for network 4, the *star network*, which is even more unbalanced.

In total, our experimental design implements the eight different communication networks depicted in Figure 3. Each of these networks corresponds to one experimental treatment; and within each study, treatments are varied within subjects (i.e., all participants in a given session of one study play the communication and voting game in all four networks) in random order. Voter groups – i.e., subject groups interacting in one network – consist of five experts and four non-experts in Study I and of three experts, four computerized partisans, and four non-experts in Study II. The four partisans divide into two A-partisans who always communicate and vote A and two B-partisans who always communicate and vote B. In online Appendix B.1, we provide a full description of the model with partisans and show that, unsurprisingly, all theoretical results obtained for the model without partisans (Propositions 2.1-2.3) carry over (Propositions B.1-B.3).

Comparing the networks in Study I with those in Study II, we can summarize that both studies implement the empty network (in which information transmission is precluded), a weakly balanced network (in which $\hat{\sigma}$ is an equilibrium), and the star network (in which $\hat{\sigma}$ is not an equilibrium).[19] While Study I accompanies the weakly balanced network with a strongly balanced network to have an example in which $\hat{\sigma}$ is efficient, Study II accompanies the star network with an unbalanced network that features different sender degrees within one treatment. Apart from the baseline treatment, the empty network, the density of the networks is held constant while the equality of the degree distribution is decreasing. Moreover, the *expected* probability of a message being true in the sincere strategy profile, given that the receiver in Study I knows that he listens to an expert, while the receiver in Study II does not know whether he listens to a partisan or an expert, is approximately equal and hence comparable in both studies.

The experiments were conducted in the WISO-lab of the University of Hamburg in November 2014 and August and September 2015, using the software z-Tree. We ran seven sessions within Study I and five sessions within Study II with $3*9 = 27$, respectively $4*7 = 28$, participants in each session. All subjects in a session played the game described above in all four networks over 40 rounds in total. For the recruitment of a total of 329 subjects, we used the software tool *hroot* (Bock et al., 2014). Virtually all subjects were undergraduate or master students at the University of Hamburg from a variety of fields. None of them had previously participated in a related experiment. At the beginning of each session, subjects randomly received the role of an expert or the role of a non-expert. These roles were fixed throughout the experiment. In each round, subjects were randomly matched into groups of nine in Study I and groups of seven in Study II. At the end of each round, the participants learned the chosen policy, the true state, and the voter turnout in their group. Groups were newly formed each round by random re-matching. Each network game was played in ten rounds in total, but the order of networks across rounds was randomized. Instructions that described the experimental session in detail were handed out at the beginning of each session and were followed by a short quiz that tested the subjects' understanding of the game.[20] Hence, the experiment started only after each subject understood the rules of the game. Moreover, there were four practicing rounds, one for each treatment, that were not payout relevant. During the entire session, each subject always knew his own network position and the structure of the network. The quality of the signal that the experts received was $p = 0.6$ in Study I and $p = 0.8$ in Study II which guaranteed that the expected probability of

[19]Note that the second network in Study I and the second network in Study II look quite similar, but are essentially different: The former is strongly balanced, the latter only weakly balanced.

[20]The instructions and the quiz can be found in online Appendix C.3.

Figure 3

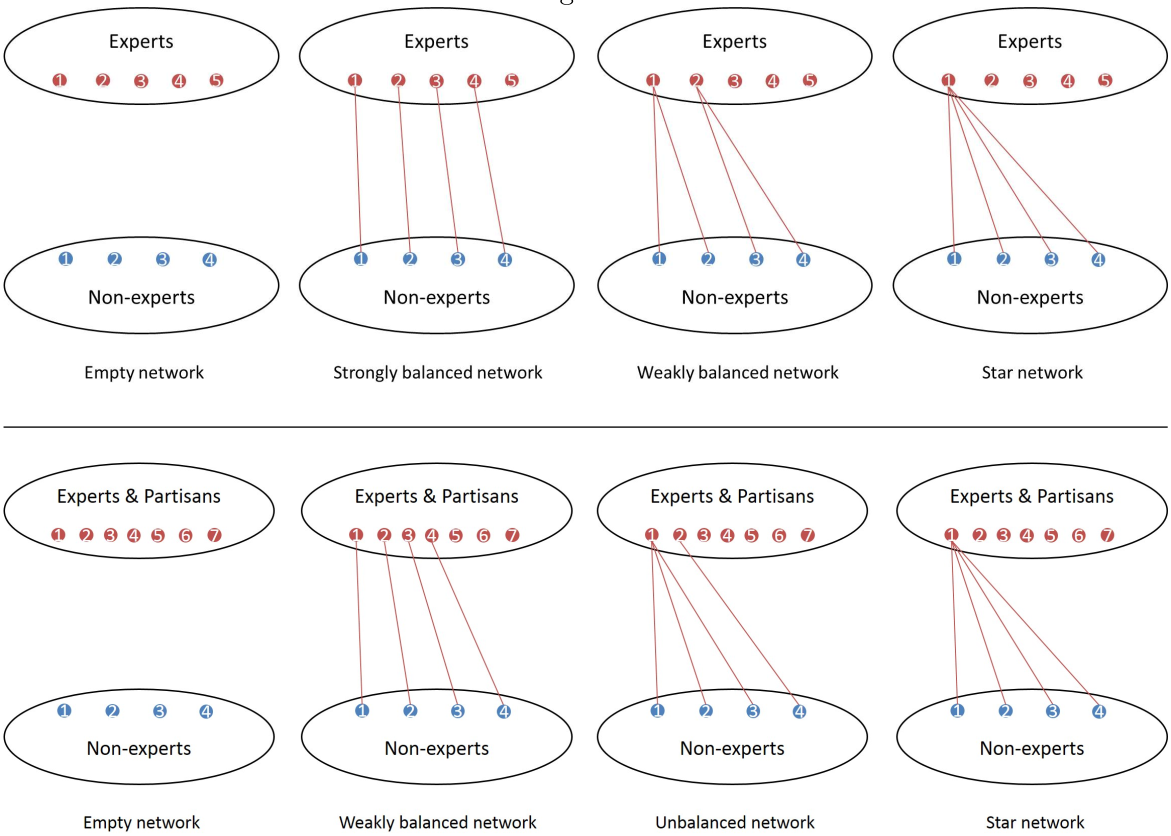


Figure 3: Upper panel: The four treatments of the Study I. Lower panel: The four treatments of the Study II.

a non-empty message being true under the sincere strategy profile was approximately equal across both studies. At the end of each session, three rounds were randomly drawn and payed out in cash and in private. On average, sessions in Study I and Study II lasted for 1.5 hours and subjects earned EUR 14.3 and EUR 16.7 on average, respectively.[21]

4 Experimental Results

Table 1 in Appendix A.2 gives a summary of the number of observations. On the group level we have 840 and 800 observations in Study I and Study II, respectively. On the individual level we have 7,560 (5,600) observations in Study I (II) with 40 decisions per subject. In total, 189 (Study I) and 140 subjects (Study II) participated in the experiments.

Pooling all treatments, experts vote for the signal they received 84% and 92% of all times in Study I and II, respectively. If they have an audience they also communicate their signal 75% and 90% of all times. Those who do not communicate their signal usually send an empty message. Non-experts vote in line with their received message on average 69% and 57% of all times. Those who receive a non-empty message but do not follow it usually abstain. Abstention is also the most common behavior of non-experts who did not receive a message. After analyzing individual behavior in section 4.1, we will turn to the question of equilibrium selection in section 4.2. We will address efficiency in section 4.3. The experimental results

[21]The norm in the WISO-lab at the University of Hamburg was EUR 10 per hour.

Figure 4

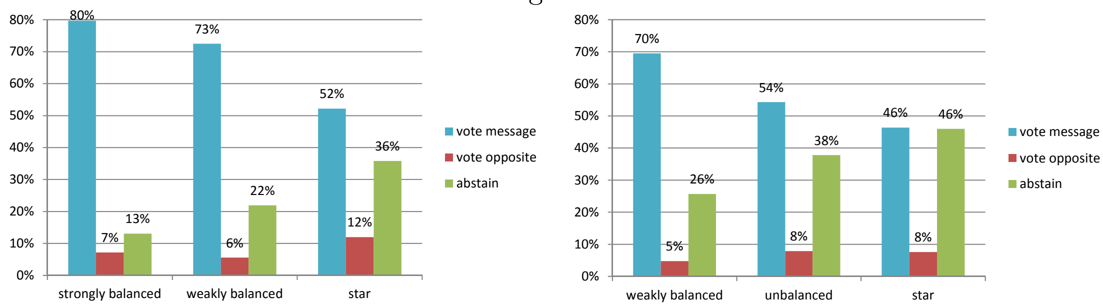


Figure 4: Frequency of non-experts' following behavior by treatment. Vote message means to vote A (B) when the message received is A (B). Vote opposite means to vote A (B) when the message received is B (A). Displayed are responses to non-empty messages. The left panel displays results for Study I. The right panel displays results for Study II. Differences between the (strongly and weakly) balanced networks and the unbalanced networks (i.e. the star network and the unbalanced network) are significant on the $p < 0.01$ level (cf. Table 3).

are illustrated in the main text by figures. The tables underlying the experimental results are collected in Appendix A.2 (and online Appendix C.1).

4.1 Individual Behavior Across Networks

First, we analyze under which conditions on the network structure non-experts who receive a vote recommendation follow it, i.e., whether laboratory participants account for our novel form of the "swing voter's curse." Second, we investigate communication behavior of experts, i.e., when participants pass on their signal to their audience.

Following of vote recommendations. Non-experts in our experiments receive vote recommendations. Apart from the empty treatments, every non-expert is linked to an expert sender, who in most cases sends a non-empty message. The equilibrium analysis of our model showed that the vote recommendation of an expert should only be followed if this expert is not "too powerful" (in terms of audience size). More precisely, the sincere strategy profile $\hat{\sigma}$ in which all non-experts follow their messages is an equilibrium in the strongly and weakly balanced networks of our experiments, but not in the unbalanced network and the star network (which is also unbalanced). As displayed in Figure 4 (and in Table 2 in column 'vote message'), in around 70% to 80% of the cases non-experts vote according to their received message in the balanced networks where the sincere strategy profile is an equilibrium, but they do so only in around 50% of the cases in the unbalanced networks such as the star. These differences are significant on the $p < 0.01$ level as can be seen from the logistic regressions in Table 3, which take the weakly balanced networks as the baseline category.[22] This holds independent of whether we restrict attention to non-experts who received a non-empty message or whether we also consider abstaining in the case of an empty message as "following."

To get more detailed evidence on when non-experts follow their vote recommendations,

[22]We always use robust standard errors clustered by the sessions. All results would also hold when clustering standard errors by subject (as reported in an earlier working paper version).

Figure 5

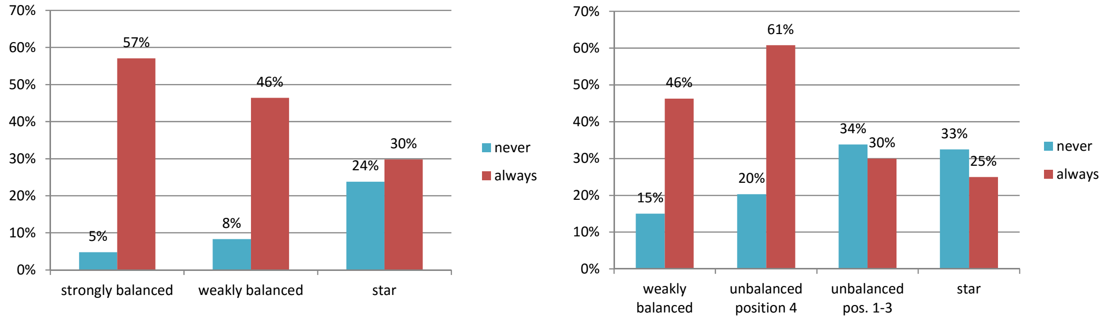


Figure 5: Frequency of individual following behavior by treatment (and position). The variable 'never', respectively 'always,' reports the fraction of individual participants who never respectively always followed the non-empty vote recommendation they received for each network position. The left panel displays results for Study I. The right panel displays results for Study II. Differences between the (strongly and weakly) balanced networks and the star network are significant on the $p < 0.01$ level (cf. Table 4). Difference within the unbalanced network between position 4 (sender has degree one) and positions 1-3 (sender has degree three) are significant on the $p < 0.01$ level (cf. Table 4b).

we move on to heterogeneity among individual participants. Figure 5 shows how many of the non-experts never and how many always followed their message in a given position. As many as 57%, respectively 46%, of the non-experts always follow their message when they are in the strongly balanced network, respectively the weakly balanced network. For the star network this number reduces to 30% (25%) in Study I (II), which is significant on the $p < 0.01$ level (as it can be seen from the last column in Table 4). This result strongly suggests that non-experts react to the relative degree of their sender, as predicted by theory.

