Heterogeneity and Unanimity: Optimal Committees with Information Acquisition*

Xin Zhao†

Economics Discipline Group, University of Technology Sydney

October 6, 2018

Abstract

This paper studies how the composition and voting rule of a decision-making committee affect the incentives for its members to acquire information. Fixing the voting rule, a more polarized committee acquires more information. If a committee designer can choose the committee members and voting rule to maximize her payoff from the collective decision, she forms a heterogeneous committee adopting a unanimous rule, in which one member moderately biased toward one decision serves as the decisive voter, and all others are extremely opposed to the decisive voter and serve as information providers. The preference of the decisive voter is not perfectly aligned with that of the designer.

Keywords: Committee design, information acquisition, heterogeneity, voting

JEL classification: C79, D71

*I am indebted to Martin J. Osborne, Xianwen Shi, and Colin Stewart for their guidance, encouragement, and persistent support throughout this project. I also thank Heski Bar-Isaac, Gustavo Bobonis, Jimmy Chan, Gonzalo Cisternas, Ettore Damiano, Rahul Deb, Deniz Dizdar, Kfir Eliaz, Jacob Goeree, Yingni Guo, Helios Herrera, Sean Horan, Tai-Wei Hu, Byung Soo Lee, Fei Li, Li Hao, Jianpei Li, Philippos Louis, Juan Ma, Matthew Mitchell, Huihua Nie, Marcin Pęski, Yuval Salant, Xi Weng, Suen Wing, Huseyin Yildirim, and participants in the theory workshop at the University of Toronto, the seminars at UIBE, Renmin University of China, Fudan University, and JXUFE, the brownbag seminar at the University of Hong Kong, CEA Annual Conference 2015, and Stony Brook Game Theory Conference 2015 for their invaluable suggestions and comments.

†E-mail: xin.zhao@uts.edu.au

1 Introduction

Committees are commonly employed to make important economic, political, and business decisions. In many situations, a decision-making committee is composed by an empowered individual, or committee designer. For instance, a city mayor may appoint an *ad hoc* committee to deal with a particular issue, and a manager or chair of an organization may form a hiring committee to screen and select job candidates. In these situations, how should the designer choose the membership of the committee, and what voting rule should the committee employ?

In this paper, I study how the composition and voting rule of a decision-making committee affect the incentives for its members to acquire information (and thus the quality of its collective decision), and characterize the optimal committee design when the designer can choose both the members and the voting rule. I find that when the voting rule is fixed, a more polarized committee acquires more information in equilibrium. To maximize her expected payoff from the collective decision, the designer will form a heterogeneous committee that adopts a unanimous rule. The heterogeneous committee consists of two types of members who have opposing interests.

The committee in the model makes a binary decision. All of its members share a common goal: matching their decision with the value of a binary underlying state. Because information about the state is imperfect, two kinds of erroneous decision can be made. The committee members differ in their losses from the two possible errors, so they have heterogeneous preferences over the decisions. The collective decision is made through voting. Prior to voting, each member can unilaterally make continuous efforts to acquire a continuous signal about the state. I focus the analysis on the case where all the information acquired is publicly observable, to exclude issues related to strategic information transmission between the members.

A member's incentive to acquire information has two components. The first component is the *incentive to prevent errors*: a member would like to have more information to reduce the probability of making an erroneous decision. This incentive exists regardless of the composition of the committee. The second component is the *incentive to reduce disagreement*. This appears only in heterogeneous committees. Consider a member who has an extreme preference for one decision over the other. If he wants to increase the probability that another member—who has an opposite but non-extreme preference—votes for his favorite decision, he will provide that member with more precise information to induce a larger response and thus make that member more likely to switch from his initially preferred decision. The magnitudes of the two incentives above are affected by the *incentive to free ride*: when other members are present and acquired information is shared within the committee prior to the final decision, a member's incentive to collect information decreases if other members acquire information, as information is a public good that is costly to obtain.

The two components above, incentive to prevent errors and incentive to reduce disagreement, depend on the preferences of all committee members and the voting rule used by the committee. However, I find that regardless of the voting rule, there is always a monotonic relationship between the preferences of the members and their incentives to acquire information in equilibrium: when the voting rule favors one of the alternatives (in a sense that will be made clear), the members who lean more toward the other alternative have a stronger incentive to acquire information. This monotonicity is primarily due to the incentive to reduce disagreement. If the voting rule favors one alternative, a member who prefers the other alternative would like to make the aggregate information available to the group more informative, to increase the probability that the members leaning toward the alternative favored by the voting rule switch their votes to his preferred decision.

The monotonicity result implies that if we make the committee members more polarized while fixing the voting rule, the members who dislike the decision favored by the voting rule have more incentive to acquire information, and the ones who prefer the decision favored by the voting rule have less incentive to acquire information. I show that the former effect dominates the latter effect, so the aggregate information acquired by the committee increases with the degree of polarization.

The voting rule, though irrelevant for the monotonicity result, is crucial for the direction of the monotonicity, because it determines which decision is favored and to what extent that decision is favored. In practice, unanimity is often required to make collective decisions. In this paper, I show that unanimous rules may not be optimal in incentivizing information acquisition. The intuition is that when we increase the number of votes required to implement one decision, the other decision becomes more favored by the voting rule, and the members leaning toward the other decision have less incentive to acquire information. This may lead the aggregate information acquired to decrease.

If a committee designer can freely choose the committee members and voting rule, how will she design the committee? An optimal committee turns out to have the following features. First, voting is unanimous: one alternative is endogenously chosen as the *status quo* and unanimity is required to overturn it. Second, the committee consists of two types of members: one member favors the *status quo*, and all others are extremely opposed to the *status quo*. Given the unanimity requirement, the single member favoring the *status quo* is decisive, and the rest of the members are mainly responsible for providing information. The monotonicity result regarding the preferences and incentive to acquire information intuitively explains why, at the optimum, the information collectors should have extreme preferences against the *status quo*. Third, the decisive member's preferences are typically not perfectly aligned with the designer's preferences. This indicates that sometimes a collective decision made by an optimal committee based on acquired information may differ from the one desired by the designer. This is because having a decisive member not aligned with her may incentivize other members to acquire more information and improve the precision of the final decision. After characterizing the optimal committees, I show that it is always optimal for the designer to delegate the decision to the designed committee, even if she can perfectly observe all the information acquired by the group.

In this paper, I use a Gaussian information structure to model the information acquisition behavior of committee members, in which every committee member has access to a signal normally distributed conditional on the true state. Members choose the precisions of their signals, and the information cost is linear in the precision. In Section 5, I extend the model to allow for convex cost and show that for the committee design problem, the main ideas carry over. In Section 6, I examine the case in which the information acquired by each member is private.

2 Related Literature

This paper is related to the literature on decision-making committees with endogenous information. Unlike this paper, most of this literature assumes that committee members are *ex ante* identical. Li (2001) and Gershkov and Szentes (2009) study *ex ante* efficient decision rules. Li (2001) finds that a distortionary decision rule that is more conservative than the *ex post* efficient one can mitigate the free-riding problem in information acquisition and improve *ex ante* efficiency. Gershkov and Szentes (2009) examine the socially optimal decision rule from a mechanism design perspective. The current paper focuses on standard voting rules, and examines their roles in information acquisition, instead of social efficiency.

Persico (2004) and Gerardi and Yariv (2008a) study homogeneous committee design with endogenous information, taking the size and decision rule of the committee as the choice variables. In both papers, each committee member can purchase a binary signal with fixed precision. Persico (2004) shows that the optimal committee adopts the *ex post* efficient voting rule, which aggregates all acquired information. This voting rule requires a high level of agreement to overturn the *status quo* only if the signals available to the committee members are very precise. Compared with Persico (2004), Gerardi and Yariv (2008a) consider more general decision rules that allow communication among the voters. They find that the *ex ante* optimal decision rule may be *ex post* inefficient. I allow each member to choose the precision of his signal, and allow the committee to be heterogeneous.

The impact of heterogeneity—either in preferences and in priors—among the members of a decision-making group on the information acquisition behavior of group members has been studied in the literature. Chan et al. (2015) employ a dynamic model to study the impact of *preference heterogeneity* on a collective decision-making process. In their paper, costly information acquisition is modeled as a collective stopping problem—public information keeps arriving over time until the committee collectively decides to stop it. They demonstrate that greater heterogeneity in committee members' preferences can induce a more stringent stopping rule, and consequently more information acquisition on average. I have a similar result regarding the impact of preference heterogeneity on information acquisition, but my result is due to the increased incentives of some members to reduce disagreement and prevent errors when preference heterogeneity increases.

Che and Kartik (2009), Van den Steen (2010), and Hirsch (2015) study decision-making groups consisting of a decision maker and an information provider. They all show that when the decision maker and an information collector have *heterogeneous priors*, there exists a "persuasion effect" that incentivizes the information provider to acquire more information than in the case of a common prior. This persuasion effect is similar to the *incentive to reduce disagreement* studied in the current paper. A key difference is that the former appears only when there is prior heterogeneity, whereas the latter exists regardless of whether the heterogeneity of committee members is in prior, or preference, or both. I study how a committee designer exploits the incentive to reduce disagreement when designing a decision-making committee with many members.

Another strand of literature related to this paper is the one on advisory committees, or informational committees, with information acquisition. Unlike a decision-making committee, an advisory committee has no decision power, but provides information to a decision maker. Gerardi and Yariv (2008b) find that the optimal advisory committee for a decision maker is composed of identical members whose preferences are opposed to that of the decision maker. Beniers and Swank (2004) study the relationship between the magnitude of the cost of information and optimal committee composition. They find that when the cost of information is low, the optimal committee is homogeneous; when the cost of information is high, the optimal committee is heterogeneous. Cai (2009) shows that more uncertainty in other members' preferences may raise one member's incentive to acquire information.

3 Model

Suppose that an n-member committee is assembled to collectively decide to accept, A, or reject, R, a proposal. A random variable $\theta \in \{0, 1\}$ captures the quality of the proposal, with $\theta = 0$ meaning that the proposal should be accepted and $\theta = 1$ meaning that the proposal should be rejected. The payoff of each member depends on the collective decision $d \in \{A, R\}$ and θ. Specifically, the payoff function $u_i : \{A, R\} \times \{0, 1\} \to \mathbb{R}$ of member $i = 1, \ldots, n$ is given by

$$u_i(A,0) = 0, \qquad u_i(R,1) = 0,$$
$$u_i(A,1) = -(1-q_i), \qquad u_i(R,0) = -q_i,$$

where $q_i \in [0,1]$ for all i. That is, the payoffs of the member from correct decisions (correctly accepting the proposal or correctly rejecting the proposal, i.e., $(d,\theta) \in \{(A,0),(R,1)\}$) are normalized to 0, the loss from false acceptance is $1-q_i$, and the loss from false rejection is q_i. Let $\mathbf{q} = (q_1, q_2, \ldots, q_n)$ denote the preference profile of the committee. I assume that $\mathbf{q}$ is common knowledge.

Committee members can differ in their preferences. Without loss of generality, I assume, throughout the paper, that

$$q_1 \leq q_2 \leq \ldots \leq q_{n-1} \leq q_n. \tag{1}$$

This assumption implies that a lower indexed member (weakly) leans more toward rejection than does a higher indexed member, as his loss from false rejection is smaller.

Two points are worth mentioning regarding the members' preferences. Firstly, whenever there is perfect information about the true state, members have no conflicts over the final decision, as all of them would like to make the correct decision. Secondly, the sum of a member's losses from the two types of errors is normalized to 1, so the heterogeneity in the members lies only in their relative concerns over the two types of error.

Members have a common prior over the state θ, with

$$\Pr(\theta = 1) = 1 - \Pr(\theta = 0) = \gamma,$$

where $\gamma \in (0,1)$. Given this prior, if $q_i < \gamma$, member i would prefer to reject the proposal, as $(1-q_i)\gamma > q_i(1-\gamma)$. We call this member pro-rejection. Similarly, if $q_i > \gamma$, we say that the member is pro-acceptance.[1]

Prior to making the final decision, each member i acquires a signal s_i, which has the structure

$$s_i = \theta + \varepsilon_i, \text{ where } \varepsilon_i \sim N(0, 1/\rho_i), \forall i,$$

where ρ_i represents the precision of signal s_i. Member i chooses the value of ρ_i, incurring the cost $C(\rho_i)$. Besides the costly signals, the committee has access to a free signal s_0, which has the same structure as the other signals and has fixed precision ρ_0. I assume that $s_0, s_1, s_2, \ldots, s_n$ are independent conditional on θ.

[1] The common prior assumption is standard in the literature on committees. Although assuming heterogeneous priors would complicate the analysis, the main insights would carry over if we reparameterize the model and assume that the *expected losses* of a member from the two types of error are summed up to be a constant, which is invariant across committee members.

The free public signal s_0 is important for the analysis. I need to assume that s_0 exists and is sufficiently precise to avoid a non-concavity issue in members' expected payoffs (see Assumption 3).[2]

Furthermore, I impose the following assumption for the rest of the analysis. The public observability of the signals excludes the issue of strategic information transmission among the members and enables us to focus on the role of information acquisition in committee decision-making. The public observability of the precision profile gives rise to the incentive to reduce disagreement, an important component of members' incentives to acquire information that can appear only in heterogeneous committees. In Section 6, I extend the analysis to the case in which the information acquired by each member is private and discuss the conditions under which the main results carry over.

Assumption 1 *The precision profile* $(\rho_0, \rho_1, \rho_2, \ldots, \rho_n)$ *and realization of* $(s_0, s_1, s_2, \ldots, s_n)$ *are observable to all members.*

Given $(\rho_0, \rho_1, \rho_2, \ldots, \rho_n)$ and $(s_0, s_1, s_2, \ldots, s_n)$, I define the "aggregate signal",

$$s = \frac{\sum_{i=0}^{n} \rho_i s_i}{\rho},$$

where $\rho = \sum_{i=0}^{n} \rho_i$. This signal has distribution $N(\theta, 1/\rho)$ conditional on θ. Let $F_1(s|\rho)$ and $F_0(s|\rho)$ respectively denote the cumulative distribution functions of s conditional on $\theta = 1$ and $\theta = 0$, and let $f_1(s|\rho)$ and $f_0(s|\rho)$ denote the corresponding density functions. Given Assumption 1 and the properties of a Gaussian information structure, each member's preferred decision depends only on s.[3] Specifically, member $i = 1, \ldots, n$ prefers to reject the

[2]In reality, decision-making committees are usually provided with information additional to the information acquired by themselves before they make the final decisions. For example, in a jury trial, before the jury determines the verdict, the judge sometimes provides the jury with a summary of the facts. In regular meetings of the Federal Open Market Committee of Federal Reserve, prior to determining the monetary policies for the upcoming periods, the staff of the Federal Reserve present information concerning "business and credit conditions and domestic and international economic and financial developments as will assist the committee in the determination of the open market policies." See Federal Open Market Committee Rules of Organization, as amended effective January 27, 2015. http://www.federalreserve.gov/monetarypolicy/rules_authorizations.htm

[3]When observing $(\rho_0, \rho_1, \rho_2, \ldots, \rho_n)$ and $(s_0, s_1, s_2, \ldots, s_n)$, member i prefers to reject the proposal if and only if

$$q_i(1-\gamma)\prod_{i=0}^{n} f_{0,i}(s_i|\rho_i) \leq (1-q_i)\gamma \prod_{i=0}^{n} f_{1,i}(s_i|\rho_i),$$

where $f_{1,i}(s_i|\rho_i)$ and $f_{0,i}(s_i|\rho_i)$ represent the density functions of signal s_i conditional on $\theta = 1$ and $\theta = 0$. This inequality is equivalent to

$$\frac{q_i(1-\gamma)}{(1-q_i)\gamma} \leq \prod_{i=0}^{n} \frac{f_{1,i}(s_i|\rho_i)}{f_{0,i}(s_i|\rho_i)} = \frac{f_1(s|\rho)}{f_0(s|\rho)},$$

where the equality is based a property of the normal distribution that can be proved using simple algebra.

proposal if and only if $s \geq \underline{s}_i(\rho)$, where $\underline{s}_i(\rho)$ satisfies

$$(1-q_i)\,\gamma f_1\left(\underline{s}_i(\rho)\,|\rho\right) = q_i\,(1-\gamma)\,f_0\left(\underline{s}_i(\rho)\,|\rho\right). \tag{2}$$

Thus, $\underline{s}_i(\rho)$ is the value of s at which the expected losses of member i from the two possible errors are equal, and the inequality $s \geq \underline{s}_i(\rho)$ indicates that the loss of member i from false acceptance is not smaller than that from false rejection.[4] From equation (2), we have

$$\underline{s}_i(\rho) = \frac{1}{2} + \frac{1}{\rho}\ln\frac{q_i\,(1-\gamma)}{(1-q_i)\,\gamma}. \tag{3}$$

Since $\rho > 0$, it is obvious that $\underline{s}_i(\rho)$ is increasing in q_i. This is intuitive, because a member more concerned with false rejection is more reluctant to vote for rejection. Given (1), $\underline{s}_i(\rho)$ is increasing in i. To simplify the notation, in the rest of the analysis I write $\underline{s}_i$ rather than $\underline{s}_i(\rho)$.

After the signals are realized, members vote to determine the collective decision. I focus on voting rules that take acceptance as the *status quo* and require k votes to reject the proposal, with $1 \leq k \leq n$. I call k the voting threshold. The assumption below allows us to focus on a reasonable set of voting strategies.