To further test this hypothesis, it is useful to observe how the network *position* affects behavior of the non-experts on top of the network type. We do so by concentrating on the unbalanced network of Study II in which the degree varies across senders. In this network, non-experts in positions 1-3 are linked to a sender with degree three such that following her message is not a best response to the sincere strategy profile $\hat{\sigma}$. By contrast, the non-expert in position 4 who is linked to the sender with degree one should best respond to $\hat{\sigma}$ by following his message. As can also be seen from Figure 5, 61% of the subjects always follow their message when they listen to the sender with degree one, while only 30% do so when linked to the sender with degree three. Differences in individual behavior across positions are tested with Wilcoxon signed-ranks tests, which are reported in Table 4. When the sender has degree three or four (i.e., in the star network and in the unbalanced network in positions 1-3) the non-experts' following behavior is different from their behavior in all other network positions ($p < 0.01$). When including situations in which individual participants receive an empty message (lower block of Table 4), the same picture arises ($p < 0.05$). Hence, the sender's (relative) degree has a strong influence on following: a substantial fraction of individuals never follows the vote recommendation of too influential senders. However, another substantial fraction always follows.

Non-experts who do not follow a message mostly abstain, as can be seen in Figure 4. Thus, the flipside of a significant decrease in followers is a significant increase in abstentions for the unbalanced networks.

Figure 6

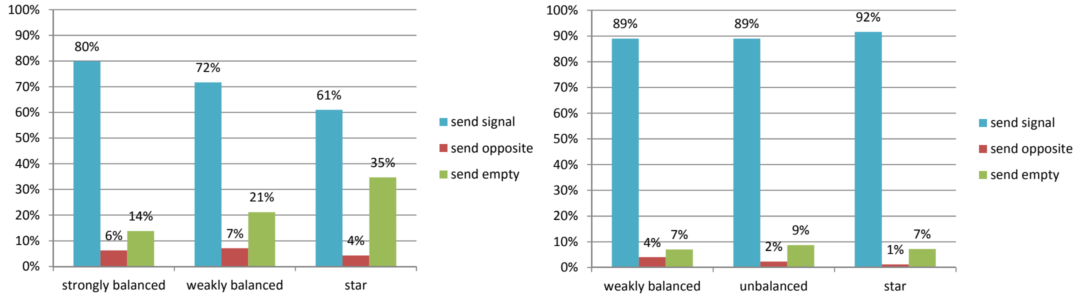


Figure 6: Frequency of experts' communication behavior by treatment. Send signal means to send message A (B) when the signal received is A^* (B^*). Send opposite means to send message A (B) when the signal received is B^* (A^*). The left panel shows results for Study I. The right panel shows results for Study II. Differences are significant on the $p < 0.05$ level in Study I (cf. Table 6a), but not significant in Study II (cf. Table 6b).

Result 1. *Non-experts follow their vote recommendation significantly more often in the (strongly and weakly) balanced networks than in the unbalanced networks (i.e., the star and the unbalanced network). Within a given unbalanced network, non-experts linked to the sender with the highest degree follow significantly less often than non-experts linked to the sender with the lowest positive degree.*

Hence, non-experts behavior is in line with the predictions of our model. Besides, there is also a minority of subjects who follow independently of their sender's degree.[23]

Vote recommendations of experts. As mentioned earlier, around 80% of the time experts vote and communicate in accordance with their signal, which is playing the sincere strategy $\hat{\sigma}_j$ (Table 5). While experts vote in line with their signal in a large majority of cases, there are some deviations from the sincere strategy profile on the communication stage, as can be seen from Figure 6. Information transmission is lowest in Study I in the star network, where only 61% of the senders communicate their signal, whereas 35% choose the empty message. This is a significant difference in communication behavior ($p < 0.05$), as Table 6a reveals. Moreover, experts send a truthful message more frequently in the strongly balanced network than in the weakly balanced network ($p < 0.01$). These effects are not present in Study II (Table 6b).[24]

To further analyze whether experts condition their behavior on the network structure

[23]There are at least three possible explanations of their behavior. One is extreme correlation neglect (see, e.g., Enke and Zimmermann, 2018, and Levy and Razin, 2015): These non-experts might ignore the perfect correlation of a message received by several members of an expert's audience, instead treating it as an independent signal. The second possible explanation is overconfidence in the truth of the signal of one's own sender (see, e.g., Ortoleva and Snowberg, 2015). The third is what one might call "pivotality neglect", i.e., the inability to condition on hypothetical events such as pivotality (see Esponda and Vespa, 2014). Obviously, also a combination of biases might explain the amount of naïve following. For instance, if a non-expert linked to the center of the star in Study I believes that all other voters randomize and that he himself is likely to be pivotal, his optimal response is indeed to vote along with the message he received (see Dittmann et al., 2014 for a combination of illusion of control, overconfidence, and overestimation of others' errors explaining excess turnout). Since our focus in this paper is not on disentangling biases that lead to irrational voting, we leave a more precise explanation of this minority behavior to further research.

[24]The latter effect cannot be addressed by Study II since there is no treatment with a strongly balanced network. The former effect, i.e., the reluctance to send the signal in the star network, may vanish in Study II based on a behavioral reaction to the presence of partisans or to the higher signal quality.

and their position, we inspect heterogeneity among individual participants. Table C.1 (in the online Appendix C.1) reports the frequency of always and of never playing sincere for both only senders, i.e., experts with a link, and only non-senders. The results are mixed. In Study I, senders' behavior in the strongly balanced network differs from their behavior in the star and the weakly balanced networks ($p < 0.05$). Senders are more often sincere in the strongly balanced network, where this is a best response to the sincere behavior of all others, than in the (unbalanced) star network, where this is not a best response. In particular, around 32% of the senders in the star network never choose the sincere strategy profile in Study I. The fact that in 73% of these latter cases the sender's signal determines her vote and the empty message is chosen is an indication that these experts actively target the LTED equilibrium. Interestingly, this effect cannot be observed in Study II, in which partisans are present and in which signal quality of experts is higher. In Study II, experts are sincere in a large majority of cases and there are no systematic deviations from this strategy.[25]

Thus, although some experts seem to target the LTED equilibrium in the star network in Study I, most of the time experts play sincere, independent of the communication structure. Note that this does not necessarily imply that those experts never target the LTED equilibrium; it might also mean that the subjects in the role of the experts intentionally delegate equilibrium selection (or "strategy profile selection") to the non-experts.[26] As our experimental data reveal, it is indeed the non-experts who strongly condition their behavior on the network structure.

4.2 Equilibrium Selection

Our setting is prone to give rise to a multiplicity of equilibria. For the Examples 1-3, all equilibria that satisfy our four selection criteria (Purity, Symmetry, Monotonicity, and Neutrality) are reported in online Appendix B.3. In the strongly balanced network there are 19 different equilibria. In the weakly balanced and the star network, we have 9 and 5 different equilibria, respectively. (In the empty network there is only one.) In the equilibrium analysis of our model, however, we focused on two pure and symmetric strategy profiles that we consider focal, namely on the sincere profile $\hat{\sigma}$ and the LTED profile σ^*. Hence, the question arises how often these two strategy profiles are indeed played in the lab, both in general and depending on the network structure.

When checking how frequently actual behavior in a group is consistent with one of the existing equilibrium strategy profiles, it turns out that the empirical frequency of almost all of these equilibria is 0%: Out of the 840 observations on the group level, respectively out of the 210 group observations per treatment, they are not even played once. There are two equilibria which are frequently played, however: the sincere and the LTED.[27] Besides these

[25]The only difference in expert sincerity that is significant on the five percent level in Study II occurs when comparing the unbalanced network with the star network. This effect suggests that experts without a link less often vote in line with their signal in the unbalanced network than in the star network. Since both these networks are unbalanced, the sincere strategy profile is not an equilibrium in any of them and hence the effect is outside of what our theory addresses.

[26]Another reason might be lying aversion which is common in lab experiments. Not sending a message or sending a message that contradicts the own signal might "feel like" lying.

[27]Sometimes there is more than one equilibrium strategy profile that induces LTED.

Figure 7

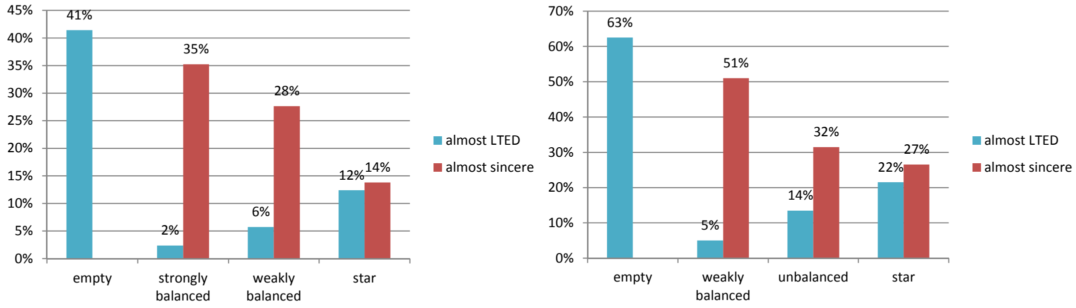


Figure 7: Frequency of behavior consistent with strategy profiles σ^* and $\hat{\sigma}$ by treatment. A strategy profile is "almost" played if at most one agent has chosen a different strategy. The left panel shows results for Study I. The right panel shows results for Study II. All differences – apart from the comparison between the strongly and weakly balanced networks and the unbalanced and star networks – are significant on the $p < 0.05$ level (Tables 8 and 9).

two focal equilibria there is only one more equilibrium that is actually ever played. This is an equilibrium in the strongly balanced network, which is highly similar to sincere behavior, but with the difference that one of the four non-experts abstains.[28] Hence, by focusing on the sincere strategy profile and the LTED strategy profile, we do not miss other relevant equilibria. Table 7 reports in the last column to which extent the two focal strategy profiles can predict the actual outcomes given the actual distribution of signals. In every treatment of both studies more than 80% of the actual outcomes are predicted by at least one of the two focal strategy profiles. This is another indication that the focus on the two focal equilibria is well justified by the data.

Finally, there could be additional equilibria involving mixed strategies. In our analysis of the experimental data we have not found any indication for the relevance of mixed strategies. When investigating an individual's behavior (such as in Figure 5 above or concerning uninformed voting) it turns out that many agents consistently choose the same action when they are in the same treatment.

It remains to investigate which of the two focal strategy profiles is played more frequently. Figure 7 and Table 7 show the frequency with which groups play either LTED σ^* or sincere $\hat{\sigma}$. We consider a group as *playing almost a strategy profile* if at most one of the nine, respectively seven, subjects has chosen a different strategy.[29] In the empty network, in which $\hat{\sigma}$ cannot be played, we find the highest level of coordination on σ^*. Considering the networks in which both profiles are possible to play, a decrease in network balancedness leads to a drop in the frequency with which groups coordinate (almost) on the sincere strategy profile $\hat{\sigma}$ and to a sizable increase in the frequency with which groups coordinate (almost) on the LTED strategy profile σ^*. Fisher exact tests reveal that – apart from the comparison between the strongly and weakly balanced networks in Study I and the unbalanced and star networks in Study II – these differences are significant on the $p < 0.05$ level (Tables 8 and 9).

Result 2. *In the (strongly and weakly) balanced networks, groups coordinate mostly on the sincere strategy profile* $\hat{\sigma}$*. With decreasing balancedness of the network, groups coordinate*

[28] In online Appendix B.3 this equilibrium is denoted by $v_1, r = 3$ and illustrated in Figure B.1, Panel (a).

[29] Recall that every group in Study I consists of nine real subjects, while every group in Study II consists of seven real subjects and four computerized partisans. The partisans play according to σ^* and $\hat{\sigma}$ by default.

less often on $\hat{\sigma}$ and more often on the LTED equilibrium σ^*. Coordination on σ^* is highest in the empty network. Equilibrium selection in favor of σ^* is mainly driven by non-experts who do not follow their message but also by some experts who send an empty message.

In sum, we find that the comparative-static predictions of the theory are well supported by our experimental findings.

4.3 Efficiency

Before we proceed to our results on the efficiency of information aggregation, a few remarks on uninformed voting are in order.

Uninformed voting. Non-experts who receive no message, either because they are in the empty network or because their sender chose the empty message, are uninformed. In most of these cases the uninformed non-experts abstain, but in a substantial fraction of around 30% of cases there is a vote by the uninformed non-experts, as can be seen from Table 2.[30] This behavior seems independent of the network structure. This observation is in line with the literature, since positive rates of uninformed voting are found in all experiments on common-interest voting. Since uninformed votes are no better than flips of a coin, they have detrimental effects on informational efficiency, well documented in the literature.[31] In our experiment, it is the empty network in which all non-experts, trivially, receive no message; hence, if they participate in the vote, this necessarily implies uninformed voting. Consequently, the absolute number of uninformed votes is much higher in the empty network than in the other networks. Thus, the possibility to communicate may serve informational efficiency by reducing the extent of uninformed voting. However, there might also be detrimental effects of communication as we will see next.

Informational efficiency. Informational efficiency is the higher the more often the signal received by the majority of experts determines the voting outcome. Figure 8 displays the degree of informational efficiency of voting outcomes across networks. As is easy to see, in both experiments the star network performs worst in terms of informational efficiency. Moreover, informational efficiency seems to be decreasing in balancedness of the network structure.

To test whether differences in informational efficiency across networks are significant, we create the variable *efficiency* that takes the value -1 if the voting outcome matches the minority signal, the value 0 if a tie occurs, and the value 1 if the voting outcome matches the majority signal. Fisher exact tests show that the star network exhibits significantly less informational efficiency than the weakly balanced and the empty network in Study II ($p < 0.01$), while the null hypothesis cannot be rejected in Study I. Other differences are not significant (except between the empty and the unbalanced network in Study II). Note that

[30] Exploring individual heterogeneity in uninformed voting reveals that around 50% of the participants never vote when uninformed, while there are almost 20% of the participants who always vote when uninformed.