Assumption 2 *At the voting stage, no member uses a weakly dominated strategy.*

Given this assumption, each member i votes for rejection if and only if $s \geq \underline{s}_i$. Thus, when the voting threshold is k, member k becomes a decisive voter: the proposal is rejected if and only if $s \geq \underline{s}_k$. This implies that voting with threshold k is equivalent to delegating the decision to voter k, in terms of equilibrium outcomes.

The goal of this paper is to study the equilibrium features of information acquisition in heterogeneous committees. Some of the features depend on the properties of the cost function $C(\rho_i)$. I first illustrate the main results using a linear cost function $C(\rho_i) = c\rho_i$, $c > 0$, then I discuss how the results extend to the case of a convex cost function.

4 Equilibrium Analysis

I start by analyzing committees that have pre-determined compositions. For such committees, I study how the members' preferences are related to their incentives to acquire information in equilibrium, and examine the effects of preference heterogeneity and voting rules on information collection. After that, I study the problem of optimal committee design.

Suppose the cost of information for every member i is $C(\rho_i) = c\rho_i$, where $c > 0$. Let $L_i(\rho_i, \rho_{-i}, \underline{s}_k; q_k)$ denote the expected payoff of member i from the collective decision given

[4] See Li (2001) for more details.

the precision profile (ρ_i, ρ_{-i}) and the $\underline{s}_k$ of the threshold voter k, which depends on preference q_k of the threshold voter k exogenous to member i's problem, so that

$$L_i(\rho_i, \rho_{-i}, \underline{s}_k; q_k) = -(1-q_i)\gamma F_1(\underline{s}_k|\rho) - q_i(1-\gamma)[1 - F_0(\underline{s}_k|\rho)], \forall i. \tag{4}$$

I use $V_i(\rho_i, \rho_{-i}, \underline{s}_k; q_k)$ to denote the total expected payoff of i in the game, so

$$\begin{aligned} V_i(\rho_i, \rho_{-i}, \underline{s}_k; q_k) &= L_i(\rho_i, \rho_{-i}, \underline{s}_k; q_k) - C(\rho_i) \\ &= -(1-q_i)\gamma F_1(\underline{s}_k|\rho) - q_i(1-\gamma)[1 - F_0(\underline{s}_k|\rho)] - c\rho_i, \forall i. \end{aligned} \tag{5}$$

It is easy to see that if the decisive voter has an extreme preference, i.e., $q_k = 0$ or 1, then no member acquires information in equilibrium, and the collective decision is always the one preferred by voter k. When q_k is sufficiently close to 0 or 1, we have the same problem, as voter k is very unlikely to switch from his *ex ante* preferred decision; the value of acquired information is small. Thus, to keep the analysis interesting, I impose a range I on the value of q_k in the following assumption for the remaining analysis in this paper.

For a committee with $q_k \in (0,1)$, $V_i(\rho_i, \rho_{-i}, \underline{s}_k; q_k)$ of a member i may fail to be quasiconcave in ρ_i given q_k, as I argue in Section 4.4. However, there exists a value $\underline{\rho}(q_k, \gamma)$, which is a function of q_k and γ, such that for $\rho \geq \underline{\rho}(q_k, \gamma)$, we have $d^2 V_i(\rho_i, \rho_{-i}, \underline{s}_k; q_k)/d\rho_i^2 < 0$, for any i. According to this property, I impose the second part of the following assumption to ensure that $V_i(\rho_i, \rho_{-i}, \underline{s}_k; q_k)$ is strictly concave in ρ_i, for any i and any $q_k \in I$. With this assumption, the committee members' efforts to acquire information are strategic substitutes, and the first order conditions of the members' payoff maximization problems are sufficient for characterizing an equilibrium. Detailed discussion of this issue is relegated to Section 4.4.

Assumption 3 *There exists a closed interval I satisfying*

$$[\min\{1/2, \gamma\}, \max\{1/2, \gamma\}] \subset I \subset (0,1)$$

such that (1) $q_k \in I$ and (2) $\rho_0 \geq \max\{\underline{\rho}(q_k, \gamma) : q_k \in I\}$.

To proceed, I first examine the marginal benefit of information to a member. For any i, taking the derivative of $L_i(\rho_i, \rho_{-i}, \underline{s}_k; q_k)$ with respect to ρ_i, we obtain

$$\frac{dL_i(\rho_i, \rho_{-i}, \underline{s}_k; q_k)}{d\rho_i} = \underbrace{\frac{\partial L_i(\rho_i, \rho_{-i}, \underline{s}_k; q_k)}{\partial \rho_i}\Big|_{\underline{s}_k}}_{\text{Incentive to Prevent Errors}} + \underbrace{\frac{\partial L_i(\rho_i, \rho_{-i}, \underline{s}_k; q_k)}{\partial \underline{s}_k}\frac{d\underline{s}_k}{d\rho_i}}_{\text{Incentive to Reduce Disagreement}}, \tag{6}$$

in which

$$\frac{\partial L_i\left(\rho_i,\rho_{-i},\underline{s}_k;q_k\right)}{\partial \rho_i}|_{\underline{s}_k} = \left(1-q_i\right)\gamma f_1\left(\underline{s}_k|\rho\right)\frac{\left(1-\underline{s}_k\right)}{2\rho}+q_i\left(1-\gamma\right)f_0\left(\underline{s}_k|\rho\right)\frac{\underline{s}_k}{2\rho},$$

$$\frac{\partial L_i\left(\rho_i,\rho_{-i},\underline{s}_k;q_k\right)}{\partial \underline{s}_k}\frac{d\underline{s}_k}{d\rho_i} = \left[-\left(1-q_i\right)\gamma f_1\left(\underline{s}_k|\rho\right)+q_i\left(1-\gamma\right)f_0\left(\underline{s}_k|\rho\right)\right]\frac{d\underline{s}_k}{d\rho_i}. \tag{7}$$

The first term of (6) reflects the incentive of member i to prevent errors, taking $\underline{s}_k$ as fixed. This incentive is present regardless of the preference heterogeneity of the members. The second term of (6), which reflects the incentive of member i to reduce disagreement, however, appears only in heterogeneous committees. (See Appendix A for the derivation of (7).) Since information is a public good that is costly to obtain, there is a free-rider problem in information acquisition: if other members acquire information, the magnitudes of the two incentives above of member i decrease and thus his incentive to acquire information decreases.[5]

The incentive to reduce disagreement is important for the analysis of heterogeneous committees. In the expression for this incentive (see (6)), the value of $\partial L_i/\partial \underline{s}_k$ satisfies

$$\frac{\partial L_i\left(\rho_i,\rho_{-i},\underline{s}_k;q_k\right)}{\partial \underline{s}_k}\begin{cases} <0, \text{ if } i<k; \\ >0, \text{ if } i>k. \end{cases} \tag{8}$$

The first inequality means that a member i who leans more toward rejection than the threshold voter would like to decrease $\underline{s}_k$. This is intuitive, because for a member i with $q_i < q_k$, his *ex post* optimal decision rule $\underline{s}_i$ is lower than $\underline{s}_k$. A similar intuition applies to the second inequality of (8). Regarding $d\underline{s}_k/d\rho_i$, we have

$$\frac{d\underline{s}_k}{d\rho_i} = -\frac{1}{\rho^2}\ln\frac{q_k\left(1-\gamma\right)}{\left(1-q_k\right)\gamma}. \tag{9}$$

This indicates that if the threshold voter k is pro-rejection (i.e., $q_k < \gamma$), then increasing ρ can raise his cautiousness in voting for rejection (i.e., $d\underline{s}_k/d\rho_i > 0$), as he responds more to signals pointing to acceptance. Combining (8) and (9), I find that when $q_k < \gamma$, the second term of (6) is negative if $i < k$ and positive if $i > k$. This is because a member i who is more (less, respectively) inclined to reject the proposal than the threshold voter would like to acquire less (more, respectively) information to decrease (increase, respectively) $\underline{s}_k$, so as to reduce the distance between $\underline{s}_k$ and his *ex post* optimal cutoff $\underline{s}_i$, i.e., reduce the chance

[5] There is a subtle but important difference between my model and the one in Li (2001). In my model, the collective decision is determined by comparing the realization of the aggregate signal with $\underline{s}_k$. In Li (2001), the collective decision of a committee is determined also by comparing the realization of the aggregate signal to a cutoff $\underline{s}$. But the cutoff $\underline{s}$ in Li (2001) is exogenously imposed and does not change with ρ. Thus, the incentive to reduce disagreement does not appear in his model. It is easy to verify that if we drop this incentive from our model, we get the same comparative statics as Li (2001).

that the threshold voter disagrees with him. Similar results can be obtained for the case where the threshold voter is pro-acceptance (i.e., $q_k > \gamma$). If $q_k = \gamma$, which means that the threshold voter is *ex ante* unbiased toward any decision, then $d\underline{s}_k/d\rho_i = 0$, and the incentive to reduce disagreement disappears.

Plugging (9) into (6), we obtain that for each member i,

$$\frac{dL_i\left(\rho_i, \rho_{-i}, \underline{s}_k; q_k\right)}{d\rho_i} = \left(1-q_i\right)\gamma f_1\left(\underline{s}_k|\rho\right)\frac{\underline{s}_k}{2\rho} + q_i\left(1-\gamma\right) f_0\left(\underline{s}_k|\rho\right)\frac{\left(1-\underline{s}_k\right)}{2\rho}. \qquad (10)$$

The first term of this derivative is the marginal benefit of member i from reducing the probability of false acceptance. More specifically, in this term, $(1-q_i)$ is the loss of member i from false acceptance and $\gamma f_1\left(\underline{s}_k|\rho\right)\underline{s}_k/2\rho$ is the marginal decrement in the probability of false acceptance when increasing ρ. Similarly, the second term of (10) is the marginal benefit of member i from reducing the probability of false rejection. According to (5), we have

$$\frac{dV_i\left(\rho_i, \rho_{-i}, \underline{s}_k; q_k\right)}{d\rho_i} = \left(1-q_i\right)\gamma f_1\left(\underline{s}_k|\rho\right)\frac{\underline{s}_k}{2\rho} + q_i\left(1-\gamma\right) f_0\left(\underline{s}_k|\rho\right)\frac{\left(1-\underline{s}_k\right)}{2\rho} - c. \qquad (11)$$

In equilibrium, $dV_i\left(\rho_i, \rho_{-i}, \underline{s}_k; q_k\right)/d\rho_i \leq 0$ for all i, because if $dV_j\left(\rho_j, \rho_{-j}, \underline{s}_k; q_k\right)/d\rho_j > 0$ for some member j, then member j has incentive to increase ρ_j. It is possible to have $dV_i\left(\rho_i, \rho_{-i}, \underline{s}_k; q_k\right)/d\rho_i < 0$, i.e., $\rho_i = 0$, for all i. This happens when ρ_0 is large and c is large. I state this result formally in the lemma below.

Lemma 1 *For any equilibrium ρ, we have $\frac{dV_i(\rho_i,\rho_{-i},\underline{s}_k;q_k)}{d\rho_i} \leq 0$, with $\frac{dV_i(\rho_i,\rho_{-i},\underline{s}_k;q_k)}{d\rho_i} = 0$ if $\rho_i > 0$, for any i.*

The next lemma shows that the equilibrium value of ρ is unique, even if there are possibly multiple equilibria. This is mainly because $dV_i\left(\rho_i, \rho_{-i}, \underline{s}_k; q_k\right)/d\rho_i$ depends only on ρ and is decreasing in ρ.

Lemma 2 *Given Assumption 3, the equilibrium level of ρ is unique.*

The proof of this result is in Appendix A.

4.1 Preferences and Information Acquisition

This subsection examines how members of a heterogeneous committee differ in their incentives to acquire information. From (11), we can see that a member's incentive to acquire information depends on the profile $\mathbf{q}$ and the voting rule, which affects q_k. The analysis below shows that regardless of the voting rule, there always exists a monotonic relationship between the preferences of members and their incentives to acquire information. The voting rule determines the direction of the monotonic relationship through q_k. I then study the impact of preference heterogeneity on information acquisition.

Using (10) and (2), we obtain

$$\frac{dL_i\left(\rho_i,\rho_{-i},\underline{s}_k;q_k\right)}{d\rho_i}-\frac{dL_j\left(\rho_j,\rho_{-j},\underline{s}_k;q_k\right)}{d\rho_j} = \frac{\left(1-\gamma\right)f_0\left(\underline{s}_k|\rho\right)\left(q_i-q_j\right)}{2\rho\left(1-q_k\right)}\left[\left(\frac{1}{2}-q_k\right)-\frac{1}{\rho}\ln\frac{q_k\left(1-\gamma\right)}{\left(1-q_k\right)\gamma}\right]. \quad (12)$$

If $q_i > q_j$, the sign of this difference is determined by the term in the brackets. For convenience, I define this term as

$$h\left(q_k,\rho,\gamma\right)\equiv\left(\frac{1}{2}-q_k\right)-\frac{1}{\rho}\ln\frac{q_k\left(1-\gamma\right)}{\left(1-q_k\right)\gamma}. \quad (13)$$

The sign of $h\left(q_k,\rho,\gamma\right)$ is the same as the sign of the difference between $\left(1-\gamma\right)f_0\left(\underline{s}_k|\rho\right)\left(1-\underline{s}_k\right)/2\rho$, the marginal decrement in the probability of false rejection when increasing ρ, and $\gamma f_1\left(\underline{s}_k|\rho\right)\underline{s}_k/2\rho$, the marginal decrement in the probability of false acceptance when increasing ρ, given q_k and γ. If $h\left(q_k,\rho,\gamma\right)>0$, increasing ρ marginally reduces the probability of false rejection more than the probability of false acceptance, so a member with a larger q has more incentive to acquire information than does one with a smaller q. The result is reversed if $h\left(q_k,\rho,\gamma\right)<0$. The lemma below summarizes how the value of $h\left(q_k,\rho,\gamma\right)$ is related to the members' incentives to acquire information in equilibrium.

Lemma 3 *In equilibrium,*

1. *if* $h\left(q_k,\rho,\gamma\right)<0$, *then* $\frac{dL_i(\rho_i,\rho_{-i},\underline{s}_k;q_k)}{d\rho_i}<\frac{dL_j(\rho_j,\rho_{-j},\underline{s}_k;q_k)}{d\rho_j}$ *if* $q_i>q_j$, *which implies that* $\rho_i>0$, *only if* q_i *is equal to* $\min_{1\le l\le n}\{q_l\}$;
2. *if* $h\left(q_k,\rho,\gamma\right)>0$, *then* $\frac{dL_i(\rho_i,\rho_{-i},\underline{s}_k;q_k)}{d\rho_i}>\frac{dL_j(\rho_j,\rho_{-j},\underline{s}_k;q_k)}{d\rho_j}$ *if* $q_i>q_j$, *which implies that* $\rho_i>0$, *only if* q_i *is equal to* $\max_{1\le l\le n}\{q_l\}$;
3. *if* $h\left(q_k,\rho,\gamma\right)=0$, *then* $\frac{dL_i(\rho_i,\rho_{-i},\underline{s}_k;q_k)}{d\rho_i}=\frac{dL_j(\rho_j,\rho_{-j},\underline{s}_k;q_k)}{d\rho_j}$, $\forall i,j$.

This lemma can be simply derived using (12) and Lemma 1, so I omit its proof.

From this lemma, we see that in equilibrium there is a monotonic relationship between the members' incentives to acquire information and their preferences. Specifically, in the case where $h\left(q_k,\rho,\gamma\right)<0$, if $q_i>q_j$ (i.e., i leans more toward acceptance than j), then member j has stronger incentive to acquire information than does member i, and a member acquires information in equilibrium only if he is among the ones most willing to reject the proposal. In the case where $h\left(q_k,\rho,\gamma\right)>0$, the direction of the monotonicity is reversed—if

$q_i > q_j$, then member i has more incentive to acquire information than does member j, and a member acquires information in equilibrium only if he is among the ones least willing to reject the proposal. When $h(q_k, \rho, \gamma) = 0$, all the members have the same incentive to acquire information.

For an established committee, ρ is endogenous, so $h(q_k, \rho, \gamma)$ is also endogenous. Thus, without knowing the equilibrium, Lemma 3 cannot tell us which type of monotonicity arises at the stage of information acquisition.

At first glance, it seems that which type of monotonicity we will observe in equilibrium depends on the entire preference profile $\mathbf{q}$, given the other primitives. However, the following proposition shows that the monotonicity is determined only by the preference q_k of the threshold voter. To proceed, let $\rho(q_k, q_{-k}; \rho_0, c, \gamma)$ denote the equilibrium aggregate precision, given the preference profile $\mathbf{q}$, voting rule k, and primitives ρ_0, c, and γ. In most of the discussion below, I replace $\rho(q_k, q_{-k}; \rho_0, c, \gamma)$ by $\rho(q_k, q_{-k})$ to simplify the notation.

Definition 1 *The preference q_k of a threshold voter is a* virtually unbiased preference *if $h(q_k, \rho(q_k, q_{-k}), \gamma) = 0$, regardless of the value of q_{-k}. A threshold voter with a virtually unbiased preference is* virtually unbiased.

According to Lemma 3, if the threshold voter is virtually unbiased, then all the members have the same incentive to acquire information, regardless of their preferences. That means the three incentives of a member—i.e., the incentive to prevent errors, the incentive to free ride, and the incentive to reduce disagreement—that shape his incentive to acquire information achieve a balance, given that threshold voter is virtually unbiased. The proposition below establishes the existence and uniqueness of a virtually unbiased preference, and shows how it can be used to determine the monotonic relationship between the members' preferences and their incentives to acquire information.