[31] Grosser and Seebauer (2016) find a 30% rate of uninformed voting. Elbittar et al. (2014) even find that 60% of the uninformed vote.

Figure 8

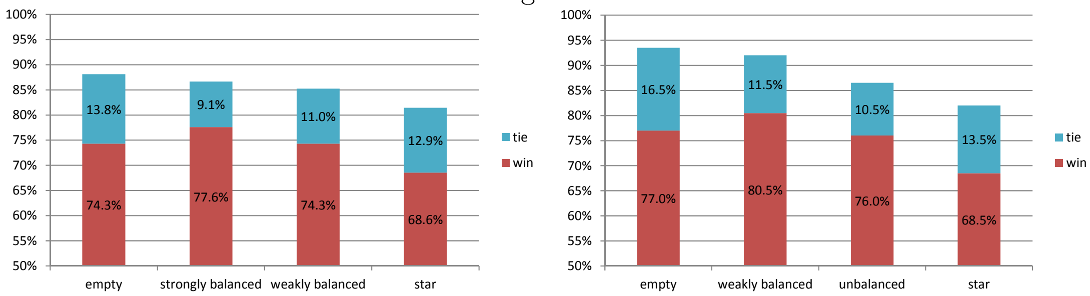


Figure 8: Frequency of informationally efficient group decisions by treatment. Left panel displays results for Study I. 'Win' means that the outcome of voting is the majority signal. 'Tie' means that there were as many votes for A as for B such that the outcome is correct with probability one half. Right panel displays results for Study II. Differences between the weakly balanced network and the star network are significant on the $p < 0.01$ level in Study II (Tables 10b and 11b). Differences between the empty network and the star network are significant on the $p < 0.05$ level in Study II (Tables 10b and 11b). Differences between the empty network and the star network are significant on the $p < 0.1$ level in Study I when controlling for the distribution of signals (Table 11a).

efficiency is also heavily affected by signal distributions. If, for instance, the five experts in Study I, or the three experts in Study II, happen to receive the same signal, say A^*, then it is easier to implement the majority signal A^* than when there are signals for both A and B, where voting errors are more likely to impair informational efficiency. We call a signal distribution of the form "5:0" ("3:0") uniform in Study I (II), a signal distribution of the form "3:2" ("2:1") non-uniform in Study I (II), and a signal distribution of the form "4:1" almost uniform. Controlling for the signal distribution reduces the noise in the analysis of efficiency. Using ordered logit models, we regress *efficiency* on the network type, controlling for the signal distribution. Results are displayed in Table 11. We find again that informational efficiency is lower in the star network than in the empty network in Study II ($p < 0.05$). Additionally, there is some evidence for the same effect in Study I ($p < 0.1$). There is also weak evidence that the unbalanced network is less efficient than the empty network ($p < 0.1$). Moreover, in Study II the star network is also less efficient than the weakly balanced network ($p < 0.01$).[32]

Result 3. *Informational efficiency is lower in the star network, compared to the empty network. In Study II, there is also evidence that the star network exhibits lower informational efficiency than the weakly balanced network and weak evidence that the unbalanced network exhibits lower informational efficiency than the empty network.*

The superiority of the empty network compared to the unbalanced networks is so striking because any strategy profile that is possible to play in the empty network is also feasible in these unbalanced networks. Providing participants with the possibility to communicate can hence have a detrimental effect on their voting outcome.

[32]This we do not find in Study I probably because one of the differences in behavior between the two experiments is that in Study I several senders in the star network choose the empty message, which mitigates the issue of unbalanced communication.

Economic efficiency. To test whether the low informational efficiency in the star network, and probably also in the unbalanced network, affects subjects in an economically meaningful way, we compute the expected payoff EP for each group in each round. If the group decision matches the true state, each member of the group earns 100 points. Hence, the variable EP coincides with the likelihood (in percentage points) of a correct collective decision, given all signals in the group. For instance in Study I, if four experts have received signal A^* and one expert B^* and the outcome of the majority vote is A, then $EP = \frac{p^4(1-p)}{p^4(1-p)+(1-p)^4 p} * 100$ which is approximately 77.14 for $p = 0.6$.[33] Computing EP by network type yields on average 61 (73) points in the star network in Study I (II) and on average 64 (79) points in the other networks in Study I (II), as displayed in Table C.3.[34]

Recall that when not controlling for the distribution of signals, there is additional noise because some treatments might happen to exhibit uniform signals and hence higher expected payoffs more often than others. We test for significant differences using OLS regressions and control for uniformity of signals (Table C.2, in the online Appendix C.1). The findings are analogous to those of Result 3: The inefficiency of the unbalanced networks, in particular of the star network, is confirmed ($p < 0.1$ in Study I and $p < 0.05$, respectively $p < 0.1$, in Study II). In addition, there is now evidence in both experiments that the star network exhibits lower efficiency than the weakly balanced network ($p < 0.1$ in Study I and $p < 0.05$ in Study II).

Result 4. *Expected payoffs are lower in the star network, compared to the empty network. There is also evidence that the unbalanced networks (including the star) exhibit lower expected payoffs than both the empty network and the weakly balanced network.*

Result 4 consists of two separate findings. The comparison among the networks in which communication is possible shows that an unbalanced communication structure can be detrimental to efficiency. The comparison of the unbalanced networks with the empty network, where communication is precluded, shows that communication itself can be detrimental to efficiency, confirming Result 3 above.

Further empirical results concern the sources of inefficiency. In online Appendix C.2 we report how the presence of partisans in Study II affects efficiency in comparison to Study I. Moreover, we show in online Appendix C.2 that most inefficient outcomes could have been avoided by some non-experts voters who had abstained.

To summarize, we find evidence in favor of the comparative statics of our theory and our subjects do switch from sincere voting to the LTED equilibrium if network balancedness decreases. However, this switching behavior is not pronounced enough to fully prevent detrimental effects of unbalanced communication on informational efficiency.

[33] If we consider reasonable values of EP to lie between the EP of a dictator who is randomly chosen from M and the EP of an efficient strategy profile, then the range for Study I is $[60, 68.3]$ and the range for Study II is $[62.9, 89.6]$.

[34] Table C.3 additionally displays the actual number of correct group decisions ('success'), which is a less reliable measure of economic efficiency than EP due to the noise induced by imperfect signals. As confirmed by t-tests (not in the appendix) the empirical values of EP are significantly below the EP of an efficient strategy profile, except for the case of a uniform signal in Study I, i.e., a signal distribution of the form "5:0," which virtually always leads to the efficient majority decision.

5 Conclusion

We have analyzed communication in social networks prior to a vote and have shown that it can lower efficiency of the voting outcome even in a common-interest setting. In contrast to public communication, where information aggregation occurs in the communication stage, we have studied private communication, which only admits information aggregation in the voting stage. Both scenarios, fully public and fully private communication, can be considered as extreme cases of more general communication structures, such as are analyzed in Appendix A.1. At the one extreme of the spectrum, communication can be fully private as studied in our basic model: The network is bipartite and the non-experts have at most degree one. After communication, each voter holds no more than one piece of information. Hence, any information aggregation can only occur in the voting stage, not through communication.

If such a social network is not strongly balanced, i.e., if it gives too much weight to voters with too little expertise, and if, at the same time, the network is not too unbalanced either, then it is an equilibrium to give and follow vote recommendations. However, the outcome of the resulting election is less likely to be optimal than under no communication. We have compared two focal strategy profiles – one without and one with private vote recommendations. In the first, efficient strategy profile, the informed vote in line with their own information and the others abstain ("let the experts decide"). In the second strategy profile, voters report their information to their neighbors in the network and everyone votes according to his or her updated belief (sincere behavior). Theoretically, we have found that sincere behavior, i.e, giving and following vote recommendations, constitutes an equilibrium in many balanced networks but is inefficient in all that are not *strongly* balanced. In two experiments, we have shown that the two focal strategy profiles are indeed the only relevant ones, and that communication indeed causes inefficiency.

In Appendix A, we generalize our model to include pre-vote communication between arbitrary voters with varying levels of expertise and in arbitrary network structures. The general model includes the other extreme of the private-public spectrum: fully public communication. It occurs if the network is complete, i.e., every voter is linked to every other voter. In this case, passing on one's signal and voting according to one's posterior belief (sincere behavior) is efficient and an equilibrium that captures ideal deliberation: The optimal alternative can be deduced by every voter; and other voting rules than the majority rule would also admit an equally efficient outcome (cf. Gerardi and Yariv, 2007).

Arguably, in reality communication is neither fully public nor fully private. Receiving multiple messages and an own signal leads to some information aggregation already in the communication stage. Participation in a majority election further aggregates information in the voting stage. Our general model accounts for this reality. Balancedness is crucial here, too: The findings from our basic model do not only remain robust but also hold in the limit when the population size converges to infinity.

We conclude that the structure of social networks and the balance – or the lack thereof – between voters' expertise and the size of their audience in the communication network are important for the functioning of democracy.

References

Agranov, M., J. K. Goeree, J. Romero, and L. Yariv (2017): "What Makes Voters Turn Out: The Effects of Polls and Beliefs," *Journal of the European Economic Association*, jvx023.

Austen-Smith, D. and J. S. Banks (1996): "Information aggregation, rationality, and the Condorcet jury theorem," *American Political Science Review*, 90, 34–45.

Austen-Smith, D. and T. J. Feddersen (2006): "Deliberation, preference uncertainty, and voting rules," *American Political Science Review*, 100, 209–217.

Battaglini, M. (2016): "Public Protests and Policy Making," *The Quarterly Journal of Economics*.

Battaglini, M., R. B. Morton, and T. R. Palfrey (2010): "The swing voter's curse in the laboratory," *The Review of Economic Studies*, 77, 61–89.

Bock, O., I. Baetge, and A. Nicklisch (2014): "hroot: Hamburg registration and organization online tool," *European Economic Review*, 71, 117–120.

Carpini, M. X. D., F. L. Cook, and L. R. Jacobs (2004): "Public deliberation, discursive participation, and citizen engagement: A review of the empirical literature," *Annu. Rev. Polit. Sci.*, 7, 315–344.

Coughlan, P. J. (2000): "In defense of unanimous jury verdicts: Mistrials, communication, and strategic voting," *American Political Science Review*, 94, 375–393.

Crawford, V. P. and J. Sobel (1982): "Strategic information transmission," *Econometrica: Journal of the Econometric Society*, 1431–1451.

De Caritat, Marie Jean Antoine Nicolas, M. d. C. (1785): *Essai sur l'application de l'analyse à la probabilité des décisions rendues à la pluralité des voix*, L'imprimerie royale.

Dittmann, I., D. Kübler, E. Maug, and L. Mechtenberg (2014): "Why votes have value: Instrumental voting with overconfidence and overestimation of others' errors," *Games and Economic Behavior*, 84, 17–38.

Elbittar, A., A. Gomberg, C. Martinelli, and T. R. Palfrey (2014): "Ignorance and bias in collective decisions," Tech. rep., California Institute of Technology.

Enke, B. and F. Zimmermann (2018): "Correlation Neglect in Belief Formation," *Review of Economic Studies*, forthcoming.

Esponda, I. and E. Vespa (2014): "Hypothetical thinking and information extraction in the laboratory," *American Economic Journal: Microeconomics*, 6, 180–202.

Feddersen, T. and W. Pesendorfer (1996): "The swing voter's curse," *American Economic Review*, 408–424.

——— (1997): "Voting behavior and information aggregation in elections with private information," *Econometrica*, 1029–1058.

——— (1998): "Convicting the innocent: The inferiority of unanimous jury verdicts under strategic voting," *American Political Science Review*, 23–35.

Gerardi, D. and L. Yariv (2007): "Deliberative voting," *Journal of Economic Theory*, 134, 317–338.

Goeree, J. K. and L. Yariv (2011): "An experimental study of collective deliberation," *Econometrica*, 79, 893–921.

Golub, B. and M. O. Jackson (2010): "Naïve Learning in Social Networks and the Wisdom of Crowds," *American Economic Journal: Microeconomics*, 2, 112–49.

——— (2012): "How homophily affects the speed of learning and best-response dynamics," *The Quarterly Journal of Economics*, 127, 1287–1338.

Grosser, J. and M. Seebauer (2016): "The curse of uninformed voting: An experimental study," *Games and Economic Behavior*, 97, 205–226.

Kawamura, K. and V. Vlaseros (2016): "Expert Information and Majority Decisions," Tech. rep., Scottish Institute for Research in Economics (SIRE).

Levy, G. and R. Razin (2015): "Correlation Neglect, Voting Behavior, and Information Aggregation," *American Economic Review*, 105, 1634–45.

Lu, L., Y. C. Yuan, and P. L. McLeod (2012): "Twenty-five years of hidden profiles in group decision making a meta-analysis," *Personality and Social Psychology Review*, 16, 54–75.

McLennan, A. (1998): "Consequences of the Condorcet jury theorem for beneficial information aggregation by rational agents," *American Political Science Review*, 92, 413–418.

Morton, R. B. and J.-R. Tyran (2011): "Let the experts decide? Asymmetric information, abstention, and coordination in standing committees," *Games and Economic Behavior*, 72, 485–509.