Proposition 1 *Given Assumption 3, there exists a* unique *virtually unbiased preference $\bar{q}^*$, which depends only on γ, ρ_0, and c. When $\gamma = 1/2$, $\bar{q}^* = 1/2$; otherwise, $\bar{q}^* \in (\min\{1/2, \gamma\}, \max\{1/2, \gamma\})$.*

1. *If $q_k < \bar{q}^*$, then $h(q_k, \rho(q_k, q_{-k}), \gamma) > 0$, $\forall q_{-k}$, so $\rho_i \geq \rho_j = 0$, for $q_i > q_j$.*
2. *If $q_k > \bar{q}^*$, then $h(q_k, \rho(q_k, q_{-k}), \gamma) < 0$, $\forall q_{-k}$, so $0 = \rho_i \leq \rho_j$, for $q_i > q_j$.*

This proposition indicates that when the prior is biased (i.e., $\gamma \neq 1/2$), the virtually unbiased threshold voter plays a role in adjusting the bias of the prior. For example, if the prior favors the state $\theta = 1$ (i.e., $1/2 < \gamma$), then $\bar{q}^*$ satisfies $1/2 < \bar{q}^*$, that is, the virtually unbiased preference favors acceptance.

Regarding information acquisition, this proposition shows that if the threshold voter is virtually biased toward rejection, i.e., $q_k < \bar{q}^*$, then the members mostly inclined to accept the proposal are the ones collecting information. In the analysis below, for such committees, I assume that member n is the only information collector, without loss of generality.[6] If the threshold voter is virtually biased toward acceptance, i.e., $q_k > \bar{q}^*$, then the members most leaning toward rejection are the ones acquiring information. Similarly, for a committee of this kind, I assume that only member 1 collects information. I interpret a voting rule with $q_k < \bar{q}^*$ as a voting rule favoring rejection, and a voting rule with $q_k > \bar{q}^*$ as a voting rule favoring acceptance.

Why does the monotonic relationship between members' incentives to acquire information and their preferences hinge on the preference of the threshold voter? The reason primarily lies in the incentive to reduce disagreement. Consider the case where $\gamma = 1/2$, i.e., the prior is unbiased. From (6), I find that when $q_k < \bar{q}^* = 1/2$, the relationship between a member's incentive to prevent errors and his preference is indeterminate, while the incentive of member i to reduce disagreement is increasing in q_i, *ceteris paribus.* (See the discussion below (9) for intuition.) The monotonicity in the members' incentives to reduce disagreement is consistent with the monotonicity described in the first case of Proposition 1. Similar results can be obtained for $q_k > \bar{q}^* = 1/2$. Therefore, the incentive to reduce disagreement explains the fact that the members' incentives to acquire information are monotonically related to their preferences hinges on q_k.

If $\gamma \neq 1/2$, the incentive to reduce disagreement is not the only driving force for the monotonicity result; the incentive to prevent error also comes into play. However, except for cases in which $q_k \in (\min\{\bar{q}^*, \gamma\}, \max\{\bar{q}^*, \gamma\})$, the incentive to reduce disagreement is still the dominant force determining the direction of the monotonicity.

In the literature on committee decision-making, preference heterogeneity among committee members is often believed to be detrimental, as it tends to block effective information sharing.[7] In this model, I show that in the absence of strategic information transmission, heterogeneity can be a blessing—a more polarized committee can induce more information acquisition in equilibrium.

Proposition 2 *Under Assumption 3, given the preference q_k of the threshold voter, making a committee more polarized, i.e., decreasing q_i if $i < k$ and increasing q_i if $i > k$, without changing the order of members' preferences, induces (weakly) more information acquisition in equilibrium.*

The proof of this proposition is useful to understand some of the results below, so I put

[6] In an established committee, it is possible that multiple members have preferences equal to $\max_{1 \leq l \leq n}\{q_l\} = q_n$. For such a committee, when $q_k < \bar{q}^*$, there are multiple equilibria if $\rho > \rho_0$. According to Lemma 2, all these equilibria have the same equilibrium ρ; they differ only in the distribution of information acquisition efforts among the members with preference $\max_{1 \leq l \leq n}\{q_l\}$.

[7] See Coughlan (2000), Li et al. (2001), Austen-Smith and Feddersen (2006), and Meirowitz (2007) for more details.

it here instead of putting it in an appendix.

Proof. First, I consider the case where the threshold voter of a committee is virtually biased toward rejection (i.e., $q_k < \bar{q}^*$). Then member n is the only one collecting information. Thus, in equilibrium, $\rho = \rho_0 + \rho_n$, $\rho_i = 0$, for $i \leq n-1$. It is possible that $\rho_n = 0$ when ρ_0 is large and c is large. If $\rho_n > 0$, then $dL_n(\rho_n, \rho_{-n}, \underline{s}_k; q_k)/d\rho_n = c$. From this condition, we obtain

$$\frac{d\rho_n}{dq_n} = -\frac{(1-\gamma) f_0(\underline{s}_k|\rho)}{2\rho} \frac{h(q_k, \rho, \gamma)}{d^2 L_n(\rho_n, \rho_{-n}, \underline{s}_k; q_k)/d\rho_n^2} > 0. \tag{14}$$

Thus, when $k \neq n$, increasing the degree of polarization of the committee (i.e., decreasing q_i if $i < k$, and increasing q_i if $i > k$, without changing q_k and the order of members' preferences) increases ρ, as q_n increases. When $k = n$, increasing the degree of polarization of the committee by decreasing other members' preferences, while fixing q_k, does not affect ρ.

For the case where the threshold voter of a committee is virtually biased toward acceptance (i.e., $q_k > \bar{q}^*$), the argument is similar to the case above.

If the threshold voter of a committee is virtually unbiased (i.e., $q_k = \bar{q}^*$), changing the preferences of non-threshold voters does not change the aggregate precision ρ. Thus, increasing the polarization of such a committee, while fixing q_k, has no effect on information acquisition. ■

This result regarding the impact of preference heterogeneity on information acquisition does not rely on the assumption of linear information cost. As I show in the next section, it holds also in certain convex cost environments.

4.2 Impact of Voting Rules

For an established committee, the adopted voting rule affects the incentives of members to collect information by affecting q_k. I study in this subsection the voting rule that maximizes information acquisition. The result is summarized in the following proposition.[8]

Proposition 3 *Given Assumption 3 and $q_i \in I$ for all i, one of the unanimous rules, i.e., either $k = 1$ or $k = n$, induces most information acquisition in equilibrium.*

To illustrate the reason, I focus on heterogeneous committees in which $q_i \neq q_j$, for $i \neq j$. To begin, consider a voting rule k with $q_k < \bar{q}^*$. In this case, member n is the only one collecting information in equilibrium, according to Proposition 1. Now if we decrease k, i.e., decrease q_k, member n is still the only information collector, but his incentive to reduce

[8]In my model, the voting rule with $k = 1$ is equivalent to the voting rule that takes C as the *status quo* and requires unanimity to accept the proposal.

disagreement increases, and consequently more information is acquired in equilibrium. Thus, the voting rule $k = 1$ outperforms any other rule with $q_k < \bar{q}^*$ in producing information. Similarly, for voting rules with $q_k > \bar{q}^*$, member 1 is the only one collecting information in equilibrium. These rules induce no more information than does the voting rule $k = n$. For a voting rule k with $q_k = \bar{q}^*$, every member has the same incentive to acquire information in equilibrium. In this case, if $k \neq 1$, we can without loss of generality let member n be the information collector, and increase information acquisition by decreasing k. The argument for the case where $q_k < \bar{q}^*$ applies. Similarly, if $k \neq n$, the argument for the case where $q_k > \bar{q}^*$ applies. For any voting rule, I have shown that there is a unanimous rule inducing more information acquisition. Therefore, the optimal voting rule that induces most equilibrium information must be one of the unanimous rules. However, this does mean that any unanimous rule outperforms all non-unanimous rules. Consider a committee with $q_n \leq \bar{q}^*$. The argument above implies that the unanimous rule with $k = 1$ induces most information acquisition, but the unanimous rule with $k = n$ induces the least information acquisition, so is outperformed by all non-unanimous rules.

4.3 Committee Design

The analysis above focuses on committees with pre-determined compositions. If a committee designer is authorized to design an n-member committee, how should she choose the composition and decision rule of the committee? This subsection is devoted to answering this question. The existing literature on committee design restricts attention to homogeneous committees, taking committee size, the communication rule, and the decision rule as the choice variables. Our analysis here extends the analysis to heterogeneous committees.

Let q_0 denote the preference of the designer, who has the same prior as the committee members. If the committee has a threshold voter with preference q_k and produces aggregate information ρ, then the expected payoff of the designer from the collective decision is

$$V_0(\rho, q_k) = -(1 - q_0)\gamma F_1(\underline{s}_k|\rho) - q_0(1 - \gamma)[1 - F_0(\underline{s}_k|\rho)]. \tag{15}$$

The objective of the designer is to maximize $V_0(\rho, q_k)$, without taking into account the costs incurred by the members in acquiring information.[9] I maintain the second part of Assumption 3, and impose the following assumption for the rest of the analysis in this

[9]The assumption that the designer does not care about the costs of information incurred by the committee members is appropriate for many collective decision-making situations. Consider the examples of trial juries and monetary policy committees. The collective decisions made by these committees affect not only the payoffs of the committee members, but also the payoffs of many other people in the society. If the objective of the designer is to maximize the expected payoff of all the people that will be affected by the decision (i.e., q_0 of the designer represents the average preference of all the people), then the efforts of the committee members devoted to collecting information are negligible.

section. The first part of this assumption states that q_0 is bounded away from 0 and 1. The second part of this assumption ensures that an optimal committee acquires a positive amount of information in equilibrium.

Assumption 4 *For the designer,*

1. *q_0 is in the interior of I, and she can choose only $q_k \in I$;*

2. *$\rho\left(q_k, q_{-k}; \rho_0, c, \gamma\right) > \rho_0$ if $q_i = q_0$ for all i, which means that a homogeneous committee having the same preference as the designer acquires information in equilibrium.*

To begin, I analyze the simplest version of the problem: designing a single-member decision-making committee, i.e., I assume $n = 1$. Such a problem can be interpreted as a delegation problem in which the principal chooses the agent to whom the decision is delegated. Unlike the literature on delegation, which usually assumes that the agent has *exogenous* private information (e.g., Dessein 2002; Li and Suen 2004; Marino 2007; Mylovanov 2008), I assume that the agent's information is *endogenous*. The problem of the designer can be formulated as follows.

$$\max_{q_1} V_0\left(\rho, q_1\right) \tag{16}$$
$$s.t.\ q_1 \in I,$$
$$\rho = \arg\max_{\hat{\rho} \geq \rho_0} -\left(1-q_1\right)\gamma F_1\left(\underline{s}_1|\hat{\rho}\right) - q_1\left(1-\gamma\right)\left[1 - F_0\left(\underline{s}_1|\hat{\rho}\right)\right] - c(\hat{\rho}-\rho_0).$$

The following proposition illustrates how the choice of the single member is related to the preference of the designer.

Proposition 4 *A designer with preference $q_0 < \bar{q}^*$ ($q_0 > \bar{q}^*$, respectively) optimally chooses $q_1 \in (q_0, \bar{q}^*)$ ($q_1 \in (\bar{q}^*, q_0)$, respectively). If $q_0 = \bar{q}^*$, she optimally chooses $q_1 = q_0$.*

As shown in the proof of Proposition 1, the information acquired by the single committee member is decreasing in the distance between q_1 and $\bar{q}^*$. Thus, a virtually biased committee designer faces a trade-off between preference alignment and decision precision. When $q_0 < \bar{q}^*$ ($q_0 > \bar{q}^*$, respectively), choosing $q_1 < \bar{q}^*$ ($q_1 > \bar{q}^*$, respectively) induces less information acquisition compared with having $q_1 = \bar{q}^*$, but increases the chance that the member chooses her preferred decision given the acquired information. This proposition shows that, as long as the selected member does not rely entirely on the free signal s_0 to make his decision (see Assumption 4), the optimal q_1 always lies between q_0 and $\bar{q}^*$. When $q_0 = \bar{q}^*$, the trade-off for the designer disappears, because choosing $q_1 = q_0$ achieves perfect preference alignment *and* induces the most information acquisition by the member.

How does the designer choose the committee member if she retains the right to make the final decision and the member is responsible only for collecting information? This question is closely related to a question asked in the literature on informational committee design. The next proposition shows that the choice of agent in this case is very different from the previous case.

Proposition 5 *If it is common knowledge that the designer retains the right to make the final decision and can observe the precision and realization of the signal obtained by the committee member, then it is optimal for her to choose* $q_1 = 1$ *(*$q_1 = 0$*, respectively) when* $q_0 < \bar{q}^*$ *(*$q_0 > \bar{q}^*$*, respectively). If* $q_0 = \bar{q}^*$*, she is indifferent between all values of* q_1*.*

This proposition indicates that a virtually biased designer optimally chooses a committee member whose preference is extremely opposed to hers. Given the previous analysis (see Proposition 2), this result is intuitive. The conflict between the designer and the information collector can incentivize the latter to acquire more information, given that the information is fully transmitted between these two parties. This intuition also underlies the analysis of multi-member committee design.

Che and Kartik (2009) study the problems in Propositions 4 and 5 using a different model with endogenous information. Unlike Proposition 4, they find that if the designer delegates the decision to the single committee member, it is *always* optimal for the designer to choose a member identical to herself. This is because in their model, when the member has the decision right, his incentive to acquire information is independent of his *ex ante* bias over the alternatives. For the problem of choosing an information collector, they show that it is always optimal for the designer to choose one different from herself due to the "persuasion effect". However, in the current model I show in Proposition 5 that it is necessary for the designer to choose an information collector different from herself only if she is biased. Moreover, unlike Che and Kartik (2009), I am able to identify the optimal information collector for each type of designer.

Now we study the design of an n-member committee, for $n \geq 2$. In this problem, the choice variables of the designer are $\mathbf{q}$, the preference profile of the committee, and k, the voting rule adopted by the committee to aggregate individual votes. The problem of the designer is

$$\max_{\mathbf{q},\, k} V_0\left(\rho, q_k\right) \tag{17}$$

$$s.t.\ 0 \leq q_1 \leq \ldots \leq q_n \leq 1,\ q_k \in I, \text{ and}$$

$$\rho = \rho\left(q_k, q_{-k}; \rho_0, c, \gamma\right).$$

It is convenient to think about the problem by first looking at the value of q_k of the threshold voter. There are three possible relationships between q_k and $\bar{q}^*$: $q_k < \bar{q}^*$, $q_k > \bar{q}^*$, or $q_k = \bar{q}^*$. If $q_k < \bar{q}^*$, then the non-threshold voters' incentives to acquire information are increasing in their inclinations to acceptance. Since the designer cares only about q_k and ρ, given that $q_k < \bar{q}^*$, she prefers that the non-threshold voters who collect information lean strongly toward acceptance. A similar analysis can be conducted for the case $q_k > \bar{q}^*$. Based on this analysis, it is natural to conjecture that an optimal committee has a two-party structure, that is, only two types of members are in the committee. The following proposition confirms this conjecture.

Proposition 6 *There exists an optimal decision-making committee satisfying one of the two following sets of conditions:*

1. $q_n > \max\{\bar{q}^*, q_0\}$*, and* $q_i = 0$*, for any* $i < n$*, with* $k = n$*;*
2. $q_1 < \min\{\bar{q}^*, q_0\}$*, and* $q_i = 1$*, for any* $i > 1$*, with* $k = 1$*.*

Three features of the optimal committees in the proposition are worth noting: (1) the adopted voting rule is unanimous, namely, requiring either unanimity to reject or unanimity to accept, (2) the non-threshold voters' preferences are extreme and opposed to that of the threshold voter, (3) the threshold voter is not perfectly aligned with the designer, and is virtually biased. Features (1) and (2) are due to Proposition 1 and Proposition 2, as I discussed immediately before the current proposition. Some papers on committee decision-making (e.g., Feddersen and Pesendorfer 1998; Gerardi 2000; Persico 2004; Gerardi and Yariv 2007) show that unanimious votings are suboptimal. Feature (1) provides a new rational for adopting unanimous rules in making collective decisions. Feature (3) indicates that the collective choice made by the committee departs from the one preferred by the designer in some cases. This results from a trade-off facing the designer: having the committee always make a decision the same as the one she would make, or having the committee make a more precise decision. This trade-off is similar to that in the single-member committee design. The difference is that the presence of other members changes the direction of the trade-off: the designer would like the threshold voter to be more biased than she is, so as to incentivize other members to collect information.

In fact, there are infinitely many other committee designs that induce the same amount of information and same expected payoff to the designer as the optimal designs I described in the proposition.[10] However, they are not robust to varying the cost of information. In the next section, we will see that when the cost of information becomes convex, other committee designs are no longer optimal.

[10] To illustrate this, suppose that there is an optimal committee having the first set of features. In this case, another committee with $\mathbf{q}' = (q'_1, \ldots, q'_n)$ and voting rule $k \neq n$ achieves the same payoff for the designer as the optimal committee if $q'_1 = 0$ and $q'_k = q_n$.

In the problem (17), I implicitly assume that the designer is committed to delegate the final decision to the committee. If the designer can observe the precisions and realizations of all the signals received by the committee, one may wonder whether she should retain the right to make the final decision. The answer is no. This is because retaining the decision right, in terms of expected payoff, is equivalent to having a committee with a threshold voter with preference q_0, so the maximum payoff attainable in this case is dominated by an optimal committee described above. I summarize this result in the following corollary.

Corollary 1 *The designer prefers to delegate the decision to the optimally designed committee rather than to retain the decision right, even if she has perfect knowledge of all the signals received by the committee, as long as her perfect knowledge is commonly known.*

In many real world situations, the decision rules adopted to make collective decisions are fixed by institutional rules, though the compositions of the committees are flexible.[11] In the rest of this subsection, I consider the case where the voting rule is fixed with $k = n$. Now the designer's problem can be formulated as

$$\max_{\mathbf{q}} V_0 (\rho, q_n) \tag{18}$$
$$s.t.\ 0 \leq q_1 \leq \ldots \leq q_n \leq 1,\ q_n \in I, \text{ and}$$
$$\rho = \rho (q_n, q_{-n}; \rho_0, c, \gamma).$$

The following proposition describes how an optimal committee design is related to the preference of the designer.

Proposition 7 *When the voting rule is $k = n$,*

1. *if $q_0 > \bar{q}^*$, then there is an optimal committee satisfying $q_n > q_0$ and $q_i = 0$ for any $i < n$;*
2. *if $q_0 < \bar{q}^*$, then there is an optimal committee that is either homogeneous with $q_1 = \ldots = q_n \in (q_0, \bar{q}^*)$ or heterogeneous with $q_n > \bar{q}^*$ and $q_i = 0$ for any $i < n$.*

The second part of this proposition indicates that when unanimity is required to change the *status quo*, an optimal committee can be homogeneous if the designer is virtually biased against the *status quo,* i.e., $q_0 < \bar{q}^*$. I briefly sketch the reason here. Among all homogeneous committees, there is an optimal one for the designer satisfying $q_1 = \ldots = q_n \in (q_0, \bar{q}^*)$. (This is follows from Proposition 4 on single-member committee design.) This optimal

[11] Here are two examples. (1) In criminal law jury trials of some jurisdictions, though the juries are temporary, their guilty verdicts require unanimity. (2) When settling disputes between WTO member countries, ad hoc panels appointed by the Dispute Settlement Body to investigate the disputes reach their decisions using the simple majority rule (whenever consensus is impossible).

homogeneous committee cannot be outperformed by any other committee with $q_n \in (q_0, \bar{q}^*]$, given the constraint $q_1 \leq \ldots \leq q_n$, in maximizing the designer's payoff, and may outperform any other committee with $q_n > \bar{q}^*$.

For the case in which $q_0 > \bar{q}^*$, a homogeneous committee is never optimal. This is because among all homogeneous committees, the optimal one has $q_1 = \ldots = q_n \in (\bar{q}^*, q_0)$. This committee is inferior to one with the same q_n but $q_i = 0$ for any $i < n$, given Proposition 2 on the impact of group polarization.

4.4 Non-quasiconcavity

At the beginning of this section, I pointed out that $V_i\left(\rho_i, \rho_{-i}, \underline{s}_k; q_k\right)$ may fail to be quasiconcave in ρ. This is because when $q_k \neq \gamma$, as $\rho \to 0$, $dV_i\left(\rho_i, \rho_{-i}, \underline{s}_k; q_k\right)/d\rho_i \to -c$, which implies that when $q_k \neq \gamma$, $V_i\left(\rho_i, \rho_{-i}, \underline{s}_k; q_k\right)$ is decreasing in ρ_i when ρ is close to 0. (See Appendix A for the proof.) If for some $\rho > 0$, we have $dV_i\left(\rho_i, \rho_{-i}, \underline{s}_k; q_k\right)/d\rho_i > 0$, then $V_i\left(\rho_i, \rho_{-i}, \underline{s}_k; q_k\right)$ is not quasiconcave in ρ_i. The non-concavity issue of $V_i\left(\rho_i, \rho_{-i}, \underline{s}_k; q_k\right)$ is not unique to the current model, and is well-known in problems with endogenous information. Radner and Stiglitz (1984) show that it is a fundamental property in some decision problems that the net value of information is not concave. Their result can be naturally extended to our game-theoretic setup. One consequence is that a pure-strategy equilibrium may not exist (Dasgupta and Maskin, 1986). Another consequence is the possible multiplicity of equilibria when $V_i\left(\rho_i, \rho_{-i}, \underline{s}_k; q_k\right)$ is not concave in ρ_i. This may complicate our comparative statics.

The reason for this non-quasiconcavity is intuitive. Information has value only if it can improve the collective decision. When ρ is small, marginally increasing ρ has very limited effect on the collective decision determined by the threshold voter, so the marginal benefit $dL_i\left(\rho_i, \rho_{-i}, \underline{s}_k; q_k\right)/d\rho_i$ is very small, and can be smaller than the marginal cost c of information. When ρ becomes large, $dL_i\left(\rho_i, \rho_{-i}, \underline{s}_k; q_k\right)/d\rho_i$ may exceed c.

To investigate how $V_i\left(\rho_i, \rho_{-i}, \underline{s}_k; q_k\right)$ changes with ρ_i given q_k, we derive the expression of $d^2V_i\left(\rho_i, \rho_{-i}, \underline{s}_k; q_k\right)/d\rho_i^2$, and find the following lemma.

Lemma 4 $\frac{d^2V_i\left(\rho_i, \rho_{-i}, \underline{s}_k; q_k\right)}{d\rho_i^2} < 0$ *if* $\rho \geq \underline{\rho}\left(q_k, \gamma\right) \equiv 6\left|\ln \frac{q_k(1-\gamma)}{(1-q_k)\gamma}\right|$.

Thus, if the equilibrium level of ρ exceeds $\underline{\rho}\left(q_k, \gamma\right)$, then the first order conditions of members' payoff maximization problems are sufficient for characterizing an equilibrium.

To ensure that $\rho \geq \underline{\rho}\left(q_k, \gamma\right)$ given q_k, γ, I assume in Assumption 3 that $\rho_0 \geq \underline{\rho}\left(q_k, \gamma\right)$ for any committee considered in this paper. This assumption guarantees that $V_i\left(\rho_i, \rho_{-i}, \underline{s}_k; q_k\right)$ is globally concave in ρ_i given q_k, regardless of $\sum_{j\neq i,0} \rho_j$. The precision choices of committee members are strategic substitutes in this case.

In some of the analysis, such as the impact of voting rules and committee design, we need q_k to be variable. The assumption $\rho_0 \geq \underline{\rho}\left(q_k, \gamma\right)$ will be violated for any finite ρ_0 if $q_k \to 0$ or

1, because $\underline{\rho}(q_k, \gamma) \to \infty$ if $q_k \to 0$ or 1. Therefore, I impose the assumption that q_k belongs to a closed interval $I \subset (0,1)$ in Assumptions 3 and 4. It is worth mentioning that I can be an arbitrarily large subset of $(0,1)$ if ρ_0 is sufficiently large.

5 Convex Information Cost

In this section, I study that case where the "production" of information exhibits diminishing returns. Specifically, I assume that $C(\rho_i)$ satisfies $C(0) = 0$, $C'(0) = 0$, and $C''(\rho_i) > 0$ for $\rho_i \geq 0$. Except the changes in the cost function, I maintain all other assumptions made before. The major insights obtained in the case of linear cost can be extended to this environment. The results in the rest of the paper are proved in Appendix B.

5.1 Preferences and Information Acquisition

As before, let us first examine the relationship between the preferences of members and their incentives to acquire information. I still use $V_i(\rho_i, \rho_{-i}, \underline{s}_k; q_k)$ defined in (5) to denote the expected payoff of member i, given the precision profile (ρ_i, ρ_{-i}) and the $\underline{s}_k$ of the threshold voter k. For any member i, the first order condition of his maximization problem is

$$\frac{dV_i(\rho_i, \rho_{-i}, \underline{s}_k; q_k)}{d\rho_i} = (1-q_i)\gamma f_1(\underline{s}_k|\rho)\frac{\underline{s}_k}{2\rho} + q_i(1-\gamma) f_0(\underline{s}_k|\rho)\frac{(1-\underline{s}_k)}{2\rho} - C'(\rho_i) = 0. \quad (19)$$

Given that $C'(0) = 0$ and $C''(\rho_i) > 0$ for $\rho_i \geq 0$, the equilibrium is interior. That is, all the members exert positive efforts in acquiring information in equilibrium. This is different from the linear cost case, in which some members may not acquire information in equilibrium.

Since all the members have the same cost function, to compare their acquired information we need to compare only their values of $dL_i/d\rho_i$. Regarding this comparison, we have a result similar to Proposition 1.

Proposition 8 *There exists a unique virtually unbiased preference $\bar{q}^*$, which depends only on γ, ρ_0, n, and $C(\cdot)$. When $\gamma = 1/2$, $\bar{q}^* = 1/2$; otherwise, $\bar{q}^* \in (\min\{1/2, \gamma\}, \max\{1/2, \gamma\})$.*

1. *If $q_k < \bar{q}^*$, then $h(q_k, \rho(q_k, q_{-k}), \gamma) > 0$, $\forall q_{-k}$, so $\rho_i > \rho_j$, for $q_i > q_j$.*

2. *If $q_k > \bar{q}^*$, then $h(q_k, \rho(q_k, q_{-k}), \gamma) < 0$, $\forall q_{-k}$, so $\rho_i < \rho_j$, for $q_i > q_j$.*

Due to the fact that the equilibrium is interior, the monotonic relationship between members' preferences and their efforts in acquiring information becomes strong: when the threshold voter is virtually biased toward rejection, the members that are more inclined to reject the proposal acquire less information in equilibrium; when the threshold voter is virtually biased toward acceptance, the members that lean more toward acceptance acquire less information in equilibrium. The intuition behind this result is the same as that for Lemma 3 and Proposition 1.

To understand the impact of preference heterogeneity on information acquisition, we consecutively study two questions: (1) how changing one non-threshold member's preference affects the equilibrium; (2) fixing the preference of the threshold member, how preference heterogeneity affects equilibrium information acquisition.[12]

Now given that the cost of information is convex, regarding the first question, we have the following proposition.

Proposition 9 *If $q_k > \bar{q}^*$, for all $i \neq k$, increasing q_i decreases ρ_i and increases ρ_j, $j \neq i$, and ρ decreases. If $q_k < \bar{q}^*$, the results are reversed. For the case in which $q_k = \bar{q}^*$, changing a non-threshold voter's preference does not affect the equilibrium outcome.*

Note the response of each member j, $j \neq i$, to a change in q_i. When q_i changes, ρ_j moves in the opposite direction to ρ_i. This results from the member j's incentive to free ride. However, this effect is dominated by the impact of the change in q_i on ρ_i, so the aggregate precision ρ changes in the same direction as ρ_i.

Regarding the second question, we no longer have a result like Proposition 2. To illustrate, I consider the following preference profile,

$$q_i = \bar{q} + \left(i - \frac{n+1}{2}\right)\delta, \; \forall i, \tag{20}$$

where $\delta \in \left(0, \min\left\{\frac{2(1-\bar{q})}{n-1}, \frac{2\bar{q}}{n-1}\right\}\right)$. In this preference profile, δ can be interpreted as a measure of preference heterogeneity in the committee, and the average preference of the committee is $\bar{q}$. Suppose that n is an odd number and $k = (n+1)/2$, i.e., the voting rule is a simple majority rule and $q_k = \bar{q}$. The following proposition shows how the impact of preference heterogeneity on information acquisition depends on $C'''(\cdot)$ in such a committee.

Proposition 10 *Given preference profile (20) and $k = (n+1)/2$ with n being an odd number, if $C'''(\cdot) > 0$, then the equilibrium value of ρ is decreasing in δ; if $C'''(\cdot) < 0$, then the equilibrium value of ρ is increasing in δ.*

A more general version of this proposition, which considers more general preference structures and other voting rules, is proved in Appendix B. The purpose of presenting this proposition here is to show that the concavity (convexity) of $C'(\cdot)$ is crucial for the impact of

[12]In the case of linear information cost, since only one member acquires information in equilibrium, we have in fact combined the analyses of these two questions in Proposition 2.

preference heterogeneity on information acquisition. Under preference structure (20), increasing δ decreases q_i for any $i < k$ and increases q_i for any $i > k$. According to Proposition 9, the decrease of q_i for $i < k$ and the increase of q_i for $i > k$ impose opposite effects on the equilibrium value of ρ. Given the symmetry of the preference profile around $\bar{q}$, Proposition 10 implies that if $C'(\cdot)$ is concave, the upward effect on ρ induced the changes in q_i's always dominates the downward effect on ρ. If $C'(\cdot)$ is convex, the result is reversed.

Without the symmetry of the preference profile in (20), though it is challenging to comprehensively analyze the impact of preference heterogeneity on information acquisition, we are still able to illustrate the impact of preference heterogeneity by comparing the performances of homogeneous committees with some specific heterogeneous committees. The comparison also relies on the concavity of $C'(\cdot)$.

Proposition 11 *Consider two committees with the same size n and average preference $\bar{q}$:*

1. *a homogeneous committee with $q_1 = \ldots = q_n = \bar{q}$;*

2. *a heterogeneous committee with threshold voter $q_k = \sum_1^n q_i/n = \bar{q}$.*

The heterogeneous committee collects more (less, respectively) information in equilibrium if $C'''(\cdot) < 0$ ($C'''(\cdot) > 0$, respectively).

5.2 Impact of Voting Rules

I now analyze the impact of voting rules on information acquisition. To proceed, I define

$$\bar{q}^e = \sum_{i=1}^{n} \lambda_i q_i, \text{ where } \lambda_i = \frac{1/C''(\rho_i)}{\sum_{l=1}^{n} 1/C''(\rho_l)}. \tag{21}$$

This definition indicates that $\bar{q}^e$ depends on $(\rho_1, \ldots, \rho_n)$ through $(\lambda_1, \ldots, \lambda_n)$. For any committee with a voting rule k, the equilibrium outcome corresponds to a value of $\bar{q}^e$. The following lemma shows how the relationship between the equilibrium value of $\bar{q}^e$ and q_k determines the impact of changing the voting rule k.

Lemma 5 *For a committee with a voting rule k, if $\bar{q}^e < q_k$ in equilibrium, then increasing the stringency of the voting rule increases the equilibrium value of ρ, i.e., $d\rho/dq_k > 0$. Otherwise, decreasing the stringency of the voting rule decreases the equilibrium value of ρ, i.e., $d\rho/dq_k < 0$.*

Since ρ_i of any member i depends on q_k and are positive, $\bar{q}^e$ depends on q_k and belongs to the open interval (q_1, q_n). From the lemma, we know that the relationship between $\bar{q}^e$ and q_k has implication for the voting rule that maximizes the equilibrium ρ. The two panels

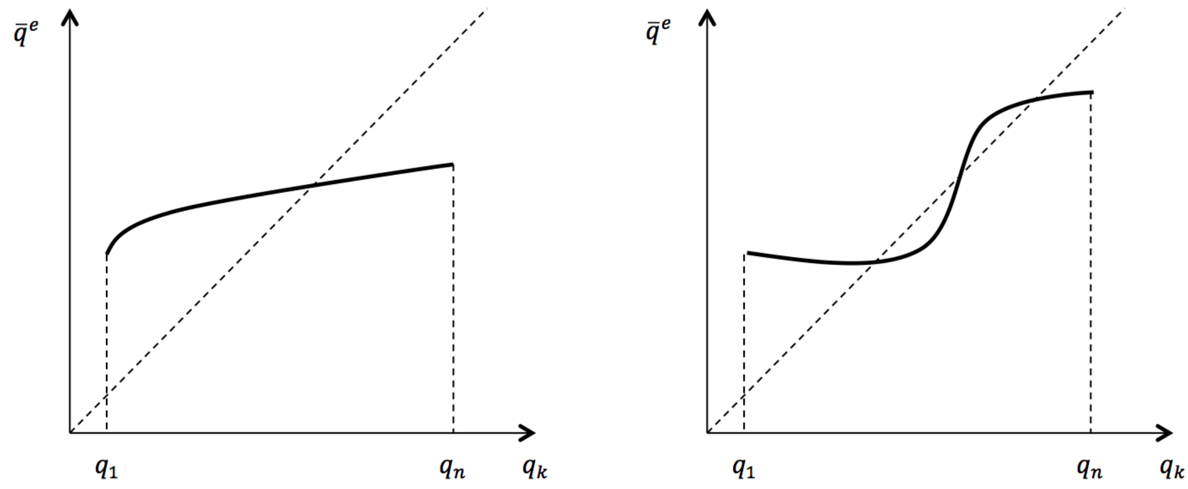

Figure 1: Relationship between $\bar{q}^e$ and q_k

in Figure 1 illustrate two types of relationship between $\bar{q}^e$ and q_k, given that $q_k \in [q_1, q_n]$ and $q_1, q_n \in (0, 1)$. In these two panels, the number of intersections between the curve of $\bar{q}^e$ and the 45-degree line is important for determining the optimal voting rule. If $\bar{q}^e$ changes with q_k as in the left panel, i.e., intersects with the 45-degree line once, then according to Lemma 5, the optimal voting rule is a unanimous rule. However, if the relationship between $\bar{q}^e$ and q_k is as in the right panel, then a non-unanimous rule might be optimal. In the next proposition, I show that if $C'''(\cdot) \leq 0$, $\bar{q}^e$ changes with q_k as in the left panel.