Ortoleva, P. and E. Snowberg (2015): "Overconfidence in political behavior," *American Economic Review*, 105, 504–35.

Palfrey, T. R. and K. Pogorelskiy (2017): "Communication among voters benefits the majority party," *The Economic Journal*.

Roth, A. E. (1988): *The Shapley value: essays in honor of Lloyd S. Shapley*, Cambridge University Press.

Shapley, L. and B. Grofman (1984): "Optimizing group judgmental accuracy in the presence of interdependencies," *Public Choice*, 43, 329–343.

A Appendix

A.1 General Model and Proofs

We now take the model as it is defined in section 2 and integrate the following two extensions. First, we relax the assumptions that only experts receive signals and that all experts' signals are of equal quality p. Instead we assume that every agent i receives a signal with idiosyncratic signal quality $p_i \in \left[\frac{1}{2}, 1\right)$. Second, we relax the assumptions on the network structure. We now admit arbitrary network structures in which agents can receive multiple messages and be informed by nature in addition.

A.1.1 Set-Up

As before, nature draws one state of the world $\omega \in \{A, B\}$ with uniform probability. There is a finite set of voters V. All agents $i \in V$ receive a private independent signal $s_i \in \{A^*, B^*\}$ about the true state of the world with quality $p_i = \Pr\{s_i = A^* \mid \omega = A\} = \Pr\{s_i = B^* \mid \omega = B\} \in \left[\frac{1}{2}, 1\right)$. Let g^V be the set of all subsets of V of size two. A network $g \subseteq g^V$ represents the communication structure between the agents. A voter of degree $d_i \geq 1$ is called sender and all voters linked to her are called her neighbors, who are denoted by $V_i := \{j \in V \mid\ ij \in g\}$.

The voting stage and the preferences are as defined in section 2. In particular, after receiving the signal, each agent may send message "A" or message "B" or an empty message $\emptyset$ to her neighbors. Then, all agents simultaneously participate in the majority vote. Note that senders may be neighbors of other senders now. Strategies can now be defined as follows: A communication strategy m_i of a voter $i \in V$ with $d_i \geq 1$ defines which message to send for each signal received, i.e. $m_i : \{A^*, B^*\} \to \{A, B, \emptyset\}$. A voting strategy v_i of a voter $i \in V$ defines whether and how to vote for each signal received and for each profile of messages received, i.e., $v_i : \{A^*, B^*\} \times \{A, B, \emptyset\}^{d_i} \to \{A, B, \emptyset\}$ if $d_i \geq 1$ and $\sigma_j : \{A^*, B^*\} \to \{A, B, \emptyset\}$ if $d_j = 0$. Again, we denote by $\sigma_i = (m_i, v_i)$ a communication and voting strategy of a voter and by $\sigma = (\sigma_i)_{i \in V}$ a strategy profile.[35]

In the general model the definition of experts and non-experts has to be reconsidered. Order the voters by their signal quality in decreasing order such that $p_1 \geq p_2 \geq ... \geq p_{|V|}$ (in case of equalities fix any such order) and consider the m best informed voters as the experts, i.e. set $M := \{j_1, j_2, ..., j_m\} \subseteq V$ with $p_m > \frac{1}{2}$. Consistently, the LTED strategy profile $\sigma^{*,m}$ will be parametrized by the number of experts m, which we require to be odd.[36]

In the simple model with homogeneous signal precision the "expertise" of a set of voters could be assessed simply by the number of signals they have received, which is the number of experts in the set. For idiosyncratic signal precision, each signal must be considered with its quality p_i, which enters into a group's expertise with its "log-odds" weight $\log(\frac{p_i}{1-p_i})$ (e.g.,

[35]This model nests our model of section 2 as follows. Let experts $M \subseteq V$ be a subset of voters who receive an informative signal of quality $p_j = p > \frac{1}{2}$ and let $N = V \setminus M$ be the non-experts, whose signal is uninformative, i.e. $p_i = \frac{1}{2}$. Moreover, we assumed that g is bipartite such that all links involve exactly one expert and one non-expert and that non-experts have at most one link.

[36]The profile $\sigma^{*,m}$ could also be called "let some(!) experts decide."

Shapley and Grofman, 1984). Hence, a set of voters S is better informed than another set S' if and only if $\sum_{i\in S}\log(\frac{p_i}{1-p_i}) > \sum_{j\in S'}\log(\frac{p_j}{1-p_j})$, which simplifies to $\prod_{i\in S}\frac{p_i}{1-p_i} > \prod_{j\in S'}\frac{p_j}{1-p_j}$.

In this more general set-up the definition of the sincere strategy profile $\hat{\sigma}$ has to be extended since voters may receive multiple messages, while still all voters with an informative signal communicate their signal. Consistent with the tag "sincere" we assume that agents vote for the message that has the higher posterior probability to coincide with the true state, given their private information, i.e. a voter i who has received signal A^* from nature and message A by the subset S of her neighbors V_i votes for A if and only if $\sum_{j\in S\cup\{i\}}\log(\frac{p_j}{1-p_j}) > \sum_{k\in V_i\setminus(S\cup\{i\})}\log(\frac{p_k}{1-p_k})$ and abstains if indifferent; and vice versa for a voter who has received signal B^*. For a voter j who talks to agents with a sufficiently low signal quality (i.e. $\log(\frac{p_j}{1-p_j}) > \sum_{k\in V_i}\log(\frac{p_k}{1-p_k})$) this simply means to vote in line with her signal. For a voter without an informative signal who listens to some equally well informed experts, $\hat{\sigma}$ means to vote in line with the message A or B that he has received more often; if both messages have been received equally frequently or if there is no message at all, she abstains. We can now reconsider our three theoretical results, Propositions 2.1 - 2.3, in the more general set-up.

A.1.2 "Let the experts decide" Revisited

Propositions 2.1 shows for the particular model that the LTED strategy profile σ^* is efficient and an equilibrium. In the general model, every odd number $m = 1, 3, 5, ...$ that is not larger than the number of informed agents defines a LTED strategy profile $\sigma^{*,m}$, in which all members of M vote their signal and all voters outside of M abstain. We find that each of these strategy profiles is an equilibrium and that efficiency holds at least asymptotically.

Proposition A.1 (LTED, general)**.** *There exist equilibria for any network structure. For instance, for any odd number m of experts (i.e. m voters with signal precision strictly above $\frac{1}{2}$ and weakly above all other voters'), the LTED strategy profile $\sigma^{*,m}$ is an equilibrium for any network structure. This strategy profile is efficient if and only if $\prod_{j\in M'}\frac{p_j}{1-p_j} \geq \prod_{k\in V\setminus M'}\frac{p_k}{1-p_k}$, where $M' := \{j_{\frac{m+1}{2}}, j_{\frac{m+3}{2}}, ..., j_m\} \subseteq M$ is the set of the $\frac{m+1}{2}$ experts with the lowest signal precision. Moreover, letting the number of experts m grow in this strategy profile $\sigma^{*,m}$, the probability of a correct decision approaches one.*

Proof. We address equilibrium, efficiency, and the limit case in turn.
Equilibrium. We first show that $\sigma^{*,m}$ is an equilibrium for any odd m. We start with showing that the experts $j \in M$ indeed prefer to vote their signal, then we turn to showing that that non-experts indeed prefer to abstain.

W.l.o.g. consider an expert j who has received signal A^*. He is pivotal if and only if A wins by one vote (m is odd). This happens if and only if there is a set of experts S of size $\frac{m-1}{2}$ who have received signal A^* as well, while the $\frac{m-1}{2}$ remaining experts $M \setminus (S \cup j)$ have received the signal B^*. Given that we are in this case (j has received signal A^*, all agents in S have received signal A^*, and all agents in $M \setminus (S \cup j)$ have received signal B^*), A is weakly more likely to be true than B if and only if

$$p_j \cdot \sum_{S\subset M\setminus j:|S|=\frac{m-1}{2}} \prod_{i\in S} p_i \cdot \prod_{k\in M\setminus(S\cup j)} (1-p_k) \geq (1-p_j)\cdot \sum_{Q\subset M\setminus j:|Q|=\frac{m-1}{2}} \prod_{i\in Q}(1-p_i)\cdot \prod_{k\in M\setminus(Q\cup j)} p_k. \tag{A.1}$$

Observing that

$$\sum_{S\subset M\setminus j:|S|=\frac{m-1}{2}} \prod_{i\in S} p_i \cdot \prod_{k\in M\setminus(S\cup j)} (1-p_k) = \sum_{Q\subset M\setminus j:|Q|=\frac{m-1}{2}} \prod_{k\in M\setminus(Q\cup j)} p_k \cdot \prod_{i\in Q}(1-p_i)$$

yields that (A.1) holds if and only if $p_j \geq 1-p_j$, which holds by assumption. Thus, $j \in M$ does not deviate from voting the received signal.

Now, we turn to a non-expert $i \in V \setminus M$. Suppose w.l.o.g. that he has received signal A^*. Then he is pivotal if and only if B wins by one vote under $\sigma^{*,m}$. This happens if and only if there is a set of experts $S \subset M$ of size $\frac{m-1}{2}$ who has received signal A^* and the $\frac{m+1}{2}$ remaining experts $M \setminus S$ have received signal B^*. Given that we are in this case (i and all experts in S have received signal A^* and all experts in $M \setminus S$ have received signal B^*), A is weakly less likely to be true than B if and only if

$$p_i \cdot \sum_{S\subset M:|S|=\frac{m-1}{2}} \prod_{j\in S} p_j \cdot \prod_{k\in M\setminus S} (1-p_k) \leq (1-p_i)\cdot \sum_{Q\subset M:|Q|=\frac{m-1}{2}} \prod_{j\in Q}(1-p_j)\cdot \prod_{k\in M\setminus Q} p_k. \tag{A.2}$$

For every summand S on the LHS there is a summand Q on the RHS which almost coincides but differs in two factors, e.g.

$$\begin{aligned} S &: \; p_1p_2...p_{\frac{m-1}{2}} \cdot (1-p_{\frac{m+1}{2}})(1-p_{\frac{m+3}{2}})...(1-p_m)\cdot p_i \\ Q &: \; (1-p_m)(1-p_{m-1})...(1-p_{\frac{m+3}{2}})\cdot p_{\frac{m+1}{2}} p_{\frac{m-1}{2}}...p_1 \cdot (1-p_i) \end{aligned}$$

differ in the factors p_i and $(1-p_i)$ and the factors $p_{\frac{m+1}{2}}$ and $(1-p_{\frac{m+1}{2}})$. For a pair S, Q that differs in the factor p_k and $(1-p_k)$, besides p_i and $(1-p_i)$, let $k(S) := k$ and let $\alpha(S) > 0$ be the common part of S and Q. Then we can reorganize (A.2) by subtracting the right-hand side (RHS) on both sides and expressing the common and different part of each pair as follows:

$$\sum_{S\subset M:|S|=\frac{m-1}{2}} \alpha(S)\cdot[(1-p_{k(S)})\cdot p_i - p_{k(S)}\cdot(1-p_i)] \leq 0. \tag{A.3}$$

We observe that $(1-p_{k(S)})\cdot p_i \leq p_{k(S)}\cdot(1-p_i)$ for $p_i \leq p_{k(S)}$, which holds by assumption because signal precision of non-expert i is by definition smaller than of any expert $k(S)$. Thus, A.3 holds. Hence, for a non-expert i pivotality implies that the outcome of the vote is more likely to be correct than what he can induce with a deviation.

Efficiency. We now show that $\sigma^{*,m}$ is efficient if and only if the following condition holds: (*) $\prod_{j\in M'} \frac{p_j}{1-p_j} \geq \prod_{k\in V\setminus M'} \frac{p_k}{1-p_k}$, where $M' := \{j_{\frac{m+1}{2}}, j_{\frac{m+3}{2}}, ..., j_m\} \subseteq M$ is the set of the $\frac{m+1}{2}$ experts with the lowest signal precision.

For a given draw of nature denote by S the set of agents who have received signal A^*. Generally, a strategy profile is efficient if and only if the outcome is A whenever A is more likely to be the true state than B, i.e. whenever

$$\sum_{j \in S} \log(\frac{p_j}{1-p_j}) > \sum_{k \in V \setminus S} \log(\frac{p_k}{1-p_k}) \tag{A.4}$$

and the outcome is B whenever inequality A.4 is reversed (e.g., Shapley and Grofman, 1984, Theorem II).

Suppose, $\sigma^{*,m}$ is efficient. Consider the draw of nature $S = M'$, i.e. in which all members of M' have received signal A^*, while all others have received signal B^*. Since $m' > \frac{m}{2}$, A wins under $\sigma^{*,m}$. By efficiency it must hold that $\sum_{j \in S} \log(\frac{p_j}{1-p_j}) \geq \sum_{k \in V \setminus S} \log(\frac{p_k}{1-p_k})$, which is equivalent to $\prod_{j \in M'} \frac{p_j}{1-p_j} \geq \prod_{k \in V \setminus M'} \frac{p_k}{1-p_k}$, i.e. condition (*) is satisfied.

Now suppose condition (*) is satisfied. Since M' is the smallest majority of experts with the least expertise, any set $S \supseteq M'$ holds more expertise than M' such that condition (*) is equivalent to $\sum_{j \in S} \log(\frac{p_j}{1-p_j}) \geq \sum_{k \in V \setminus S} \log(\frac{p_k}{1-p_k})$ if and only if $|M \cap S| > \frac{m}{2}$. Take any draw of nature and denote by S the set of agents who have received signal A^*. Suppose first that inequality A.4 holds. Then by (*), $|M \cap S| > \frac{m}{2}$ holds. Under $\sigma^{*,m}$ the outcome is A. Suppose the reverse of inequality A.4 holds. Then by (*), $|M \cap S| < \frac{m}{2}$ holds and B wins. Hence, $\sigma^{*,m}$ is efficient.

Limit. Finally, we show that letting the number of experts m grow in this strategy profile $\sigma^{*,m}$, the probability of an efficient outcome approaches one.

For every m, the probability of an efficient outcome under $\sigma^{*,m}$ is larger than in the hypothetical case that every expert in M has signal precision $p_m > 0.5$ (which is the lowest among the experts) and also votes her signal. For the hypothetical case, the Condorcet Jury theorem applies, showing that the probability of a correct decision approaches one as $m \to \infty$. Hence, this is also true for $\sigma^{*,m}$.

□

This result shows robustness of the LTED equilibrium to the two extensions. First, trivially, more general network structures cannot affect an equilibrium which does not involve information transmission. Second, the LTED equilibrium extends to heterogeneous signal precisions. Efficiency of LTED, however, only holds in finite populations if even the weakest majority of experts (M') holds more expertise than the strongest minority of experts together with all non-experts. This means that efficiency in finite populations requires that the experts' signal quality is not too heterogeneous and that the non-experts' signal quality is sufficiently low, compared to the experts'.

However, we show in the proof of Proposition A.1 (in Appendix A.1) that the potential inefficiency of LTED vanishes when the absolute number of experts m grows large. In that sense not only existence, but also efficiency of LTED extends to the general model.

A.1.3 Sincere Voting Revisited

We now turn to the extension of Propositions 2.2 and hence to the sincere equilibrium $\hat{\sigma}$. The intuition that the sincere equilibrium $\hat{\sigma}$ requires a network structure that balances a group of experts' "expertise" with their "power" fully carries over. We only have to extend the notion of balancedness, which requires some additional notation.[37]

For a fixed set of agents $S \subseteq V$, partition the voters V into *believers* $V^+(S)$, *non-believers* $V^-(S)$, and *neutrals* $V^0(S)$ as follows: i is called a believer of the set S, i.e. $i \in V^+(S)$, if, from what i can observe in his neighborhood $(V_i \cup i)$, S is better informed than the complementary set, i.e. $\sum_{j\in(V_i\cup i)\cap S} \log(\frac{p_j}{1-p_j}) > \sum_{k\in(V_i\cup i)\setminus S} \log(\frac{p_k}{1-p_k})$. Analogously, i is called a non-believer of the set S, i.e. $i \in V^-(S)$, if, from what i can observe in his neighborhood $(V_i \cup i)$, S is less well informed than the complementary set, i.e. $\sum_{j\in(V_i\cup i)\cap S} \log(\frac{p_j}{1-p_j}) < \sum_{k\in(V_i\cup i)\setminus S} \log(\frac{p_k}{1-p_k})$. Finally, i is called a neutral with respect to the set S, i.e. $i \in V^0(S)$, if he is neither a believer nor a non-believer, which happens when the above condition holds with equality. In the special case of homogenous signal precision, the number of links into a given set S determines whether an agent is a believer, a non-believer, or a neutral.

Definition A.1 (Balancedness, general). *(a) Given a profile of signal precisions p_j, a network is called* "strongly balanced" *if every set of voters which is better informed than the complementary set has more believers than non-believers, i.e.* $\forall S \subseteq V$, $\prod_{j\in S} \frac{p_j}{1-p_j} > \prod_{k\in V\setminus S} \frac{p_k}{1-p_k}$ *implies* $|V^+(S)| > |V^-(S)|$.

(b) For a voter $i \in V$, let $\mathcal{S}_i$ collect all sets of voters S, of which i is a believer, i.e. $i \in V^+(S)$, and which have slightly more believers than non-believers, i.e. $|V^+(S)| - |V^-(S)| \in \{0, 1, 2\}$. Let $\mathcal{Q}_i$ collect all subsets of these sets that belong to i's neighborhood, i.e. $\mathcal{Q}_i := \{Q \subseteq V | Q = (V_i \cup i) \cap S$ for some $S \in \mathcal{S}_i\}$. A network is called "weakly balanced" *if for every voter $i \in V$ and for every $Q \in \mathcal{Q}_i$, there is a corresponding set of agents S with $Q \subseteq S \in \mathcal{S}_i$, which is weakly better informed than the complementary set, i.e. $\prod_{j\in S} \frac{p_j}{1-p_j} \geq \prod_{k\in V\setminus S} \frac{p_k}{1-p_k}$.*

Strong balancedness requires that any group of voters S which is better informed than the complementary set is also considered as better informed by a majority of voters. Weak balancedness addresses groups of voters Q within a given voter's neighborhood, which together with some voters outside of the neighborhood would have slightly more believers than non-believers. When the agent is a believer of such a group Q, there must be one corresponding group of voters outside the agent's neighborhood such that both groups together are weakly better informed than the complementary set.

Proposition A.2. *The sincere strategy profile $\hat{\sigma}$ is* efficient *if and only if the network is strongly balanced. The sincere strategy profile $\hat{\sigma}$ is an equilibrium* if *(a) the network is strongly balanced and* only if *(b) the network is weakly balanced.*

[37] Applying the corresponding upcoming Definition A.1 to the specific set-up of section 2 leads to a notion of balancedness that is equivalent to Definition 2.2. This is shown in the online Appendix B.4.

Proof. We begin with strong balancedness and then turn to weak balancedness. *Strong balancedness.* We first show equivalence between strong balancedness and efficiency of $\hat{\sigma}$.

For a given draw of nature denote by S the set of experts who have received signal A^*. Generally, a strategy profile is efficient if and only if the outcome is A whenever A is more likely to be the true state than B, i.e. whenever

$$\sum_{j\in S}\log(\frac{p_j}{1-p_j}) > \sum_{k\in V\setminus S}\log(\frac{p_k}{1-p_k}) \tag{A.5}$$

and the outcome is B whenever inequality A.5 is reversed (e.g., Shapley and Grofman, 1984, Theorem II). Now, consider that under $\hat{\sigma}$ an agent i votes A if and only if he is a believer of the group S who have received signal A^*, i.e. $i \in V^+(S)$. Indeed, a voter $i \in V$ votes A if and only if A has the higher posterior probability to be the true state of the world given $i's$ information, which is $\sum_{j\in(V_i\cup i)\cap S}\log(\frac{p_j}{1-p_j}) > \sum_{k\in(V_i\cup i)\setminus S}\log(\frac{p_k}{1-p_k})$, which is the definition of $i \in V^+(S)$. Hence, the number of A votes is $|V^+(S)|$, while the number of B votes is $|V^-(S)|$ (again, for the draw of nature that gives signal A^* to S and signal B^* to $V \setminus S$).

If inequality A.5 holds, then strong balancedness implies $|V^+(S)| > |V^-(S)|$ such that A receives a majority of votes. If inequality A.4 is reversed, then by strong balancedness B receives a majority of votes. If the RHS and LHS of inequality A.5 are equal, then both states of the world are equally likely and any outcome is consistent with efficiency. Hence, strong balancedness implies efficiency of $\hat{\sigma}$.

Now, suppose that g is not strongly balanced. Then there is a set $S \subseteq V$ with $\sum_{i\in S}\log(\frac{p_i}{1-p_i}) > \sum_{j\in V\setminus S}\log(\frac{p_j}{1-p_j})$, but $|V^+(S)| \leq |V^-(S)|$. Suppose all $i \in S$ receive signal A^* and all $j \in V \setminus S$ receive signal B^*. Then $\hat{\sigma}$ leads to outcome B or to a tie, while A is more likely to be true. Hence, efficiency of $\hat{\sigma}$ requires strong balancedness. (We have established that $\hat{\sigma}$ is efficient if and only if the network is strongly balanced.)

Efficiency of a strategy profile implies that it is an equilibrium, since every player's expected utility is maximal.

Weak balancedness. Suppose weak balancedness is violated, i.e. there is a voter $i \in V$ and a set $Q \in \mathcal{Q}_i$, such that there is *no* corresponding set of agents S with $Q \subseteq S \in \mathcal{S}_i$ and $\prod_{j\in S}\frac{p_j}{1-p_j} \geq \prod_{k\in V\setminus S}\frac{p_k}{1-p_k}$, i.e. which is weakly better informed than the complementary set. Then $\forall S \in \mathcal{S}_i$, we have $\sum_{j\in S}\log(\frac{p_j}{1-p_j}) < \sum_{k\in V\setminus S}\log(\frac{p_k}{1-p_k})$ and $\mathcal{S}_i \neq \emptyset$ because $\mathcal{Q}_i \neq \emptyset$ by assumption.

Consider a draw of nature such that within i's neighborhood all voters in Q have received signal A^* and all others $(V_i \cup i) \setminus Q$ have received signal B^*. Since $i \in V^+(S)$ for $Q \subseteq S \in \mathcal{S}_i$, it also holds that $i \in V^+(Q)$, and i will vote for A under $\hat{\sigma}$.

Consider the deviation of i to vote B in this case (i.e. when from his own signal and the messages of V_i, i infers that within $(V_i \cup i)$ exactly subset Q has received signal A^*). Let X denote the set of other agents $j \in V \setminus (V_i \cup i)$ who have received signal A^*. If $(Q \cup X) \notin \mathcal{S}_i$, then the deviation has not affected the outcome since it is not the case that there is a slight majority for alternative A under $\hat{\sigma}$. If $(Q \cup X) \in \mathcal{S}_i$, then the deviation has turned the outcome from A to B, or from A to a tie, or from a tie to B. This improves expected utility if the probability that B is the true state is larger than that A is true. By the property that $\forall S \in \mathcal{S}_i$, we have $\sum_{j\in S} \log(\frac{p_j}{1-p_j}) < \sum_{k\in V\setminus S} \log(\frac{p_k}{1-p_k})$, B is indeed more likely to be true than A. Hence, when weak balancedness is violated there is a beneficial deviation from $\hat{\sigma}$.

□

To interpret Proposition A.2 part (a), consider first the special case of homogenous signal precision $p_i = p$ for all voters i. Strong balancedness then means that every voter i is equally *powerful*.[38] Turning to heterogeneous signal precision, strong balancedness means that heterogeneity in expertise is matched by the heterogeneity in power. For instance, as we have discussed, in Example 2, the star network, as well as in Example 3, sincere voting is not efficient for homogeneous signal precision. However, in Example 2 sincere behavior $\hat{\sigma}$ would be efficient if signal precisions were, e.g., $(p_1, ..., p_9) = (.9, .6, .6, .6, .6, .5, .5, .5, .5)$. Similarly, in Example 3, sincere behavior would be efficient if, e.g., signal precisions were $(p_1, ..., p_9) = (.9, .9, .6, .6., .6, .5, .5, .5, .5)$. Hence strong balancedness does not generally refer to an equality of power, but rather to a *balance of power with expertise*.[39]

To interpret Proposition A.2 part (b), consider an agent i who observes message A from all agents in a set Q, of which i is a believer. Sincere behavior is to follow this message. Deviations from sincere behavior only affect the outcome when the number of A votes under $\hat{\sigma}$ is slightly larger than the number of B votes. Suppose that in any of those cases A is less likely to be true than B. Then i can beneficially deviate from $\hat{\sigma}$ by voting B. We have constructed a violation of weak balancedness and argued that then $\hat{\sigma}$ is not an equilibrium. In fact, the agent i in the example is "cursed" in the sense that when he follows the vote recommendations of the set Q whenever his vote has an effect, it has the undesirable effect of switching the outcome to the less likely state.

This is illustrated by the following example.

Example 4 (not weakly balanced)**.** *Let $V = \{i_1, i_2, ..., i_9\}$, the network g as illustrated in Figure A.1, and let the signal precision of all agents i be equal $p_i = p > \frac{1}{2}$. This network violates weak balancedness: Consider agent i_1 and set $Q = \{i_2, i_3\}$. Agent i_1 is a believer of set Q since he assigns more expertise to this set ($(V_1 \cup i) \cap Q = \{i_2, i_3\}$) than to the complementary set, of which he can only observe himself ($(V_1 \cup i) \setminus Q = \{i_1\}$). There are many elements in $\mathcal{S}_1$. For instance, Q together with $X = \{i_8, i_9\}$ forms a set $S = \{i_2, i_3, i_8, i_9\} \in \mathcal{S}_1$, which indeed has slightly more believers than non-believers since there are five believers ($\{i_1, i_2, i_3, i_8, i_9\}$) and four non-believers ($\{i_4, i_5, i_6, i_7\}$). Other examples that contain set Q are $S' = \{i_2, i_3, i_8, i_4\} \in \mathcal{S}_1$, or $S'' = \{i_2, i_3, i_4, i_5\} \in \mathcal{S}_1$. Indeed, each of these sets has slightly more believers than non-believers. However, there is no extension of Q in $\mathcal{S}_1$, which contains more than four players. Weak balancedness would require that at least one S with $Q \subseteq S \in \mathcal{S}_1$ is better informed than the complementary set, but this is not true*

[38] This result is shown as Proposition B.9 in online Appendix B.5. Power is defined as the Shapley-Shubik index or the Banzhaf index in a cooperative voting game that incorporates how many believers each coalition has. Online Appendix B.5 introduces this framework, provides the result, and also gives some intuition for how individual power is determined by the network structure.