Proposition 12 *For a heterogeneous committee, the impact of the voting rule on equilibrium value of ρ depends on $C'''(\cdot)$. If $C'''(\cdot) \leq 0$, then the voting rule inducing the most information acquisition is a unanimous rule.*

5.3 Committee Design

For the problem of committee design, the change in the cost function changes only the constraint on the equilibrium value of ρ. As before, we can formulate the designer's problem as

$$\max_{\mathbf{q},k} V_0(\rho; q_k) \tag{22}$$

$$s.t.\ 0 \leq q_1 \leq \ldots \leq q_n \leq 1,\ q_k \in I, \text{ and}$$

$$\sum_{i=1}^{n} C'^{-1}\left(\frac{dL_i(\rho_i, \rho_{-i}, \underline{s}_k; q_k)}{d\rho_i}\right) = \rho - \rho_0.$$

The proposition below characterizes the optimal committee.

Proposition 13 *For a committee designer with q_0, the optimal decision-making committee satisfies one of the two following conditions:*

1. $q_n > \bar{q}^*$, *and* $q_i = 0$ *for any* $i < n$, *with* $k = n$;

2. $q_1 < \bar{q}^*$, *and* $q_i = 1$ *for any* $i > 1$, *with* $k = 1$.

This proposition, unlike Proposition 6, does not have a clear statement regarding the relationship between q_0 and the preference of the threshold voter in the optimal committee. This is primarily because the threshold voter in the environment with convex information cost also collects information in equilibrium. Consider a committee with $q_n = q_0 > \bar{q}^*$, and $q_i = 0$ for any $i < n$, with $k = n$. Increasing q_n in the neighborhood of q_0 increases the incentive of the non-threshold voters to acquire information, but will decrease the threshold voter's efforts in collecting information. The aggregate effect of increasing q_n on ρ is thus indeterminate. Therefore, we cannot determine the magnitude of q_n relative to q_0.

When we fix the voting rule as $k = n$, a result similar to Proposition 7 can be easily derived. I omit a detailed discussion of this result.

6 Private Information

In the analysis above, I rule out strategic information transmission among committee members by imposing Assumption 1, which states that the precision and realization of the signal acquired by each committee member are observable to others. I show in this section that relaxing this assumption, i.e., assuming instead that both the precision and realization of a signal are private, does not overturn my main findings if the signals are (verifiable) hard evidence regarding the true state and the members are allowed to communicate before they vote.

For this private information case, I specify the timing of the game as follows. In stage 1, every committee member chooses the precision of his private signal. In stage 2, the public signal and the private signals are all realized, and each member observes the public signal and his own private signal. In stage 3, every member decides whether to reveal his signal, including its precision and realization. (The members cannot manipulate or partially reveal their signals.) In stage 4, the members vote to determine the ultimate decision.

All my assumptions except Assumption 1 are left unchanged. The results below hold both in the linear cost case and in the convex cost case.

Proposition 14 *In the private information case, for every committee and every voting threshold, there is an equilibrium in which every member acquires the same amount of information as in the public information case and always reveals his information.*

This proposition indicates that for an arbitrary committee, the equilibrium outcome in the public information case is also an equilibrium outcome in the private information case. Preference heterogeneity among the committee members does not prevent full information sharing. Consider, for example, a non-threshold member who leans more toward acceptance than the threshold voter *ex ante*. He has an incentive to conceal his information only when doing so can induce the threshold voter to vote for acceptance more often, given that other members reveal their information. If the threshold voter always votes for rejection when this non-threshold voter refuses to reveal his information, then his incentive to conceal the information is gone. The following corollary is a natural consequence of this proposition, combined with Propositions 6 and 13.

Corollary 2 *In the private information case, there exists a heterogeneous committee whose full-information-aggregation equilibrium outperforms, from the perspective of the committee designer, the full-information-aggregation equilibrium of every other committee.*

Proposition 14 and Corollary 2 indicate that the information collected by committee members need not be public as long as we assume that (1) the information is verifiable and (2) the committee members can communicate before voting. Without assumption (1), communication among the members becomes cheap talk. In this setting, Li et al. (2001) show that for any two-player heterogeneous committee, full information aggregation is impossible; however, the closer the players' preferences are, the more information they will share. My conjecture is that the incentive to reduce disagreement still plays a role in incentivizing members to collect information, thus some preference heterogeneity in a committee can improve the designer's payoff.

Without assumption (2), the members vote strategically to determine the collective decision. A comprehensive analysis of the committee design problem in this case is very complicated. However, I show in a two-player setting that some degree of preference heterogeneity is typically desirable for the designer. The analysis is at the end of Appendix B.

7 Discussion and Conclusion

In collective decision-making problems, members of the decision-making committees can collect decision-related information before they make their choices. The amount of information acquired by the members is potentially affected by the committee composition, size, and the decision rule. The existing literature examining the impacts of decision-making environments on information acquisition focuses on homogeneous committees. The current paper studies heterogeneous committees, with an emphasis on the roles of preference heterogeneity and voting rules in information collection.

When studying the problem of committee design, I assume that the size of the committee is fixed. If the designer is allowed to choose the committee size, how large is the optimal committee? The answer depends on the information cost function. With linear cost, the designer does not benefit from increasing the size of the committee beyond two members, as only one non-threshold voter collects information. Thus, a two-member committee is good enough for the designer. With convex cost, the designer's payoff is increasing in the size of the committee; adding more voters increases the aggregate information collected. Intuitively, a larger committee can distribute the information acquired across more members, lowering the total cost.

One assumption important for the analysis in the model is Assumption 3, which precludes non-concavity in the value of information. Setting aside the technical details, this assumption makes the precision choices strategic substitutes. Analyzing the case in which information acquired by the members can be either substitutes or complements is worth exploring.

Another assumption important for the analysis is that the members of a committee simultaneously acquire information. Some real world situations may not fit this assumption well. For example, in recruitment committees, some members may be responsible for reviewing the applications while others are responsible for interviewing candidates. In this situation, information is acquired sequentially by different members in the committee, with the followers being able to observe the findings of the earlier movers. One can imagine that if the earlier signals induce extreme posteriors, then the followers may not have a strong incentive to collect information; if the earlier signals make the followers quite unsure about the qualities of the candidates, then they will have a strong incentive to collect information. It may be interesting to characterize the optimal order in which the members collect information.

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Appendix A

Derivation of Equation (7)

To derive the expression of $\frac{\partial L_i(\rho_i,\rho_{-i},\underline{s}_k;q_k)}{\partial \rho_i}|_{\underline{s}_k}$, we use the fact that $F_1(\underline{s}_k|\rho) = \Phi(\sqrt{\rho}(\underline{s}_k - 1))$ and $F_0(\underline{s}_k|\rho) = \Phi(\sqrt{\rho}\underline{s}_k)$, where Φ denotes the CDF of the standard normal distribution. From (4), we have

$$\begin{aligned}\frac{\partial L_i(\rho_i,\rho_{-i},\underline{s}_k;q_k)}{\partial \rho_i}|_{\underline{s}_k} &= -(1-q_i)\gamma\frac{\partial \Phi(\sqrt{\rho}(\underline{s}_k-1))}{\partial \rho_i}|_{\underline{s}_k} - q_i(1-\gamma)\frac{\partial[1-\Phi(\sqrt{\rho}\underline{s}_k)]}{\partial \rho_i}|_{\underline{s}_k} \\ &= (1-q_i)\gamma\phi(\sqrt{\rho}(\underline{s}_k-1))\frac{(1-\underline{s}_k)}{2\sqrt{\rho}} + q_i(1-\gamma)\phi(\sqrt{\rho}\underline{s}_k)\frac{\underline{s}_k}{2\sqrt{\rho}},\end{aligned}$$

where ϕ denotes the density function of the standard normal distribution. Since $f_1(s|\rho) = \frac{\partial F_1(s|\rho)}{\partial s} = \sqrt{\rho}\phi(\sqrt{\rho}(s-1))$ and $f_0(s|\rho) = \frac{\partial F_0(s|\rho)}{\partial s} = \sqrt{\rho}\phi(\sqrt{\rho}s)$, we obtain the expression of $\frac{\partial L_i(\rho_i,\rho_{-i},\underline{s}_k;q_k)}{\partial \rho_i}|_{\underline{s}_k}$ in equation (**7**).

To derive the expression of $\frac{\partial L_i(\rho_i,\rho_{-i},\underline{s}_k;q_k)}{\partial \underline{s}_k}\frac{d\underline{s}_k}{d\rho_i}$, we still use the fact that $F_1(\underline{s}_k|\rho) = \Phi(\sqrt{\rho}(\underline{s}_k - 1))$ and $F_0(\underline{s}_k|\rho) = \Phi(\sqrt{\rho}\underline{s}_k)$. From (4), we have

$$\begin{aligned}\frac{\partial L_i(\rho_i,\rho_{-i},\underline{s}_k;q_k)}{\partial \underline{s}_k} &= -(1-q_i)\gamma\frac{\partial \Phi(\sqrt{\rho}(\underline{s}_k-1))}{\partial \underline{s}_k} - q_i(1-\gamma)\frac{\partial[1-\Phi(\sqrt{\rho}\underline{s}_k)]}{\partial \underline{s}_k} \\ &= -(1-q_i)\gamma\sqrt{\rho}\phi(\sqrt{\rho}(\underline{s}_k-1)) + q_i(1-\gamma)\sqrt{\rho}\phi(\sqrt{\rho}\underline{s}_k).\end{aligned}$$

Because $f_1(\underline{s}_k) = \sqrt{\rho}\phi(\sqrt{\rho}(\underline{s}_k-1))$ and $f_0(\underline{s}_k) = \sqrt{\rho}\phi(\sqrt{\rho}\underline{s}_k)$, we obtain the expression of $\frac{\partial L_i(\rho_i,\rho_{-i},\underline{s}_k;q_k)}{\partial \underline{s}_k}\frac{d\underline{s}_k}{d\rho_i}$ in equation (**7**).

Proof of Lemma 2

Suppose that the equilibrium value of ρ is not unique. Let ρ' and ρ'' denote two of the equilibrium levels, with $\rho_0 \le \rho' < \rho''$. Since $\rho'' > \rho_0$, we have $\rho''_j > 0$ for some member j in the ρ''-equilibrium. For this member in the ρ''-equilibrium, we have

$$\frac{dV_j\left(\rho''_j,\rho''_{-j},\underline{s}_k;q_k\right)}{d\rho_j} = 0. \tag{23}$$

In the ρ'-equilibrium, for the same member j, we have $dV_j\left(\rho'_j,\rho'_{-j},\underline{s}_k;q_k\right)/d\rho_j \le 0$, according to Lemma 1. Since $dV_j(\rho_j,\rho_{-j},\underline{s}_k;q_k)/d\rho_j$ is a function of the aggregate precision ρ, we have

$$\frac{d^2V_j(\rho_j,\rho_{-j},\underline{s}_k;q_k)}{d\rho_j^2} = \frac{d^2V_j(\rho_j,\rho_{-j},\underline{s}_k;q_k)}{d\rho_j d\rho}, \text{ for all } (\rho_j,\rho_{-j}) \text{ and } q_k.$$

Given Assumption 3, we have $d^2 V_j\left(\rho_j, \rho_{-j}, \underline{s}_k; q_k\right)/d\rho_j d\rho < 0$ for $\rho > \rho'$. Thus, we have

$$\frac{dV_j\left(\rho_j'', \rho_{-j}'', \underline{s}_k; q_k\right)}{d\rho_j} < \frac{dV_j\left(\rho_j', \rho_{-j}', \underline{s}_k; q_k\right)}{d\rho_j} \leq 0,$$

due to $\rho' < \rho''$. This contradicts the equilibrium condition (23).

Proof of Proposition 1

If $\gamma = 1/2$, then based on the definition of $h\left(q_k, \rho, \gamma\right)$ in (13), for any ρ,

$$h\left(q_k, \rho, \gamma\right) \begin{cases} > 0, \text{ if } q_k < 1/2; \\ = 0, \text{ if } q_k = 1/2; \\ < 0, \text{ if } q_k > 1/2. \end{cases}$$

Therefore, for any q_{-k}, we have

$$h\left(q_k, \rho\left(q_k, q_{-k}\right), \gamma\right) \begin{cases} > 0, \text{ if } q_k < 1/2; \\ = 0, \text{ if } q_k = 1/2; \\ < 0, \text{ if } q_k > 1/2, \end{cases}$$

which means that $q_k = 1/2$ is the unique virtually unbiased preference.

The proof for the case $\gamma \neq 1/2$ is more complex. To begin, consider a homogeneous committee in which all members have the same preference q_k. Let $\rho\left(q_k\right)$ denote the equilibrium aggregate precision of this committee, $\rho\left(q_k\right) \geq \rho_0$. It is easy to verify that $\rho\left(q_k\right)$ is continuous in q_k, using the maximum theorem. Thus, $h\left(q_k, \rho\left(q_k\right), \gamma\right)$ is continuous in q_k. Since

$$h\left(q_k, \rho\left(q_k\right), \gamma\right) \begin{cases} > 0, \text{ if } q_k = \min\left\{1/2, \gamma\right\}; \\ < 0, \text{ if } q_k = \max\left\{1/2, \gamma\right\}, \end{cases}$$

according to the intermediate value theorem, there exists $\bar{q}^* \in \left(\min\left\{1/2, \gamma\right\}, \max\left\{1/2, \gamma\right\}\right)$ such that

$$h\left(\bar{q}^*, \rho\left(\bar{q}^*\right), \gamma\right) = 0. \tag{24}$$

Before proceeding to heterogeneous committees, we first show that $\bar{q}^*$ is unique. At $\bar{q}^*$ satisfying (24), we have either $\rho\left(\bar{q}^*\right) = \rho_0$ or $\rho\left(\bar{q}^*\right) > \rho_0$. I consider these two cases separately below.

Case 1: $\rho\left(\bar{q}^*\right) = \rho_0$.

In this case, for any member i of the committee, we have

$$\frac{dL_i\left(\rho_i, \rho_{-i}, \underline{s}_k; \bar{q}^*\right)}{d\rho_i} = \left(1 - \bar{q}^*\right)\gamma f_1\left(\underline{s}_k|\rho_0\right)\frac{\underline{s}_k}{2\rho_0} + \bar{q}^*\left(1 - \gamma\right) f_0\left(\underline{s}_k|\rho_0\right)\frac{\left(1 - \underline{s}_k\right)}{2\rho_0} \leq c. \tag{25}$$

We examine how $dL_i/d\rho_i$ at the point $\rho = \rho_0$ changes with q_k. For convenience, in the rest of the analysis I use $\frac{dL_i(\rho_i,\rho_{-i},\underline{s}_k;q_k)}{d\rho_i}|_{\rho=\hat{\rho}}$ to denote the value of $dL_i/d\rho_i$ at the point $\rho = \hat{\rho}$ given q_k and use $\frac{d^2L_i(\rho_i,\rho_{-i},\underline{s}_k;q_k)}{d\rho_i dq_k}|_{\rho=\hat{\rho}}$ to the derivative of $\frac{dL_i(\rho_i,\rho_{-i},\underline{s}_k;q_k)}{d\rho_i}|_{\rho=\hat{\rho}}$ w.r.t. q_k. We obtain

$$
\begin{aligned}
&\frac{d^2L_i\left(\rho_i,\rho_{-i},\underline{s}_k;q_k\right)}{d\rho_i dq_k}|_{\rho=\rho_0} \\
&= \frac{(1-\gamma)\,f_0\left(\underline{s}_k|\rho_0\right)}{2\rho_0\left(1-q_k\right)} h\left(q_k,\rho_0,\gamma\right) \\
&\quad + \frac{1}{2}\left[\left(1-q_k\right)\gamma f_1\left(\underline{s}_k|\rho_0\right) - q_k\left(1-\gamma\right) f_0\left(\underline{s}_k|\rho_0\right)\right] \frac{\left[\frac{1}{\rho_0}+\underline{s}_k\left(1-\underline{s}_k\right)\right]}{\rho_0 q_k\left(1-q_k\right)} \\
&= \frac{(1-\gamma)\,f_0\left(\underline{s}_k|\rho_0\right)}{2\rho_0\left(1-q_k\right)} h\left(q_k,\rho_0,\gamma\right), \qquad (26)
\end{aligned}
$$

The second equality is due to the fact that $\left(1-q_k\right)\gamma f_1\left(\underline{s}_k|\rho_0\right) = q_k\left(1-\gamma\right) f_0\left(\underline{s}_k|\rho_0\right)$. (See the discussion for equations (2) and (3).) From (26) and the fact that $h\left(q_k,\rho_0,\gamma\right)$ is decreasing in q_k, we have

$$
\frac{d^2L_i\left(\rho_i,\rho_{-i},\underline{s}_k;q_k\right)}{d\rho_i dq_k}|_{\rho=\rho_0} \begin{cases} >0, \text{ if } q_k < \bar{q}^*; \\ =0, \text{ if } q_k = \bar{q}^*; \\ <0, \text{ if } q_k > \bar{q}^*. \end{cases}
$$

This implies that for $q_k \neq \bar{q}^*$,

$$
\frac{dL_i\left(\rho_i,\rho_{-i},\underline{s}_k;q_k\right)}{d\rho_i}|_{\rho=\rho_0} < \frac{dL_i\left(\rho_i,\rho_{-i},\underline{s}_k;\bar{q}^*\right)}{d\rho_i}|_{\rho=\rho_0} \leq c,
$$

where the second inequality is due to (25). Therefore, $\rho\left(q_k\right) = \rho_0$ for any q_k, and $h\left(q_k,\rho\left(q_k\right),\gamma\right)$ is strictly decreasing in q_k.