[39] With our experimental design we purposefully keep expertise constant among experts to observe *unbalanced power* directly in the network structure.

Figure A.1

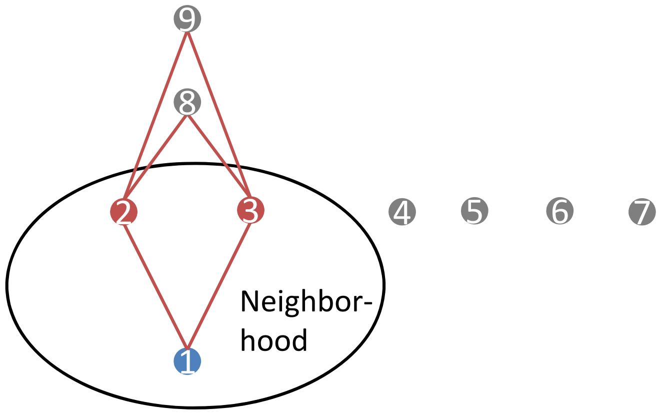


Figure A.1: Example 4, a network in which weak balancedness is violated. Voter i_1 is "cursed" if his signal differs from the signals of voters i_2 and i_3.

when only a minority of informed agents are in S. Thus, by Proposition A.2 part (b), the sincere strategy profile $\hat{\sigma}$ is not an equilibrium.

In the example, agent i_1 has an incentive to deviate from the sincere strategy profile when he infers from their messages that the agents $Q = \{i_2, i_3\}$ have received, e.g., signal A^*, while he has received signal B^*. Given this private information, A is clearly more likely to be true than B since two out of three "observable" voters have received signal A^*. However, conditioning on pivotality implies that at least five voters (e.g. $\{i_1, i_4, i_5, i_6, i_7\}$) must have received signal B^*. Thus, in this situation the unconditional posterior of voter i_1 differs crucially from the posterior conditional on pivotality, which is the reason for the "swing voter's curse." The source of this curse is the power of agents i_2 and i_3 regarding the votes of agents i_1, i_8, and i_9.

More generally, suppose there is an agent who observes a set of agents Q sending the same message, say A. If for any additional set of agents whose votes for A would render i pivotal (call this set X), it holds that these two sets together are less well-informed than the complementary set $V \setminus (Q \cup X)$, then voting for A is not a best response.

Inefficient equilibria revisited. Turning to Proposition 2.3, the existence of inefficient equilibria with information transmission trivially extends to the more general framework. Thus, there are network structures and distributions of expertise that lead to inefficient equilibria. However, the question arises whether the inefficiency that we uncovered for unbalanced information transmission vanishes for large electorates, as it does for LTED.

To address this question, reconsider Example 3 and the corresponding network illustrated in Figure 2 and let it grow infinitely in discrete steps $t = 1, 2, 3, ...$ by adding two non-experts to each audience and two experts without an audience in each step. The t-th network then has two experts of degree $2t$ and $2t + 1$ experts of degree zero. This example demonstrates the following proposition (cf. proof of Proposition A.3).

Proposition A.3. *There are networks in which the sincere strategy profile $\hat{\sigma}$ is both an equilibrium and exhibits informational inefficiency. This inefficiency does not necessarily* *vanish when the number of experts grows large.*

Proof. We show existence of inefficient strategy profiles with the network introduced in Example 3 and extensions of it. For any $t = 1, 2, ...$ we consider a network with two experts of degree $2t$, $1 + 2t$ experts of degree zero and $4t$ non-experts of degree one. For $t = 1$ this is exactly the network depicted in Figure 2. All experts have signal quality $p_j = p > 0.5$, all non-experts signal quality $p_i = 0.5$. For any $t = 1, 2, ...$, denote the corresponding game by Γ^t and the sincere strategy profile in that game by $\hat{\sigma}^t$.

Under $\hat{\sigma}^t$, $3+6t$ agents participate in the vote. If the two senders receive the same signal, say A^*, then A is the outcome since the two senders induce $2 * (1 + 2t) \geq 2 + 3t$ A-votes. If both senders receive different signals, A^* and B^*, then A wins if and only if A receives $k \geq 1 + t$ votes of the $1 + 2t$ experts with degree zero. Supposing that A is the true state, the probability that the outcome is A provides the general probability that the outcome coincides with the true state since $\hat{\sigma}^t$ treats A and B interchangeably. Thus, under $\hat{\sigma}^t$ the probability that the outcome coincides with the true state is

$$EU(\hat{\sigma}^t) = p^2 * 1 + 2p(1-p) \sum_{k=t+1}^{2t+1} \binom{2t+1}{k} p^k (1-p)^{2t+1-k} + (1-p)^2 * 0. \tag{A.6}$$

Inefficiency. We establish inefficiency of $\hat{\sigma}^t$ for any t and also in the limit. (Recall that a strategy profile is efficient if and only if for any draw of nature it selects the outcome that maximizes the probability to match the true state.) Consider the draw of nature in which both senders receive signal A^* and all other experts receive signal B^*. An efficient strategy profile would implement (the majority signal) B^*, but $\hat{\sigma}^t$ leads to A.

For an efficient strategy profile σ^t the probability that the outcome coincides with the true state is below one for finite t, but converges to one for growing t, i.e. $\lim_{t\to\infty} EU(\sigma^t) = 1$ when σ^t efficient. Under $\hat{\sigma}^t$, when both senders happen to receive the incorrect signal, then the outcome does not coincide with the true state. Thus, the probability of implementing the incorrect outcome under $\hat{\sigma}^t$ is at least $(1 - p)^2$, which is independent of t. Hence, $\lim_{t\to\infty} EU(\hat{\sigma}^t) \leq 1 - (1 - p)^2 < 1$, i.e. inefficiency does not vanish for growing t.

Now, we establish that $\hat{\sigma}^t$ is an equilibrium for any t. We show first that there is no profitable deviation that occurs on the voting stage only. Then we show that there is no profitable deviation that affects both stages voting and communication.

Deviations on the voting stage only. Consider a voter $i \in V$ who considers to deviate from $\hat{\sigma}^t$ by changing his voting strategy v_i. This can be a non-expert who does not follow the received message or an expert who does not vote the received signal, but chooses some different strategy instead.

Suppose one sender (i.e. a voter with $p_j = p > 0.5$ and $d_j = 2t$) receives signal A^* and the other sender receives signal B^*. Then A receives more votes than B under $\hat{\sigma}^t$ if and only if more experts with degree zero (i.e. voters with $p_j = p > 0.5$ and $d_j = 0$) have received signal A^*. Hence, when the two senders have not received the same signal, then $\hat{\sigma}^t$ always implements the majority signal and thus induces the outcome that is more likely to be true. Hence, if there is a beneficial deviation, then it must also change outcomes in which both senders have received the same signal.

Suppose that both senders have received the same signal, say A^*. Then the number of A-votes under $\hat{\sigma}^t$ is at least $2 + 4t$ (since two senders, and $2 * 2t$ non-experts vote for A) and the number of B-votes is hence at most $3 + 6t - (2 + 4t) = 1 + 2t$. The number of A-votes thus exceeds the number of B-votes by at least $2 + 4t - (1 + 2t) = 1 + 2t \geq 3$ votes. Hence, a single agent who changes her vote cannot affect the outcome if the two senders have received the same signal.

Taken together a deviation that only changes one vote is neither beneficial if both senders have received the same signal nor if they have received different signals. This precludes deviation incentives of non-experts, of experts with degree zero, as well as of senders who consider to deviate in their voting behavior only, i.e. all deviations that happen on the voting stage only. We now turn to deviations that also affect the communication stage, i.e. which involve a sender who does not truthfully transmit her signal, and show that any of those is neither beneficial.[40]

Deviations on both stages. Consider a sender $j \in V$ with $d_j > 0$. This expert has $(3\times3)^2 = 81$ strategies because she chooses one of three messages and one of three voting actions after receiving one of two signals.[41] To evaluate different strategies we can assume w.l.o.g. that the expert has received signal A^* because neither the utility function nor the strategy profile depends on the label of the alternatives. This reduces the number of strategies to the following nine: $(m_j(A^*), v_j(A^*)) \in \{(A, A), (A, B), (A, \emptyset), (B, A), (B, B), (B, \emptyset), (\emptyset, A), (\emptyset, B), (\emptyset, \emptyset)\}$. The first strategy (A, A) is sincere and hence not a deviation. The strategies (A, B) and $(A, \emptyset)$ only involve deviations on the voting stage and are hence not beneficial by the paragraph above. This leads to the following six remaining deviations $\tilde{\sigma}$ and their corresponding expected utilities $EU(\tilde{\sigma}^t)$:[42]

1. Sender j sends the opposite message and votes the signal.

$$EU(\tilde{\sigma}^t) = p^2 \sum_{k=t}^{2t+1} \binom{2t+1}{k} p^k (1-p)^{2t+1-k} + p(1-p) + (1-p)^2 \sum_{k=t+2}^{2t+1} \binom{2t+1}{k} p^k (1-p) \quad \text{(A.7)}$$

[40] For large t this is simple to show. In the case in which the deviating agent receives the correct signal, say A^*, and the other sender receives the incorrect signal, the probability that the outcome is A approaches zero for growing t. Hence, the expected utility of any such deviation is bounded from above by $\lim_{t\to\infty} EU(\tilde{\sigma}^t) \leq 1 - p(1-p) < 1 - (1-p)^2 = \lim_{t\to\infty} EU(\hat{\sigma}^t)$.

[41] In general, voters with positive degree $d_i > 0$ have more pure strategies. In this example, the senders are linked to non-experts (i.e voters i with $p_i = 0.5$) who are assumed by convention not to send a message under $\hat{\sigma}^t$. Since a message of an uninformed voter is meaningless, a change of convention would not affect the result.

[42] Deviations that involve to vote and/or communicate an alternative unconditionally, i.e. independent of the signal, need not be considered here because of the symmetry between the alternatives. Indeed, if it is beneficial to vote B after receiving A^*, then it is also beneficial to vote A after receiving B^*, which is to vote the opposite of the signal. Similarly, there is no need to consider strategies that involve the empty message and/or to abstain only after one of the two signals. Indeed, if it is beneficial e.g. to abstain after having received signal A^*, then it is also beneficial to abstain after having received signal B^*, which is to abstain unconditionally. Hence, if none of the six symmetric deviations is an improvement over $\hat{\sigma}^t$, then neither is a deviation that treats the alternatives A and B asymmetrically.

2. Sender j sends the opposite message and votes the opposite.

$$EU(\tilde{\sigma}^t) = [p^2 + (1-p)^2] \sum_{k=t+1}^{2t+1} \binom{2t+1}{k} p^k (1-p)^{2t+1-k} + p(1-p) \tag{A.8}$$

3. Sender j sends the opposite message and abstains.

$$\begin{aligned} EU(\tilde{\sigma}^t) = p^2 & \left[\frac{1}{2} \binom{2t+1}{t} p^t (1-p)^{t+1} + \sum_{k=t+1}^{2t+1} \binom{2t+1}{k} p^k (1-p)^{2t+1-k} \right] \\ & + p(1-p) + (1-p)^2 \left[\frac{1}{2} \binom{2t+1}{t+1} p^{t+1} (1-p)^t + \sum_{k=t+2}^{2t+1} \binom{2t+1}{k} p^k (1-p)^{2t+1-k} \right] \end{aligned} \tag{A.9}$$

4. Sender j sends the empty message and votes the signal.

$$EU(\tilde{\sigma}^t) = p^2 + p(1-p)p^{2t+1} + p(1-p) \sum_{k=1}^{2t+1} \binom{2t+1}{k} p^k (1-p)^{2t+1-k} \tag{A.10}$$

5. Sender j sends the empty message and votes the opposite.

$$EU(\tilde{\sigma}^t) = p^2 \sum_{k=1}^{2t+1} \binom{2t+1}{k} p^k (1-p)^{2t+1-k} + p(1-p) + (1-p)^2 p^{2t+1} \tag{A.11}$$

6. Sender j sends the empty message and abstains.

$$EU(\tilde{\sigma}^t) = p^2[1 - \frac{1}{2}(1-p)^{2t+1}] + p(1-p)\frac{1}{2}p^{2t+1} + p(1-p)[1 - \frac{1}{2}(1-p)^{2t+1}] + (1-p)^2 \frac{1}{2} p^{2t+1} \tag{A.12}$$

The derivation of the expressions (A.7)-(A.12) is shown in online Appendix B.6. We can now compare the expected utility $EU(\tilde{\sigma}^t)$ of each deviation, which is given by (A.7)-(A.12), with the expected utility of the sincere strategy profile $EU(\hat{\sigma}^t)$, which is given by (A.6).

Consider, for instance, the fifth deviation: Sender j sends the empty message and votes the opposite of the signal. There are $3+4t$ votes and $2+2t$ is a majority. Denote by (s_j, s_k) the signals of the two senders. There are four possibilities.