Case 2: $\rho\left(\bar{q}^*\right) > \rho_0$

In this case, for any member i of the committee

$$
\begin{aligned}
\frac{dL_i\left(\rho_i,\rho_{-i},\underline{s}_k;\bar{q}^*\right)}{d\rho_i} &= \left(1-\bar{q}^*\right)\gamma f_1\left(\underline{s}_k|\rho\left(\bar{q}^*\right)\right)\frac{\underline{s}_k}{2\rho\left(\bar{q}^*\right)} + \bar{q}^*\left(1-\gamma\right) f_0\left(\underline{s}_k|\rho\left(\bar{q}^*\right)\right)\frac{\left(1-\underline{s}_k\right)}{2\rho\left(\bar{q}^*\right)} \\
&= c. \qquad (27)
\end{aligned}
$$

This equation implies that $\rho\left(q_k\right)$ is differentiable in the neighborhood of $\bar{q}^*$. By total differentiation, we can derive the following equation from (27) for q_k in the neighborhood of $\bar{q}^*$,

$$
\frac{(1-\gamma)\,f_0\left(\underline{s}_k|\rho\left(q_k\right)\right)}{2\rho\left(q_k\right)\left(1-q_k\right)} h\left(q_k,\rho\left(q_k\right),\gamma\right) + \frac{d^2L_i\left(\rho_i,\rho_{-i},\underline{s}_k;q_k\right)}{d\rho_i^2}\frac{d\rho\left(q_k\right)}{dq_k} = 0. \qquad (28)
$$

Since $h(\bar{q}^*, \rho(\bar{q}^*), \gamma) = 0$, we have $\frac{d\rho(q_k)}{dq_k}|_{q_k=\bar{q}^*} = 0$. Thus,

$$\frac{dh(q_k, \rho(q_k), \gamma)}{dq_k}|_{q_k=\bar{q}^*} = -\left[1 + \frac{1}{\rho(\bar{q}^*)\bar{q}^*(1-\bar{q}^*)}\right] + \frac{1}{\rho(\bar{q}^*)^2}\ln\frac{\bar{q}^*(1-\gamma)}{(1-\bar{q}^*)\gamma}\frac{d\rho(q_k)}{dq_k}|_{q_k=\bar{q}^*}$$
$$= -\left[1 + \frac{1}{\rho(\bar{q}^*)\bar{q}^*(1-\bar{q}^*)}\right] < 0.$$

According to the discussion for the two cases above, we can see that $h(q_k, \rho(q_k), \gamma)$ is decreasing at $q_k = \bar{q}^*$. This implies that $\bar{q}^*$ satisfying (24) is unique.

We now switch to heterogeneous committees. I first prove that $\bar{q}^*$ is a virtually unbiased preference, i.e., $h(\bar{q}^*, \rho(\bar{q}^*, q_{-k}), \gamma) = 0$, for any q_{-k}. Given that $h(\bar{q}^*, \rho(\bar{q}^*), \gamma) = 0$, I show that $h(\bar{q}^*, \rho(\bar{q}^*, q_{-k}), \gamma) = 0$ holds for any q_{-k} by showing that $\rho(\bar{q}^*, q_{-k}) = \rho(\bar{q}^*)$ for any q_{-k}. From Lemma 3, it is clear that regardless of q_{-k}, when $q_k = \bar{q}^*$ and $\rho = \rho(\bar{q}^*)$,

$$\frac{d^2 L_i(\rho_i, \rho_{-i}, \underline{s}_k; q_k)}{d\rho_i dq_i} = 0, \forall i. \tag{29}$$

Since $\rho(\bar{q}^*)$ is the equilibrium precision for the homogeneous committee with $q_i = \bar{q}^*$ for any i, (29) and Lemma 2 imply that $\rho(\bar{q}^*)$ is also the unique equilibrium precision for any committee with $q_k = \bar{q}^*$, i.e., $\rho(\bar{q}^*, q_{-k}) = \rho(\bar{q}^*)$ for any q_{-k}. Therefore, $\bar{q}^*$ is a virtually unbiased preference.

Now I show that $\bar{q}^*$ is the unique virtually unbiased preference. I first prove that the equilibrium precision $\rho(q_k, q_{-k})$ under (q_k, q_{-k}) is continuous in q_k. For any given profile q_{-k}, according to Lemma 1, the equilibrium precision $\rho(q_k, q_{-k})$ satisfies

$$\rho(q_k, q_{-k}) = \min\left\{\rho \geq \rho_0 : \max_{i\in\{1,\ldots,n\}} \frac{dL_i(\rho_i, \rho_{-i}, \underline{s}_k; q_k)}{d\rho_i} \leq c\right\}.$$

Since $dL_i(\rho_i, \rho_{-i}, \underline{s}_k; q_k)/d\rho_i$ is continuous in (ρ, q_k) for all i, $\max_{i\in\{1,\ldots,n\}} dL_i(\rho_i, \rho_{-i}, \underline{s}_k; q_k)/d\rho_i$ is continuous in (ρ, q_k). Thus, $\rho(q_k, q_{-k})$ is continuous in q_k, which implies that the function $h(q_k, \rho(q_k, q_{-k}), \gamma)$ is continuous in q_k and satisfies

$$h(q_k, \rho(q_k, q_{-k}), \gamma) \begin{cases} > 0, \text{ if } q_k = \min\{1/2, \gamma\}; \\ < 0, \text{ if } q_k = \max\{1/2, \gamma\}, \end{cases} \tag{30}$$

and $h(\bar{q}^*, \rho(\bar{q}^*, q_{-k}), \gamma) = 0$. Now I show that for any q_{-k}, there is no other value of q_k satisfying $h(q_k, \rho(q_k, q_{-k}), \gamma) = 0$. I prove this by contradiction. Suppose that there exists $\hat{q}^* \in (\min\{1/2, \gamma\}, \max\{1/2, \gamma\})$ such that $h(\hat{q}^*, \rho(\hat{q}^*, q_{-k}), \gamma) = 0$ for some q_{-k} and $\hat{q}^*$. This implies that a homogeneous committee with all members having preference $\hat{q}^*$ satisfies $h(\hat{q}^*, \rho(\hat{q}^*), \gamma) = 0$, following our discussion are (29). This contradicts the uniqueness of $\bar{q}^*$ for homogeneous committees. Therefore, $\bar{q}^*$ is the unique value satisfying $h\left(\bar{q}^*, \rho\left(\bar{q}^*, q_{-k}\right), \gamma\right) = 0$, so it is the unique virtually unbiased preference. Combining this uniqueness with (30) and the continuity of $\rho\left(q_k, q_{-k}\right)$ in q_k, we have for $q_k < \bar{q}^*$, $h\left(q_k, \rho\left(q_k, q_{-k}\right), \gamma\right) > 0$ for any q_{-k}, and for $q_k > \bar{q}^*$, $h\left(q_k, \rho\left(q_k, q_{-k}\right), \gamma\right) < 0$ for any q_{-k}.

Proof of Proposition 3

I divide my discussion into three cases below.

Case 1: Under voting rule k, $q_k > \bar{q}^*$.

According to Proposition 1, member 1 has the most incentive to acquire information, i.e., $\frac{dL_1}{d\rho_1} \geq \frac{dL_i}{d\rho_i}$ for all $i \neq 1$ in equilibrium. Taking the derivative of $\frac{dL_1}{d\rho_1}$ w.r.t. q_k, while fixing (ρ_1, ρ_{-1}), yields

$$\frac{d^2 L_1\left(\rho_1, \rho_{-1}, \underline{s}_k; q_k\right)}{d\rho_1 dq_k} = \frac{1}{2}\left[(1-q_1)\gamma f_1\left(\underline{s}_k|\rho\right) - q_1(1-\gamma) f_0\left(\underline{s}_k|\rho\right)\right] \frac{\left[\frac{1}{\rho} + \underline{s}_k\left(1-\underline{s}_k\right)\right]}{\rho q_k\left(1-q_k\right)}. \quad (31)$$

In this equation, $\frac{1}{\rho} + \underline{s}_k\left(1-\underline{s}_k\right) > 0$, given Assumption 3 and the expression of $\underline{\rho}\left(q_k, \gamma\right)$ in (38). Thus, $\frac{d^2 L_1\left(\rho_1, \rho_{-1}, \underline{s}_k; q_k\right)}{d\rho_1 dq_k}$ has the same sign as $\left[(1-q_1)\gamma f_1\left(\underline{s}_k|\rho\right) - q_1(1-\gamma) f_0\left(\underline{s}_k|\rho\right)\right]$ on the RHS of (31). If $q_k > q_1$, $\frac{d^2 L_1\left(\rho_1, \rho_{-1}, \underline{s}_k; q_k\right)}{d\rho_1 dq_k} > 0$, i.e., member 1's incentive to acquire information is increasing in q_k. Since $q_k > \bar{q}^*$, increasing q_k does not change the fact that member 1 has the most incentive to acquire information. Therefore, the aggregate information acquired is increasing in q_k, and (weakly) increasing in k. If $q_k = q_1$, we have $\frac{d^2 L_1\left(\rho_1, \rho_{-1}, \underline{s}_k; q_k\right)}{d\rho_1 dq_k} = 0$, but the continuity of $\frac{d^2 L_1\left(\rho_1, \rho_{-1}, \underline{s}_k; q_k\right)}{d\rho_1 dq_k}$ in q_k implies that the argument above still applies. Therefore, the voting rule $k = n$ induces (weakly) more information acquisition than does any rule in this case.

Case 2: Under voting rule k, $q_k < \bar{q}^*$.

For this case, we can use a similar argument as above to show that the voting rule $k = 1$ induces (weakly) more information acquisition than does any other rule.

Case 3: Under voting rule k, $q_k = \bar{q}^*$.

For this case, all the members have the same incentive to acquire information, i.e., $\frac{dL_i}{d\rho_i} = \frac{dL_j}{d\rho_j}$ for $i \neq j$. We can, without loss of generality, let member 1 or member n be the only information collector, and adopt the arguments in the two cases above to show that at least one of the rules, $k = 1$ or $k = n$, outperforms any other rules.

Therefore, based on the analysis in the three cases above, we can conclude that one of the unanimous rule induces most information acquisition in equilibrium. However, this does not mean that both unanimous rules outperform all non-unanimous rules. Consider a committee with $q_n \leq \bar{q}^*$. The argument above implies that the unanimous rule with $k = 1$ induces most information acquisition, but the unanimous rule with $k = n$ induces the least information acquisition, and is outperformed by all non-unanimous rules.

Proof of Proposition 4

To simplify the notation, we use $V_0(q_0, q_1)$ to denote the expected payoff of a designer with preference q_0 from choosing a committee member with preference q_1, i.e.,

$$V_0(q_0, q_1) = -(1 - q_0)\gamma F_1(\underline{s}_1|\rho) - q_0(1 - \gamma)[1 - F_0(\underline{s}_1|\rho)].$$

Taking the derivative of $V_0(q_0, q_1)$ w.r.t. q_1, we obtain

$$\begin{aligned} \frac{dV_0(q_0, q_1)}{dq_1} = & [-(1 - q_0)\gamma f_1(\underline{s}_1|\rho) + q_0(1 - \gamma) f_0(\underline{s}_1|\rho)] \frac{\partial \underline{s}_1}{\partial q_1} \\ & + \left[(1 - q_0)\gamma f_1(\underline{s}_1|\rho)\frac{\underline{s}_1}{2\rho} + q_0(1 - \gamma) f_0(\underline{s}_1|\rho)\frac{(1 - \underline{s}_1)}{2\rho}\right]\frac{d\rho}{dq_1}, \end{aligned} \tag{32}$$

where $\partial \underline{s}_1 / \partial q_1$ is the derivative of $\underline{s}_1$ w.r.t. q_1 when fixing ρ, so

$$\frac{\partial \underline{s}_1}{\partial q_1} = \frac{1}{\rho q_1(1 - q_1)} > 0.$$

I should point out here that the equilibrium ρ may not be differentiable w.r.t. q_1 everywhere. However, the failure of differentiability at some point does not matter for our proof, as we care only about the direction of the change in the equilibrium value of ρ w.r.t q_1. From equations (26) and (28) in the proof of Proposition 1, the equilibrium value of ρ is (weakly) increasing in q_1 if $q_1 < \bar{q}^*$ and (weakly) decreasing in q_1 if $q_1 > \bar{q}^*$.

I discuss the three cases, $q_0 < \bar{q}^*$, $q_0 > \bar{q}^*$, and $q_0 = \bar{q}^*$, separately below.

Case 1: $q_0 < \bar{q}^*$.

If $q_1 < q_0$, then $V_0(q_0, q_1)$ is increasing in q_1, as the first line of (32) is positive and the second line is non-negative. Thus, $q_1 < q_0$ is not optimal. If $q_1 > \bar{q}^*$, then $V_0(q_0, q_1)$ is decreasing in q_1, as the first line of (32) is negative and the second line is non-positive. For $q_1 \in [q_0, \bar{q}^*]$, according to Assumption 4, we have $\rho > 0$ in equilibrium. At $q_1 = q_0$, we have $\frac{d\rho}{dq_1} > 0$, so $\frac{dV_0(q_0,q_1)}{dq_1} > 0$, as the first line of 32 is 0 and the second line is positive. At $q_1 = \bar{q}^*$, we have $\frac{d\rho}{dq_1} = 0$, so $\frac{dV_0(q_0,q_1)}{dq_1} < 0$, as the first line of 32 is negative and the second line is 0. Therefore, the optimal q_1 must be in $(q_0, \bar{q}^*)$.

Case 2: $q_0 > \bar{q}^*$.

Using an argument similar to the case above, we can conclude that the optimal q_1 must be in $(\bar{q}^*, q_0)$.

Case 3: $q_0 = \bar{q}^*$.

In this case, it is obvious that the optimal $q_1 = q_0$. If $q_1 < q_0 = \bar{q}^*$, then the first line of 32 is positive and the second line is non-negative. If $q_1 > q_0 = \bar{q}^*$, then the first line of 32 is negative and the second line is non-positive. At $q_1 = q_0 = \bar{q}^*$, we have $\frac{dV_0(q_0,q_1)}{dq_1} = 0$.

If Assumption 4 does not hold, then the optimal committee member may have $q_1 = q_0$, that is, the designer chooses one having the same preferences as herself. I omit a detailed discussion of this case.

Proof of Proposition 5

If the designer retains the right of making the final decision, the committee design problem becomes

$$\max_{q_1} V_0 (\rho, q_0)$$
$$s.t.\ 0 \leq q_1 \leq 1, \text{ and}$$
$$\rho = \arg\max_{\hat{\rho} \geq \rho_0} L_1 (\hat{\rho}, \underline{s}_0; q_0) - c(\hat{\rho} - \rho_0).$$

where

$$L_1 (\hat{\rho}, \underline{s}_0; q_0) = - (1 - q_1) \gamma F_1 (\underline{s}_0 | \hat{\rho}) - q_1 (1 - \gamma) [1 - F_0 (\underline{s}_0 | \hat{\rho})],$$

which denotes the expected payoff of member 1 from his decision given the aggregate precision $\hat{\rho}$.

For $V_0 (\rho, q_0)$, we have

$$\frac{dV_0 (\rho, q_0)}{d\rho} = (1 - q_0) \gamma f_1 (\underline{s}_0 | \rho) \frac{\underline{s}_0}{2\rho} + q_0 (1 - \gamma) f_0 (\underline{s}_0 | \rho) \frac{(1 - \underline{s}_0)}{2\rho} > 0,$$

which implies that the payoff of the designer is increasing in ρ. In equilibrium, ρ satisfies

$$\frac{dL_1 (\rho, \underline{s}_0; q_0)}{d\rho} - c \leq 0. \tag{33}$$

Given Assumption 4, we have that equilibrium $\rho > \rho_0$ at $q_1 = q_0$, so condition (33) holds with equality at $q_1 = q_0$. Thus, for q_1 in the neighborhood of q_0, we have

$$\frac{d\rho}{dq_1} = -\frac{(1 - \gamma) f_0 (\underline{s}_0 | \rho)}{2\rho} \frac{h (q_0, \rho, \gamma)}{d^2 L_1 (\rho, \underline{s}_0; q_0) / d\rho^2}.$$

If $q_0 < \bar{q}^*$, then according to equation (14), we have that $\frac{d\rho}{dq_1} > 0$ for $q_1 \geq q_0$. The intuition is the same as (14). For $q_1 < q_0$, our monotonicity result implies that the amount of information acquired in this case is less than that acquired in the case of $q_1 = q_0$. Therefore, a member 1 with $q_1 = 1$ acquires the most information.

If $q_0 > \bar{q}^*$, then the argument is reversed, and a member 1 with $q_1 = 0$ acquires the most information.

If $q_0 = \bar{q}^*$, the definition of $\bar{q}^*$ directly implies that any $q_1 \in [0, 1]$ induces the same amount of information.

Proof of Proposition 6

From the designer's problem (17), we can see that the non-threshold voters affect the payoff of the designer through ρ. Since

$$\frac{dV_0(\rho, q_k)}{d\rho} = (1 - q_0)\gamma f_1(\underline{s}_k|\rho)\frac{\underline{s}_k}{2\rho} + q_0(1-\gamma) f_0(\underline{s}_k|\rho)\frac{(1 - \underline{s}_k)}{2\rho} > 0,$$

the designer would like to have the non-threshold voters collect as much information as possible, given q_k. The impact of q_k on the designer's payoff is more complicated. Let $V_0(q_0, q_k, q_{-k}) \equiv V_0(\rho(q_k, q_{-k}; \rho_0, c, \gamma), q_k)$. Taking the derivative of $V_0(q_0, q_k, q_{-k})$ w.r.t. q_k, we obtain

$$\begin{aligned}\frac{dV_0(q_0, q_k, q_{-k})}{dq_k} &= [-(1 - q_0)\gamma f_1(\underline{s}_k|\rho) + q_0(1-\gamma) f_0(\underline{s}_k|\rho)]\frac{\partial \underline{s}_k}{\partial q_k} \\ &+ \left[(1 - q_0)\gamma f_1(\underline{s}_k|\rho)\frac{\underline{s}_k}{2\rho} + q_0(1-\gamma) f_0(\underline{s}_k|\rho)\frac{(1 - \underline{s}_k)}{2\rho}\right]\frac{d\rho}{dq_k},\end{aligned} \tag{34}$$

where $\partial \underline{s}_k / \partial q_k$ is the derivative of $\underline{s}_k$ w.r.t. q_k when fixing ρ.

Case 1: $q_0 < \bar{q}^*$

Suppose that the designer chooses $q_k < \bar{q}^*$. For such a committee, the proof of Proposition 5 implies that having $q_i = 1$, $i \neq k$, induces the most information acquisition. Thus, given $q_k < \bar{q}^*$, the designer always (weakly) prefers to have $q_i = 1$, $i \neq k$. Given $q_i = 1$ for all $i \neq k$, if $q_k \in [q_0, \bar{q}^*)$, then Assumption 4 implies that $\rho > \rho_0$ in equilibrium, thus we have $dV_0(q_0, q_k, q_{-k})/dq_k < 0$, as the first line of (34) is non-positive and its second line is negative due to

$$\frac{d\rho_j}{dq_k} = \frac{1}{2}(1-\gamma) f_0(\underline{s}_k|\rho)\frac{\left[\frac{1}{\rho} + \underline{s}_k(1 - \underline{s}_k)\right]}{\rho q_k(1 - q_k)} / \frac{d^2 L_j(\rho_j, \rho_{-j}, \underline{s}_k; q_k)}{d\rho_j^2} < 0, \tag{35}$$

for any information collector $j \neq k$. The intuition for (35) is the same as that for Proposition 3. This result indicates that among all committees with $q_k < \bar{q}^*$, there is an optimal one satisfying $q_k < q_0$ and $q_i = 1$, $i \neq k$.

Similar to the argument above, among all committees with $q_k > \bar{q}^*$, there is an optimal one satisfying $q_k > q_0$ and $q_i = 0$, $i \neq k$.

If the designer chooses $q_k = \bar{q}^*$, it is indifferent for her to choose any non-threshold voters, so the homogeneous committee with $q_i = \bar{q}^*$ for all i, will give her the highest payoff. However, for this homogeneous committee, we have $\frac{d\rho}{dq_k} = 0$ and $dV_0/dq_k < 0$. This means that this committee is dominated by one with $q_k < \bar{q}^*$ and $q_i = 1$, $i \neq k$.

Therefore, we conclude that for a designer with $q_0 < \bar{q}^*$, there is an optimal committee satisfying either $q_n \in (\bar{q}^*, 1)$ and $q_i = 0$, $i < n$, with $k = n$, or $q_1 \in (0, q_0)$ and $q_i = 1$, $i > 1$, with $k = 1$.

Case 2: $q_0 > \bar{q}^*$

Similar to the argument above, we conclude that there is an optimal committee satisfying either $q_n \in (q_0, 1)$ and $q_i = 0$, $i < n$, with $k = n$, or $q_1 \in (0, \bar{q}^*)$ and $q_i = 1$, $i > 1$, with $k = 1$.

Case 3: $q_0 = \bar{q}^*$

For this case, I show that a committee with $q_k = \bar{q}^*$ is not optimal. Given that $q_k = \bar{q}^*$, the equilibrium ρ does not change with the preferences of the non-threshold voters. Thus, the designer is indifferent between a committee with $q_k = \bar{q}^*$, $q_i = 1$, $i \neq k$ and a committee with $q_k = \bar{q}^*$, $q_i = 0$, $i \neq k$. It is obvious that for the former one, $dV_0\left(q_0, q_k, q_{-k}\right)/dq_k < 0$, so it is outperformed by a committee with $q_k < \bar{q}^*$, $q_i = 1$, $i \neq k$. For the latter one, $dV_0\left(q_0, q_k, q_{-k}\right)/dq_k > 0$, so it is outperformed by a committee with $q_k > \bar{q}^*$, $q_i = 0$, $i \neq k$. Thus, a committee with $q_k = \bar{q}^*$ is not optimal. Adopting an argument similar to the two cases above, we conclude that there is an optimal committee satisfying either $q_n \in (q_0, 1)$ and $q_i = 0$, $i < n$, with $k = n$, or $q_1 \in (0, q_0)$ and $q_i = 1$, $i > 1$, with $k = 1$.

Proof of Proposition 7

Proof of this proposition can be easily obtained based on the proof above for Proposition 6, taking into account the constraint $q_i \leq q_k$, for all $i \neq k$.

Proof of the Non-quasiconcavity of $V_i\left(\rho_i, \rho_{-i}, \underline{s}_k; q_k\right)$

I prove this by showing that $\frac{dL_i(\rho_i, \rho_{-i}, \underline{s}_k; q_k)}{d\rho_i} \to 0$ as $\rho \to 0$, when $q_k \neq \gamma$. From (10), we have

$$\lim_{\rho \to 0^+} \frac{dL_i\left(\rho_i, \rho_{-i}, \underline{s}_k; q_k\right)}{d\rho_i} = \lim_{\rho \to 0^+} \frac{\left(1-q_i\right)\gamma e^{-\frac{\rho}{2}\left(\underline{s}_k - 1\right)^2}\left[\frac{\rho}{2} + \ln\frac{q_k(1-\gamma)}{(1-q_k)\gamma}\right] + q_i(1-\gamma)e^{-\frac{\rho}{2}\underline{s}_k^2}\left[\frac{\rho}{2} - \ln\frac{q_k(1-\gamma)}{(1-q_k)\gamma}\right]}{2\sqrt{2\pi}\rho^{3/2}}.$$

Given the expression of $\underline{s}_k$, the limit above is proportional to the following limit

$$\lim_{\rho\to 0^+}\frac{e^{-\frac{1}{2\rho}\left(\ln\frac{q_k(1-\gamma)}{(1-q_k)\gamma}\right)^2}}{\rho^{3/2}}=\lim_{\rho\to 0^+}\frac{1}{\rho^{3/2}e^{\frac{1}{2\rho}\left(\ln\frac{q_k(1-\gamma)}{(1-q_k)\gamma}\right)^2}}.$$

The value of $\rho^{3/2}e^{\frac{1}{2\rho}\left(\ln\frac{q_k(1-\gamma)}{(1-q_k)\gamma}\right)^2}$ is increasing without bound when $\rho\to 0^+$. Thus, $\lim_{\rho\to 0^+}\frac{dL_i(\rho_i,\rho_{-i},\underline{s}_k;q_k)}{d\rho_i}=0$.

Proof of Lemma 4

For any i, we have

$$\begin{aligned}\frac{d^2V_i\left(\rho_i,\rho_{-i},\underline{s}_k;q_k\right)}{d\rho_i^2}&=\frac{d^2L_i\left(\rho_i,\rho_{-i},\underline{s}_k;q_k\right)}{d\rho^2}\\&=-\frac{(1-\gamma)f_0\left(\underline{s}_k|\rho\right)}{2\left(1-q_k\right)\rho}\left[\frac{1}{\rho}+\left(1-\underline{s}_k\right)\underline{s}_k\right]\left[\left(1-q_i\right)q_k\underline{s}_k+\left(1-q_k\right)q_i\left(1-\underline{s}_k\right)\right]\\&\quad+\frac{(1-\gamma)f_0\left(\underline{s}_k|\rho\right)}{\left(1-q_k\right)\rho^3}\ln\frac{q_k\left(1-\gamma\right)}{\left(1-q_k\right)\gamma}\left[\left(1-q_k\right)q_i-\left(1-q_i\right)q_k\right].\end{aligned}\tag{36}$$

In (36), we factor out $\frac{(1-\gamma)f_0(\underline{s}_k|\rho)}{2(1-q_k)\rho}$ and obtain

$$\begin{aligned}&\frac{d^2V_i\left(\rho_i,\rho_{-i},\underline{s}_k;q_k\right)}{d\rho_i^2}\\&=\frac{(1-\gamma)f_0\left(\underline{s}_k|\rho\right)}{2\left(1-q_k\right)\rho}\left\{\begin{array}{l}-\left[\frac{1}{\rho}+\left(1-\underline{s}_k\right)\underline{s}_k\right]\left[\left(1-q_i\right)q_k\underline{s}_k+\left(1-q_k\right)q_i\left(1-\underline{s}_k\right)\right]\\+\frac{2}{\rho^2}\ln\frac{q_k(1-\gamma)}{(1-q_k)\gamma}\left[\left(1-q_k\right)q_i-\left(1-q_i\right)q_k\right]\end{array}\right\}.\end{aligned}\tag{37}$$

Thus, $\frac{d^2V_i(\rho_i,\rho_{-i},\underline{s}_k;q_k)}{d\rho_i^2}/\frac{(1-\gamma)f_0(\underline{s}_k|\rho)}{2(1-q_k)\rho}$ is equal to the expression in the large brackets. We rewrite the term $\frac{2}{\rho^2}\ln\frac{q_k(1-\gamma)}{(1-q_k)\gamma}$ in the large brackets as $\frac{1}{\rho}\left(2\underline{s}_k-1\right)$. Then, we have.

$$\begin{aligned}&\frac{d^2V_i\left(\rho_i,\rho_{-i},\underline{s}_k;q_k\right)}{d\rho_i^2}/\frac{(1-\gamma)f_0\left(\underline{s}_k|\rho\right)}{2\left(1-q_k\right)\rho}\\&=-\left(1-\underline{s}_k\right)\underline{s}_k\left[\left(1-q_i\right)q_k\underline{s}_k+\left(1-q_k\right)q_i\left(1-\underline{s}_k\right)\right]\\&\qquad-\frac{1}{\rho}\left\{\left(1-q_i\right)q_k\left(3\underline{s}_k-1\right)+\left(1-q_k\right)q_i\left(2-3\underline{s}_k\right)\right\}.\end{aligned}$$

We can see that if $3\underline{s}_k-1>0$ and $2-3\underline{s}_k>0$, i.e., $\underline{s}_k\in\left(\frac{1}{3},\frac{2}{3}\right)$, then $\frac{d^2V_i(\rho_i,\rho_{-i},\underline{s}_k;q_k)}{d\rho_i^2}/\frac{(1-\gamma)f_0(\underline{s}_k|\rho)}{2(1-q_k)\rho}<0$. Since $\underline{s}_k=\frac{1}{2}+\frac{1}{\rho}\ln\frac{q_k(1-\gamma)}{(1-q_k)\gamma}$, we have $\underline{s}_k\in\left(\frac{1}{3},\frac{2}{3}\right)$ if and only if $\frac{1}{\rho}\ln\frac{q_k(1-\gamma)}{(1-q_k)\gamma} \in \left(-\frac{1}{6},\frac{1}{6}\right)$, i.e.,

$$\left|\frac{1}{\rho}\ln\frac{q_k\left(1-\gamma\right)}{\left(1-q_k\right)\gamma}\right| < \frac{1}{6},$$

or equivalently,

$$\rho > \underline{\rho}\left(q_k,\gamma\right) \equiv 6\left|\ln\frac{q_k\left(1-\gamma\right)}{\left(1-q_k\right)\gamma}\right|. \tag{38}$$

Therefore, given that $\frac{(1-\gamma)f_0(\underline{s}_k|\rho)}{2(1-q_k)\rho} > 0$, if $\rho > \underline{\rho}\left(q_k,\gamma\right)$, then $\frac{d^2V_i(\rho_i,\rho_{-i},\underline{s}_k;q_k)}{d\rho_i^2} < 0$.

Appendix B

Proof of Proposition 8

The proof of Proposition 1 applies to this proposition, with modifications as follows. First of all, since every committee members acquire information in equilibrium and $\rho(q_k, q_{-k})$ is differentiable with respect to (q_k, q_{-k}), we exclude the discussion on the case $\rho(\bar{q}^*) = \rho_0$ and the continuity of $\rho(q_k, q_{-k})$ in q_k. Secondly, we replace equations (27) and (28) by the following ones, respectively,

$$\begin{aligned}\frac{dL_i(\rho_i, \rho_{-i}, \underline{s}_k; \bar{q}^*)}{d\rho_i} &= (1-\bar{q}^*)\,\gamma f_1(\underline{s}_k|\rho(\bar{q}^*))\frac{\underline{s}_k}{2\rho(\bar{q}^*)} + \bar{q}^*(1-\gamma)\,f_0(\underline{s}_k|\rho(\bar{q}^*))\frac{(1-\underline{s}_k)}{2\rho(\bar{q}^*)} \\ &= C'(\rho_i),\end{aligned}$$

and

$$\frac{(1-\gamma)\,f_0(\underline{s}_k|\rho(q_k))}{2\rho(q_k)(1-q_k)}h(q_k, \rho(q_k);\gamma) + \frac{d^2L_i(\rho_i, \rho_{-i}, \underline{s}_k; q_k)}{d\rho_i^2}\frac{d\rho(q_k)}{dq_k} = C''(\rho_i)\frac{d\rho(q_k)}{dq_k}.$$

Proof of Proposition 9

I examine the impact of change in q_j, $j \neq k$, on information acquisition. From the first order conditions (19), we obtain

$$\begin{aligned}\sum_{l=1}^{n}\frac{d^2L_i(\rho_i, \rho_{-i}, \underline{s}_k; q_k)}{d\rho_i d\rho_l}\frac{d\rho_l}{dq_j} - C''(\rho_i)\frac{d\rho_i}{dq_j} &= 0, \forall i \neq j, \\ \frac{(1-\gamma)\,f_0(\underline{s}_k|\rho)}{2\rho(1-q_k)}h(q_k, \rho;\gamma) + \sum_{l=1}^{n}\frac{d^2L_j(\rho_j, \rho_{-j}, \underline{s}_k; q_k)}{d\rho_j d\rho_l}\frac{d\rho_l}{dq_j} - C''(\rho_j)\frac{d\rho_j}{dq_j} &= 0,\end{aligned}$$

or equivalently, using the fact that for any i and l, $d^2L_i(\rho_i, \rho_{-i}, \underline{s}_k; q_k)/d\rho_i d\rho_l = d^2L_i(\rho_i, \rho_{-i}, \underline{s}_k; q_k)/d\rho_i^2$,

$$\frac{1}{C''(\rho_i)}\frac{d^2L_i(\rho_i, \rho_{-i}, \underline{s}_k; q_k)}{d\rho_i^2}\frac{d\rho}{dq_j} = \frac{d\rho_i}{dq_j}, \forall i \neq j, \tag{39}$$

$$\frac{1}{C''(\rho_j)}\frac{(1-\gamma)\,f_0(\underline{s}_k|\rho)}{2\rho(1-q_k)}h(q_k, \rho;\gamma) + \frac{1}{C''(\rho_j)}\frac{d^2L_j(\rho_j, \rho_{-j}, \underline{s}_k; q_k)}{d\rho_j^2}\frac{d\rho}{dq_j} = \frac{d\rho_j}{dq_j}. \tag{40}$$

We add up all the equations above together and obtain

$$\frac{1}{C''(\rho_j)}\frac{(1-\gamma)\,f_0(\underline{s}_k|\rho)}{2\rho(1-q_k)}h(q_k, \rho;\gamma) = \left[1 - \sum_{l=1}^{n}\left(\frac{1}{C''(\rho_l)}\frac{d^2L_l(\rho_l, \rho_{-l}, \underline{s}_k; q_k)}{d\rho_l^2}\right)\right]\frac{d\rho}{dq_j}. \tag{41}$$

Since $\sum_{l=1}^{n}\left(\frac{1}{C''(\rho_l)}\frac{d^2L_l(\rho_l,\rho_{-l},\underline{s}_k;q_k)}{d\rho_l^2}\right) < 0$, we conclude that if $q_k > \bar{q}^*$, $\frac{d\rho}{dq_j} < 0$, and if $q_k < \bar{q}^*$,

$\frac{d\rho}{dq_j} > 0$. From equation (39), we have that $\frac{d\rho_i}{dq_j} > 0$ if $q_k > \bar{q}^*$, and $\frac{d\rho_i}{dq_j} < 0$ if $q_k < \bar{q}^*$. The sign of $\frac{d\rho_j}{dq_j}$ is consistent with that of $\frac{d\rho}{dq_j}$, as $\frac{d\rho_i}{dq_j}$, $i \neq j$, always has a sign opposed to the sign of $\frac{d\rho}{dq_j}$.

Proof of Proposition 10

I prove a more general version of Proposition 10. I assume that the voting threshold is k, with $1 < k < n$, and the preference profile of the committee has the following structure

$$q_i = \begin{cases} q_k + (i-k)\,\delta, \text{ if } i \leq k, \\ q_k + (i-k)\,\tilde{\delta}, \text{ if } i > k, \end{cases}$$

where $\tilde{\delta}$ satisfies

$$\tilde{\delta} = \frac{k\,(k-1)\,\delta}{(n+1-k)\,(n-k)},\ \delta > 0.$$

With such a preference profile, the average preference of the committee is always q_k regardless of the value of δ. Proposition **10** is only for the special case of this environment that n is an odd number and $k = (n+1)/2$.