- (A^*, A^*): A wins if there are at least $2+2t-(1+2t) = 1$ A^*-signals among the experts of degree zero.
- (A^*, B^*): A never wins since B receives at least $2+2t$ votes.
- (B^*, A^*): A wins since it receives at least $2+2t$ votes.
- (B^*, B^*): A wins if there are at least $2+2t-1 = 2t+1$ A^*-signals among the experts of degree zero, i.e. all of them have signal A^*.

We now show that this deviation is not beneficial by considering the change in expert j's expected utility (which is the expected utility of every agent). Supposing that the true state is A, the expected utility is the likelihood that A is indeed implemented. Hence,

$$EU(\tilde{\sigma}^t) = p^2 \sum_{k=1}^{2t+1} \binom{2t+1}{k} p^k (1-p)^{2t+1-k} + p(1-p)*0 + p(1-p)*1 + (1-p)^2 p^{2t+1},$$

which directly simplifies to (A.11).

For the upcoming simplifications we use the following two properties:

1. $\sum_{k=0}^{2t+1} \binom{2t+1}{k} p^k (1-p)^{2t+1-k} = 1$ and
2. $\binom{2t+1}{k} = \binom{2t+1}{2t+1-k}$ for any $k = 0, ..., 2t+1$.

Let $\Delta := EU(\hat{\sigma}^t) - EU(\tilde{\sigma}^t)$. Then

$$\Delta = p^2 \left[1 - \sum_{k=1}^{2t+1}(...)\right] + p(1-p)\left[2 \sum_{k=t+1}^{2t+1} \binom{2t+1}{k} p^k (1-p)^{2t+1-k} - 1\right] - (1-p)^2 p^{2t+1}$$

$$\begin{aligned}
\Delta &= p^2 \left[\sum_{k=0}^{2t+1}(...) - \sum_{k=1}^{2t+1}(...)\right] + p(1-p)\left[2 \sum_{k=t+1}^{2t+1} \binom{2t+1}{k} p^k (1-p)^{2t+1-k} - 1\right] \\
&\quad -(1-p)^2 p^{2t+1} \\
\Delta &= p^2(1-p)^{2t+1} + p(1-p) \underbrace{\left[\sum_{k=t+1}^{2t+1}(...) - \sum_{k=0}^{2t+1}(...)\right]}_{=-\sum_{k=0}^{t}(...)} + \underbrace{p(1-p) \sum_{k=t+1}^{2t+1}(...) - (1-p)^2 p^{2t+1}}_{\geq p(1-p)\sum_{k=t+1}^{2t}(...)}
\end{aligned}$$

To simplify the last part of the equation notice the following:

- First, $\sum_{k=t+1}^{2t+1} (p^k (1-p)^{2t+1-k} = \sum_{k=t}^{2t} (p^k (1-p)^{2t+1-k} + \binom{2t+1}{2t+1} p^{2t+1} (1-p)^0$.
- Second, $\binom{2t+1}{2t+1} p^{2t+1} (1-p)^0 = p^{2t+1}$.
- Third, $p(1-p)p^{2t+1} - (1-p)^2 p^{2t+1} = [p(1-p) - (1-p^2)] p^{2t+1} \geq 0$.

Thus,

$$\begin{aligned}
\Delta &\geq p^2(1-p)^{2t+1} - p(1-p) \sum_{k=0}^{t} \binom{2t+1}{k} p^k (1-p)^{2t+1-k} + p(1-p) \sum_{k=t+1}^{2t}(...) \\
\Delta &\geq \underbrace{p^2(1-p)^{2t+1} - p(1-p) \binom{2t+1}{0} p^0 (1-p)^{2t+1}}_{\geq 0} - p(1-p) \sum_{k=1}^{t}(...) + p(1-p) \sum_{k=t+1}^{2t}(...) \\
\Delta &\geq \underbrace{p(1-p)}_{\geq 0} \left[\sum_{k=t+1}^{2t} \binom{2t+1}{k} p^k (1-p)^{2t+1-k} - \sum_{k=1}^{t} \binom{2t+1}{k} p^k (1-p)^{2t+1-k}\right]
\end{aligned}$$

Hence, $\Delta \geq 0$ if

$$\sum_{k=t+1}^{2t} \binom{2t+1}{k} p^k (1-p)^{2t+1-k} \geq \sum_{k=1}^{t} \binom{2t+1}{k} p^k (1-p)^{2t+1-k}. \tag{A.13}$$

To show that inequality A.13 holds, we substitute k in the first sum by $l \equiv 2t+1-k$ and consistently sum over $l = 1, ..., t$ (instead over $k = t+1, ..., 2t$). Moreover, we use $\binom{2t+1}{k} = \binom{2t+1}{2t+1-k}$.

$$\begin{aligned}
\sum_{l=1}^{t} \binom{2t+1}{l} p^{2t+1-l}(1-p)^l - \sum_{k=1}^{t} \binom{2t+1}{k} p^k (1-p)^{2t+1-k} &\geq 0 \\
\sum_{l=1}^{t} \binom{2t+1}{l} \left(p^{2t+1-l}(1-p)^l - p^l(1-p)^{2t+1-l} \right) &\geq 0.
\end{aligned}$$

For every $l = 1, ..., t$, we have $2t+1-l > l$. This implies for the expression in brackets that the first product $(p^{2t+1-l}(1-p)^l)$ is larger than the second product $(p^l(1-p)^{2t+1-l})$. Hence, the inequality above holds, which implies inequality A.13. Thus, $EU(\hat{\sigma}^t) \geq EU(\tilde{\sigma}^t)$ and hence this deviation $\tilde{\sigma}^t$ is not beneficial.

Using the same techniques as for the this deviation, we can show for all six deviations $\tilde{\sigma}^t$ that $EU(\tilde{\sigma}^t) \leq EU(\hat{\sigma}^t)$.[43] Hence, no deviation that involves both stages communication and voting is profitable.

□

A.1.4 Multiplicity

In the sincere strategy profile $\hat{\sigma}$, all communication channels, i.e. links in g, are used. Generally, the information transmission network g^* under some strategy profile σ need not coincide with the exogenous network g, but can be any subnetwork ($g^* \subseteq g$) of it, which uses some but not necessarily all of the given communication channels (cf. online Appendix B.3). For instance, any network g that contains a subnetwork $g' \subseteq g$ which satisfies strong balancedness admits an efficient equilibrium by using the subnetwork as communication network, i.e., $g^* = g'$. Our model extension admits denser networks g and hence gives rise to many more information transmission networks $g^* \subseteq g$ than our baseline model. As a consequence, coordination on an efficient equilibrium might become even harder than in the baseline model.

Private versus public communication. With overlapping audiences, we can not only model private communication but also public communication. Communication is fully public if the network g is complete ($g = g^V$), i.e., every voter is linked to every other voter. In that case, the sincere strategy profile $\hat{\sigma}$ is efficient and an equilibrium. In this *deliberation equilibrium* the optimal alternative can be deduced by every voter such that this information aggregation within each individual determines votes unanimously (and other voting rules than the majority rule would also admit a similar equilibrium, cf. Gerardi and Yariv, 2007). More generally, in every network g, in which a non-empty subset S of voters is linked to all experts, there are efficient equilibria in which the members of S vote for the more likely alternative. This is how public communication admits efficient information aggregation in the communication stage.

[43] These derivations can be found in online Appendix B.6.

At the other extreme of the spectrum, communication can be fully private as in the model studied in section 2, i.e. when the network g is bipartite and voters in one group (the non-experts) have at most degree one. There each voter holds at most one piece of information after communication such that information aggregation can only occur in the voting stage. Arguably, in reality communication is neither fully public nor fully private. Receiving multiple messages and an own signal leads to information aggregation already in the communication stage. Participation in a majority election further aggregates information in the voting stage. Whether such institutions are efficient depends on the balancedness of the social network.

A.2 Tables

Table 1a. Observations

treatment	groups	experts	non-experts	senders	receivers
empty	210	1,050	840	0	0
strongly balanced	210	1,050	840	840	840
weakly balanced	210	1,050	840	420	840
star	210	1,050	840	210	840
Total	840	4,200	3,360	1,470	2,520

Table 1a: Number of observations in Study I. Senders are experts who are in a network position with an audience. Non-experts are receivers if they are linked to a sender.

Table 1b. Observations

treatment	groups	experts	non-experts	senders	receivers
empty	200	600	800	0	0
weakly balanced	200	600	800	347	800
unbalanced	200	600	800	178	800
star	200	600	800	83	800
Total	800	2,400	3,200	608	2,400

Table 1b: Number of observations in Study II. Senders are experts who are in a network position with an audience. The number of partisan senders is not displayed. Non-experts are receivers if they are linked to a sender (expert or partisan).

Table 2a. Behavior of non-experts

	vote message	vote opposite	vote uninformed	sincere
empty	-	-	265	*575*
($N = 840$)	-	-	31.6%	*68.5%*
s. balanced	577	52	29	664
($N = 840$)	79.7%	7.2%	25.0%	79.1%
w. balanced	480	37	49	609
($N = 840$)	72.5%	5.6%	27.5%	72.5%
star	286	66	108	470
($N = 840$)	52.2%	12.0%	37.0%	56.0%
Total	1,343	155	451	2,318
($N = 3,360$)	69.4%	8.0%	31.6%	69.0%

Table 2a: Behavior of non-experts by treatment in Study I. In the empty network all non-experts are uninformed. In the other networks this happens only if an expert sender chose the empty message. The action 'vote message' means that A (B) is voted after message A (B) has been received. In addition to the displayed categories 'vote message' and 'vote opposite' non-experts who received message A or B could abstain. In addition to the displayed category 'vote uninformed' non-experts who received an empty message could abstain. Non-experts with no message or an empty message are sincere if they abstain. Non-experts with message A (B) are sincere if they vote A (B).

Table 2b. Behavior of non-experts

	vote message	vote opposite	vote uninformed	sincere
empty	-	-	220	*580*
($N = 800$)	-	-	27.5%	*72.5%*
weakly balanced	540	37	6	557
($N = 800$)	69.5%	4.8%	26.1%	69.6%
unbalanced	417	61	11	438
($N = 800$)	54.3%	7.9%	34.4%	54.8%
position 1-3	278	52	9	293
($N = 600$)	48.3%	9.0%	37.5%	48.8%
position 4	139	9	2	145
($N = 200$)	72.4%	4.7%	25.0%	72.5%
star	360	59	7	377
($N = 800$)	46.4%	7.6%	29.2%	47.1%
Total	1,317	157	244	1,952
($N = 3,200$)	56.7%	6.76%	27.8%	61.0%

Table 2b: Behavior of non-experts by treatment (and position) in Study II. The network positions in the unbalanced network refer to Figure 3. In the empty network all non-experts are uninformed. In the other networks this happens only in 79 cases, where an expert sender chose the empty message. The action 'vote message' means that A (B) is voted after message A (B) has been received. In addition to the displayed categories 'vote message' and 'vote opposite' non-experts who received message A or B could abstain. In addition to the displayed category 'vote uninformed' non-experts who received an empty message could abstain. Non-experts with no message or an empty message are sincere if they abstain. Non-experts with message A (B) are sincere if they vote A (B).

Table 3a. Dependent variable: Following of non-experts

	Logit 1		Logit 2	
Variable	Coefficient	(Std. Err.)	Coefficient	(Std. Err.)
strongly balanced	0.398	(0.266)	0.358	(0.227)
star	-0.882***	(0.160)	-0.730***	(0.160)
Intercept	0.970***	(0.249)	0.969***	(0.211)
N	1,934		2,520	
Log-likelihood	-1133.96		-1501.53	
Wald $\chi^2_{(2)}$	83.96		49.45	
p-value Wald test	0.000		0.000	

$^{*}p < 0.10, ^{**}p < 0.05, ^{***}p < 0.01$

Table 3a: Estimation results for Study I: Logistic regression with decision to follow message as dependent variable. Robust standard errors in parentheses adjusted for sessions. Baseline category is the weakly balanced network. Model 1 restricts attention to non-experts who received message A or B. Model 2 also considers non-experts who received an empty message, for which following means abstention. Following coincides with sincere behavior of non-experts.

Table 3b. Dependent variable: Following of non-experts

	Logit 1		Logit 2	
Variable	Coefficient	(Std. Err.)	Coefficient	(Std. Err.)
unbalanced	-0.651***	(0.229)	-0.639***	(0.218)
star	-0.968***	(0.296)	-0.945***	(0.272)
Intercept	0.824***	(0.136)	0.830***	(0.131)
N	2,321		2,400	
Log-likelihood	-1543.26		-1595.30	
Wald $\chi^2_{(2)}$	11.07		13.10	
p-value Wald test	0.004		0.001	

$^{*}p < 0.10, ^{**}p < 0.05, ^{***}p < 0.01$

Table 3b: Estimation results for Study II: Logistic regression with decision to follow message as dependent variable. Robust standard errors in parentheses adjusted for sessions. Baseline category is the weakly balanced network. Model 1 restricts attention to non-experts who received message A or B. Model 2 also considers non-experts who received an empty message, for which following means abstention. Following coincides with sincere behavior of non-experts.

Table 4a. Individual sincere behavior of non-experts by position

	never	always	s. balanced	w. balanced	star
s. balanced	4.8%	57.1%		0.127	0.000
w. balanced	8.33%	46.43%			0.000
star	23.8%	29.8%			
empty	*19.1%*	*54.8%*	*0.033*	*0.545*	*0.032*
s. balanced	1.2%	51.2%		0.008	0.000
w. balanced	0.0%	31.0%			0.000
star	1.2%	16.7%			

Table 4a: Individual behavior of non-experts by position in Study I: for each individual in each network position (he is in) there is a variable capturing the frequency of sincere actions. The first block restricts attention to instances in which a non-empty message is received and thus reports on following of non-empty vote recommendations. The second block considers all ten decisions of each individual in each position. In the empty network a non-expert never receives a message. Column 2 and 3 report the fraction of participants who *never* respectively *always* chose the sincere strategy in the given position. Columns 4-6 of the table show the p-values of Wilcoxon matched-pairs signed-ranks test.

Table 4b. Individual sincere behavior of non-experts by position

	never	always	empty	w. balanced	unbalanced	star
w. balanced	15.0%	46.3%				0.000
unbalanced *pos. 4*	20.3%	60.8%		0.855		0.000
unbalanced *pos. 1-3*	33.8%	30.0%		0.000	0.001[a]	0.533
star	32.5%	25.0%				
empty	*17.5%*	*60.0%*		*0.572*		*0.001*
w. balanced	11.3%	43.8%				0.000
unbalanced *pos. 4*	17.6%	59.5%	0.873	0.964		0.000
unbalanced *pos. 1-3*	22.5%	25.0%	0.003	0.000	0.001[a]	0.444
star	21.3%	18.8%				

Table 4b: Individual behavior of non-experts by position in Study II: for each individual in each network position (he is in) there is a variable capturing the frequency of sincere actions. The network positions in the unbalanced network refer to the lower panel of Figure 3. Non-experts in position 4 are linked to a sender with degree one (similar to the weakly balanced network); non-experts in positions 1-3 are linked to a sender with degree three (similar to the star network). The first block restricts attention to instances in which a non-empty message is received and thus reports on following of non-empty vote recommendations. The second block considers all decisions of each individual in each position. In the empty network a non-expert never receives a message. Column 2 and 3 report the fraction of participants who *never* respectively *always* chose the sincere strategy in the given position. Columns 4-6 of the table show the p-values of Wilcoxon matched-pairs signed-ranks test.
Note a: This is the comparison between non-experts in network positions 1-3 and network position 4 in the unbalanced treatment.

Table 5a. Behavior of experts

	vote signal	vote opposite	send signal	send opposite	sincere
empty	919	62	-	-	*919*
($N = 1,050$)	87.5%	5.9 %	-	-	*87.5%*
strongly balanced	884	75	671	53	798
($N = 1,050$)	84.2%	7.1%	79.9%	6.3%	76.0%
weakly balanced	878	74	301	30	803
($N = 1,050$)	83.6%	7.1%	71.7%	7.1%	76.5%
star	854	84	128	9	794
($N = 1,050$)	81.3%	8.0%	61.0%	4.3%	75.6%
Total	3,535	295	1,100	92	3,314
($N = 4,200$)	84.2%	7.0%	74.8%	6.3 %	78.9%

Table 5a: Behavior of experts by treatment in Study I. The action 'vote (send) opposite' means vote (send message) A when signal is B^* and vice versa. In addition to the displayed categories 'vote signal' and 'vote opposite' experts could abstain. In addition to the displayed categories 'send signal' and 'send opposite' experts could send an empty message. Experts without an audience are sincere if they vote their signal. Experts with an audience are sincere if they vote their signal and also send it.

Table 5b. Behavior of experts

	vote signal	vote opposite	send signal	send opposite	sincere
empty	560	21	-	-	*560*
($N = 600$)	93.3%	3.5%	-	-	*93.3%*
weakly balanced	550	31	309	15	530
($N = 600$)	91.7%	5.2%	89.1%	4.3%	88.3%
unbalanced	552	22	158	4	534
($N = 600$)	92.0%	3.7%	88.8%	2.3%	89.0%
star	556	27	76	1	550
($N = 600$)	92.7%	4.5%	91.6%	1.2%	91.7%
Total	2,218	101	543	20	2,174
($N = 2,400$)	92.4%	4.2%	89.3%	3.3%	90.6%

Table 5b: Behavior of experts by treatment in Study II. The action 'vote (send) opposite' means vote (send message) A when signal is B^* and vice versa. In addition to the displayed categories 'vote signal' and 'vote opposite' experts could abstain. In addition to the displayed categories 'send signal' and 'send opposite' experts could send an empty message. Experts without an audience are sincere if they vote their signal. Experts with an audience are sincere if they vote their signal and also send it.

Table 6a. Sincere senders

	Logit 1: Send Signal		**Logit 2: Sincere**	
Variable	Coefficient	(Std. Err.)	Coefficient	(Std. Err.)
strongly balanced	0.451***	(0.175)	0.505***	(0.115)
star	-0.483**	(0.191)	-0.486***	(0.159)
Intercept	0.928***	(0.189)	0.619***	(0.122)
N	1,470		1,470	
Log-likelihood	-812.55		-884.94	
Wald $\chi^2_{(2)}$	9.33		19.24	
p-value Wald test	0.009		0.000	

$^{*}p < 0.10, ^{**}p < 0.05, ^{***}p < 0.01$

Table 6a: Estimation results for Study I: Logistic regression sincere senders by treatment. Senders are experts with at least one link. Dependent variable in Model 1 is 'send signal,' which is 1 if the expert's message equals her signal (and zero otherwise). Dependent variable in Model 2 is sincere behavior, which equals 1 if sender both sends and votes her signal. Robust standard errors in parentheses adjusted for sessions. Baseline category is the weakly balanced network.

Table 6b. Sincere senders

Variable	Logit 1: Send Signal Coefficient	(Std. Err.)	Logit 2: Sincere Coefficient	(Std. Err.)
unbalanced	-0.029	(0.264)	0.080	(0.301)
star	0.289	(0.356)	0.506	(0.366)
Intercept	2.096***	(0.320)	1.878***	(0.235)
N	608		608	
Log-likelihood	-206.44		-226.34	
Wald $\chi^2_{(2)}$	1.49		6.95	
p-value Wald test	0.475		0.031	

$^{*}p < 0.10, ^{**}p < 0.05, ^{***}p < 0.01$

Table 6b: Estimation results for Study II: Logistic regression sincere senders by treatment. Senders are experts with at least one link. Dependent variable in Model 1 is 'send signal,' which is 1 if the expert's message equals her signal (and zero otherwise). Dependent variable in Model 2 is sincere behavior, which equals 1 if sender both sends and votes her signal. Robust standard errors in parentheses adjusted for sessions. Baseline category is the weakly balanced network. Observe that Model 1 is not well-specified according to Wald test.

Table 7a. Strategy profiles

	LTED σ^*	almost LTED	sincere $\hat{\sigma}$	almost sincere	explained
empty (N=210)	11.0%	41.4%			81.9%
strongly balanced[a] (N=210)	0.0%	2.4%	10.0%	35.2%	81.0%
weakly balanced (N=210)	1.0%	5.7%	7.6%	27.6%	82.9%
star (N=210)	2.4%	12.4%	2.4%	13.8%	90.5%
Total (N=840)	3.6%	15.5%	6.7%	25.6%	84.0%

Table 7a: Frequency of strategy profiles. A group plays "almost" a strategy profile if there is at most one player whose strategy differs from the profile. An outcome is explained if the actual outcome in a group (i.e. majority decision A or B) is predicted by at least one of the two strategy profiles, given the distribution of signals.
Note a: For the strongly balanced network there is another equilibrium besides LTED and sincere, which is played with frequency 11.0%. This strategy profile differs from the sincere strategy profile in that one of the four non-experts abstains. In online Appendix B.3 this equilibrium is denoted by $v_1, r = 3$ and illustrated in Figure B.1, Panel (a). All other equilibria, which are also characterized in online Appendix B.3, have empirical frequency 0.0%, i.e. they are never played in any group. Therefore they are not listed in this table.

Table 7b. Strategy profiles

	LTED σ^*	almost LTED	sincere $\hat{\sigma}$	almost sincere	explained
empty (N=200)	21.5%	62.5%			83.0%
weakly balanced (N=200)	0.0%	5.5%	16.0%	51.0%	89.5%
unbalanced (N=200)	1.5%	13.5%	3.0%	31.5%	94.5%
star (N=200)	5.5%	21.5%	5.5%	26.5%	95.5%
Total (N=800)	7.1%	25.8%	8.2%	36.3%	90.6%

Table 7b: Frequency of strategy profiles. A group plays "almost" a strategy profile if there is at most one player whose strategy differs from the profile. An outcome is explained if the actual outcome in a group (i.e. majority decision A or B) is predicted by at least one of the two strategy profiles, given the distribution of signals.

Table 8a. Fisher exact tests on almost σ^*

	strongly balanced	weakly balanced	star
empty	0.000	0.000	0.000
strongly balanced		0.135	0.000
weakly balanced			0.026

Table 8a: p-values of Fisher exact tests comparing the frequency of the "LTED" strategy profile σ^* between two treatments in Study I. A group plays "almost" σ^* if there is at most one player whose strategy differs from the profile.

Table 8b. Fisher exact tests on almost σ^*

	weakly balanced	unbalanced	star
empty	0.000	0.000	0.000
weakly balanced		0.010	0.000
unbalanced			0.048

Table 8b: p-values of Fisher exact tests comparing the frequency of the "LTED" strategy profile σ^* between two treatments in Study II. A group plays "almost" σ^* if there is at most one player whose strategy differs from the profile.

Table 9a. Fisher exact tests on almost $\hat{\sigma}$

	weakly balanced	star
strongly balanced	0.115	0.000
weakly balanced		0.001

Table 9a: p-values of Fisher exact tests comparing the frequency of the sincere strategy profile $\hat{\sigma}$ between two treatments (in the empty network $\hat{\sigma}$ cannot be played) in Study I. A group plays "almost" $\hat{\sigma}$ if there is at most one player whose strategy differs from the profile.

Table 9b. Fisher exact tests on almost $\hat{\sigma}$

	unbalanced	star
weakly balanced	0.000	0.000
unbalanced		0.321

Table 9b: p-values of Fisher exact tests comparing the frequency of the sincere strategy profile $\hat{\sigma}$ between two treatments (in the empty network $\hat{\sigma}$ cannot be played) in Study II. A group plays "almost" $\hat{\sigma}$ if there is at most one player whose strategy differs from the profile.

Table 10a. Fisher exact tests on efficiency

	strongly balanced	weakly balanced	star
empty	0.299	0.543	0.170
strongly balanced		0.705	0.117
weakly balanced			0.429

Table 10a: p-values of Fisher exact tests comparing efficiency between two treatments in Study I. Efficiency is 1 if majority signal wins, 0 in case of a tie, and -1 if majority signal loses.

Table 10b. Fisher exact tests on efficiency

	weakly balanced	unbalanced	star
empty	0.323	0.022	0.002
weakly balanced		0.219	0.007
unbalanced			0.244

Table 10b: p-values of Fisher exact tests comparing efficiency of two treatments in Study II. Efficiency is 1 if majority signal wins, 0 in case of a tie, and -1 if majority signal loses.

Table 11a. Dependent variable: Efficiency

	ologit 1		**ologit 2**	
Variable	Coeff.	(Std. Err.)	Coeff.	(Std. Err.)
empty			-0.016	(0.185)
strongly balanced	0.110	(0.265)	0.095	(0.238)
weakly balanced	0.016	(0.185)		
star	-0.236*	(0.141)	-0.252	(0.174)
uniform signal	3.173***	(0.593)	3.173***	(0.593)
almost uniform signal	1.579***	(0.367)	1.579***	(0.367)
Intercept cut 1	-1.296	(0.110)	-1.311	(0.152)
Intercept cut 2	-0.492	(0.121)	-0.508	(0.126)
N	840		840	
Log-likelihood	-580.612		-580.612	

$^{*}p < 0.10,^{**}p < 0.05,^{***}p < 0.01$

Table 11a: Estimation results for Study I: Ordered logit. Efficiency is 1 if majority signal wins, 0 in case of a tie, and -1 if majority signal loses. Robust standard errors in parentheses adjusted for sessions. Less clusters than parameters simply mean that joint significance (Wald test) cannot be tested. The first model uses the empty network as baseline category. The second model uses the weakly balanced network as baseline category.

Table 11b. Dependent variable: Efficiency

	ologit 1		**ologit 2**	
Variable	Coeff.	(Std. Err.)	Coeff.	(Std. Err.)
empty			-0.059	(0.140)
weakly balanced	0.059	(0.140)		
unbalanced	-0.276*	(0.164)	-0.335	(0.210)
star	-0.711**	(0.319)	-0.770***	(0.243)
uniform signal	2.027***	(0.135)	2.027***	(0.135)
Intercept cut 1	-1.611	(0.208)	-1.670	(0.251)
Intercept cut 2	-0.572	(0.122)	-0.631	(0.179)
N	800		800	
Log-likelihood	-513.262		-513.262	

$^{*}p < 0.10,^{**}p < 0.05,^{***}p < 0.01$

Table 11b: Estimation results for Study II: Ordered logit. Efficiency is 1 if majority signal wins, 0 in case of a tie, and -1 if majority signal loses. Robust standard errors in parentheses adjusted for sessions. Less clusters than parameters simply mean that joint significance (Wald test) cannot be tested. The first model uses the empty network as baseline category. The second model uses the weakly balanced network as baseline category.