Now I examine the change of δ on the equilibrium efforts of the committee members in acquiring information. From (19), we have that for $i \leq k$,

$$\frac{(1-\gamma)\,f_0\,(\underline{s}_k|\rho)}{2\rho\,(1-q_k)} h\,(q_k,\rho,\gamma)\,(i-k) + \frac{d^2 L_i\,(\rho_i,\rho_{-i},\underline{s}_k;q_k)}{d\rho_i^2}\frac{d\rho}{d\delta} = C''\,(\rho_i)\,\frac{d\rho_i}{d\delta},$$

and for $i > k$,

$$\frac{(1-\gamma)\,f_0\,(\underline{s}_k|\rho)}{2\rho\,(1-q_k)} h\,(q_k,\rho,\gamma)\,(i-k)\,\frac{k\,(k-1)}{(n+1-k)\,(n-k)} + \frac{d^2 L_i\,(\rho_i,\rho_{-i},\underline{s}_k;q_k)}{d\rho_i^2}\frac{d\rho}{d\delta}$$
$$= C''\,(\rho_i)\,\frac{d\rho_i}{d\delta}.$$

Multiplying $\frac{\delta}{C''(\rho_i)}$ on both sides of the equations, and then sum them up across i, we obtain

$$\frac{(1-\gamma)\,f_0\,(\underline{s}_k|\rho)}{2\rho\,(1-q_k)} h\,(q_k,\rho,\gamma)\left[\sum_{i=1}^{n}\lambda_i\,(q_i-q_k)\right]\sum_{l=1}^{n}\frac{1}{C''\,(\rho_l)}$$
$$= \delta\left[1-\left(\sum_{i=1}^{n}\lambda_i\frac{d^2 L_i\,(\rho_i,\rho_{-i},\underline{s}_k;q_k)}{d\rho_i^2}\right)\sum_{l=1}^{n}\frac{1}{C''\,(\rho_l)}\right]\frac{d\rho}{d\delta},$$

in which

$$\lambda_i = \frac{1/C''\,(\rho_i)}{\sum_{l=1}^{n} 1/C''\,(\rho_l)} \in (0,1)\,,\text{ and } \sum_{i=1}^{n}\lambda_i = 1.$$

Since $d^2 L_i(\rho_i, \rho_{-i}, \underline{s}_k; q_k)/d\rho_i^2 < 0$, we have

$$\sum_{i=1}^{n} \lambda_i \frac{d^2 L_i(\rho_i, \rho_{-i}, \underline{s}_k; q_k)}{d\rho_i^2} < 0.$$

Thus, the sign of $\frac{d\rho}{d\delta}$ is the same as that of the term $\frac{(1-\gamma)f_0(\underline{s}_k|\rho)}{2\rho(1-q_k)} h(q_k, \rho, \gamma)\left[\sum_{i=1}^{n} \lambda_i (q_i - q_k)\right]$. If $q_k = \bar{q}^*$, then $h(q_k, \rho, \gamma) = 0$, $\frac{d\rho}{d\delta} = 0$. So with a virtually unbiased threshold voter, changing the preference polarization among a group will not affect information collection. However, if $q_k \neq \bar{q}^*$, the degree of preference polarization matters. Let us first consider the case where $C'''(\rho_i) > 0$. In this case, if $q_k > \bar{q}^*$, then $h(q_k, \rho, \gamma) < 0$ and ρ_i is decreasing in i. This implies that λ_i is increasing in i, and

$$\sum_{i=1}^{n} \lambda_i (q_i - q_k) > 0.$$

So $\frac{(1-\gamma)f_0(\underline{s}_k|\rho)}{2\rho(1-q_k)} h(q_k, \rho, \gamma)\left[\sum_{i=1}^{n} \lambda_i (q_i - q_k)\right] < 0$, and $\frac{d\rho}{d\delta} < 0$. If $q_k > \bar{q}^*$, then $h(q_k, \rho, \gamma) < 0$ and ρ_i is increasing in i, which leads to the result that

$$\sum_{i=1}^{n} \lambda_i (q_i - q_k) < 0.$$

So $\frac{d\rho}{d\delta} < 0$ as well. Thus, with $C'''(\rho_i) > 0$, increasing preference polarization of a committee *decreases* the amount of information collected by the group in equilibrium. The result will be reversed for the case in which $C'''(\rho_i) < 0$.

Proof of Proposition 11

We compare the equilibrium aggregate precision $\rho = \sum_{i=0}^{n} \rho_i$ of the heterogeneous committee with that of the homogeneous one. From (19), we obtain

$$(1-\bar{q})\gamma f_1(\underline{s}_k|\rho)\frac{\underline{s}_k}{2\rho} + \bar{q}(1-\gamma) f_0(\underline{s}_k|\rho)\frac{(1-\underline{s}_k)}{2\rho} = \frac{1}{n}\sum_{i=1}^{n} C'(\rho_i), \tag{42}$$

where

$$\bar{q} = \frac{\sum_{i=1}^{n} q_i}{n}$$

If C' is concave, i.e., $C''' < 0$, we have

$$\frac{1}{n}\sum_{i=1}^{n} C'(\rho_i) \leq C'\left(\frac{\sum_{i=1}^{n}\rho_i}{n}\right) = C'\left(\frac{\rho-\rho_0}{n}\right),$$

which implies that, combining with (42),

$$(1-\bar{q})\,\gamma f_1\left(\underline{s}_k|\rho\right)\frac{\underline{s}_k}{2\rho}+\bar{q}\,(1-\gamma)\,f_0\left(\underline{s}_k|\rho\right)\frac{(1-\underline{s}_k)}{2\rho}\leq C'\left(\frac{\rho-\rho_0}{n}\right). \tag{43}$$

For the homogeneous committee with $q_i=\bar{q}$ for all i, let ρ^s be the aggregate precision in equilibrium. Then, we have

$$(1-\bar{q})\,\gamma f_1\left(\underline{s}_k|\rho^s\right)\frac{\underline{s}_k}{2\rho^s}+\bar{q}\,(1-\gamma)\,f_0\left(\underline{s}_k|\rho^s\right)\frac{(1-\underline{s}_k)}{2\rho^s}=C'\left(\frac{\rho^s-\rho_0}{n}\right). \tag{44}$$

Given the concavity of $L_i\left(\rho_i,\rho_{-i},\underline{s}_k;q_k\right)$ and the convexity of $C\left(\rho_i\right)$ in ρ_i, it is clear that

$$\rho\geq\rho^s,$$

that is, the heterogeneous committee acquires more information than the homogeneous one that has the same size and average preference. If the marginal cost function C' is convex, i.e., $C'''>0$, then the above result will be reversed, that is,

$$\rho\leq\rho^s.$$

Proofs of Lemma 5 and Proposition 12

From (19), we obtain

$$C'^{-1}\left(\frac{dL_i\left(\rho_i,\rho_{-i},\underline{s}_k;q_k\right)}{d\rho_i}\right)=\rho_i,\forall i. \tag{45}$$

Adding up such equalities across all players, we can obtain

$$\sum_{i=1}^{n}C'^{-1}\left(\frac{dL_i\left(\rho_i,\rho_{-i},\underline{s}_k;q_k\right)}{d\rho_i}\right)=\rho-\rho_0. \tag{46}$$

Total differentiation of (46) w.r.t. q_k and ρ gives

$$\sum_{i=1}^{n}\frac{1}{C''\left(\rho_i\right)}\left[\frac{d^2L_i\left(\rho_i,\rho_{-i},\underline{s}_k;q_k\right)}{d\rho_i dq_k}dq_k+\frac{d^2L_i\left(\rho_i,\rho_{-i},\underline{s}_k;q_k\right)}{d\rho_i^2}d\rho\right]=d\rho. \tag{47}$$

We rewrite (47) as

$$\frac{1}{2}\left[\left(1-\bar{q}^{e}\right)\gamma f_{1}\left(\underline{s}_{k}|\rho\right)-\bar{q}^{e}\left(1-\gamma\right)f_{0}\left(\underline{s}_{k}|\rho\right)\right]\frac{\left[\frac{1}{\rho}+\underline{s}_{k}\left(1-\underline{s}_{k}\right)\right]}{\rho q_{k}\left(1-q_{k}\right)}\left(\sum_{l=1}^{n}\frac{1}{C''\left(\rho_{l}\right)}\right)$$
$$=\left[1-\left(\sum_{i=1}^{n}\lambda_{i}\frac{d^{2}L_{i}\left(\rho_{i},\rho_{-i},\underline{s}_{k};q_{k}\right)}{d\rho_{i}^{2}}\right)\sum_{l=1}^{n}\frac{1}{C''\left(\rho_{l}\right)}\right]\frac{d\rho}{dq_{k}}. \quad (48)$$

Lemma 5 can be easily derived using (48). It is obvious that the sign of $d\rho/dq_k$ is the same as the sign of the term $\left[\left(1-\bar{q}^{e}\right)\gamma f_{1}\left(\underline{s}_{k}|\rho\right)-\bar{q}^{e}\left(1-\gamma\right)f_{0}\left(\underline{s}_{k}|\rho\right)\right]$ on the LHS of (48). Given the definition of $\underline{s}_k$, it is clear that if $\bar{q}^e < q_k$, then the term is positive, so $d\rho/dq_k > 0$. If $\bar{q}^e > q_k$, then the term is negative, so $d\rho/dq_k < 0$. The rest of the proof is for Proposition **12.**

The definition of $\bar{q}^e$ indicates that it is a continuous function of q_k. We use $\bar{q}^e(q_k)$ to denote the value of $\bar{q}^e$ given q_k. Since for any i, $\rho_i > 0$ and $C''(\rho_i) > 0$, there is

$$q_1 < \bar{q}^e(q_k) < q_n.$$

Thus, $\bar{q}^e$ is a continuous function mapping from $[q_1, q_n]$ to $[q_1, q_n]$. According to Brouwer's fixed point theorem, there exists $\hat{q}_k \in (q_1, q_n)$, such that

$$\bar{q}^e(\hat{q}_k) = \hat{q}_k.$$

If the fixed point is unique, then Lemma 5, which is proved based on (48), implies that the optimal voting rule maximizing information is necessarily a unanimous rule. This is because if $\hat{q}_k$ is the unique fixed point, then $\bar{q}^e(q_k) > q_k$ for $q_k < \hat{q}_k$ and $\bar{q}^e(q_k) < q_k$ for $q_k > \hat{q}_k$. Thus, according to Lemma 5, voting rule $k = 1$ induces more information acquisition than any other rule k with $q_k < \hat{q}_k$, and voting rule $k = n$ induces more information acquisition than any other rule k with $q_k > \hat{q}_k$. Therefore, the optimal voting rule maximizing information is necessarily a rule with $k = 1$ or $k = n$. However, the fixed point of $\bar{q}^e(q_k)$ may not be unique. We examine the slope of $\bar{q}^e(q_k)$ at $q_k = \hat{q}_k$ to see if there is a unique fixed point. If the slope is proved to be smaller than 1, then uniqueness is guaranteed. Otherwise, $\bar{q}^e(q_k)$

may have multiple fixed points. We take derivative of $\bar{q}^e(q_k)$ w.r.t. q_k and obtain

$$\frac{d\bar{q}^e(q_k)}{dq_k} = \frac{-\left(\sum_{i=1}^n \frac{C'''(\rho_i)}{C''(\rho_i)^2}\frac{d\rho_i}{dq_k}q_i\right)\left(\sum_{l=1}^n \frac{1}{C''(\rho_l)}\right)+\left(\sum_{i=1}^n \frac{q_i}{C''(\rho_i)}\right)\left(\sum_{i=1}^n \frac{C'''(\rho_i)}{C''(\rho_i)^2}\frac{d\rho_i}{dq_k}\right)}{\left(\sum_{l=1}^n \frac{1}{C''(\rho_l)}\right)^2} \tag{49}$$

$$= \frac{-\left(\sum_{i=1}^n \frac{C'''(\rho_i)}{C''(\rho_i)^2}\frac{d\rho_i}{dq_k}q_i\right)+\bar{q}^e\left(\sum_{i=1}^n \frac{C'''(\rho_i)}{C''(\rho_i)^2}\frac{d\rho_i}{dq_k}\right)}{\sum_{l=1}^n \frac{1}{C''(\rho_l)}}$$

$$= \sum_{i=1}^n \left[\frac{C'''(\rho_i)}{C''(\rho_i)}\frac{d\rho_i}{dq_k}\lambda_i(\bar{q}^e - q_i)\right].$$

Now we look at the sign of $\frac{d\bar{q}^e(q_k)}{dq_k}$ at $q_k = \hat{q}_k$. From equation (45), we have

$$\frac{1}{C''(\rho_i)}\left\{\begin{array}{c}\frac{1}{2}\left[(1-q_i)\gamma f_1(\underline{s}_k|\rho) - q_i(1-\gamma) f_0(\underline{s}_k|\rho)\right]\frac{\left[\frac{1}{\rho}+\underline{s}_k(1-\underline{s}_k)\right]}{\rho q_k(1-q_k)} \\ +\frac{d^2L_i(\rho_i,\rho_{-i},\underline{s}_k;q_k)}{d\rho_i^2}\frac{d\rho}{dq_k}\end{array}\right\} = \frac{d\rho_i}{dq_k}.$$

Equation (48) indicates that at $q_k = \hat{q}_k$, $\frac{d\rho}{dq_k} = 0$. Thus, we have $\frac{d\rho_i}{dq_k}|_{q_k=\hat{q}_k} > 0$ if $q_i < \hat{q}_k$, and $\frac{d\rho_i}{dq_k}|_{q_k=\hat{q}_k} < 0$ if $q_i > \hat{q}_k$. Therefore, according to (49), when $C'''(\cdot) < 0$, there is $\frac{d\bar{q}^e(q_k)}{dq_k}|_{q_k=\hat{q}_k} < 0$, and when $C'''(\cdot) > 0$, $\frac{d\bar{q}^e(q_k)}{dq_k}|_{q_k=\hat{q}_k} > 0$. Therefore, for the case in which $C'''(\cdot) < 0$, the fixed point of $\bar{q}^e(q_k)$ is unique, and the optimal voting rule which maximizes the amount of information collected by the committee is a unanimous rule. Otherwise, the optimal voting rule may be a non-unanimous rule.

Proof of Proposition 13

This proof is similar to the one for Proposition 6. Still, let $V_0(q_0, q_k, q_{-k}) \equiv V_0(\rho(q_k, q_{-k}; \rho_0, c, \gamma), q_k)$, where $\rho(q_k, q_{-k}; \rho_0, c, \gamma)$ is determined by the equality constraint. Taking derivatives of $V_0(q_0, q_k, q_{-k})$ with respect to q_k and q_i for any $i \neq k$, we obtain

$$\frac{dV_0(q_0,q_k,q_{-k})}{dq_k} = \left[-(1-q_0)\gamma f_1(\underline{s}_k|\rho) + q_0(1-\gamma) f_0(\underline{s}_k|\rho)\right]\frac{\partial \underline{s}_k}{\partial q_k}$$
$$+\left[(1-q_0)\gamma f_1(\underline{s}_k|\rho)\frac{\underline{s}_k}{2\rho} + q_0(1-\gamma) f_0(\underline{s}_k|\rho)\frac{(1-\underline{s}_k)}{2\rho}\right]\frac{d\rho}{dq_k},$$
$$\frac{dV_0(q_0,q_k,q_{-k})}{dq_i} = \left[(1-q_0)\gamma f_1(\underline{s}_k|\rho)\frac{\underline{s}_k}{2\rho} + q_0(1-\gamma) f_0(\underline{s}_k|\rho)\frac{(1-\underline{s}_k)}{2\rho}\right]\frac{d\rho}{dq_i}, \forall i \neq k.$$

According to equation (41) in the proof of Proposition 9, we have

$$\frac{d\rho}{dq_i} = \frac{(1-\gamma) f_0(\underline{s}_k|\rho)}{2\rho(1-q_k)}\frac{h(q_k,\rho,\gamma)}{C''(\rho_i)\left[1-\sum_{l=1}^n\left(\frac{1}{C''(\rho_l)}\frac{d^2L_l(\rho_l,\rho_{-l},\underline{s}_k;q_k)}{d\rho_l^2}\right)\right]}.$$

To obtain the expression of $\frac{d\rho}{dq_k}$, we employ the F.O.C's in (19), and obtain

$$\begin{aligned}&\frac{(1-\gamma)\, f_0\left(\underline{s}_k|\rho\right)}{2\rho\,(1-q_k)\, C''\left(\rho_k\right)} h\left(q_k,\rho,\gamma\right)\\&\quad+\frac{1}{2}\left[\left(1-\bar{q}^e\right)\gamma f_1\left(\underline{s}_k|\rho\right)-\bar{q}^e\left(1-\gamma\right) f_0\left(\underline{s}_k|\rho\right)\right]\frac{\left[\frac{1}{\rho}+\underline{s}_k\left(1-\underline{s}_k\right)\right]}{\rho q_k\left(1-q_k\right)}\left(\sum_{l=1}^{n}\frac{1}{C''\left(\rho_l\right)}\right)\\&=\left[1-\left(\sum_{i=1}^{n}\lambda_i\frac{d^2 L_i\left(\rho_i,\rho_{-i},\underline{s}_k;q_k\right)}{d\rho_i^2}\right)\sum_{l=1}^{n}\frac{1}{C''\left(\rho_l\right)}\right]\frac{d\rho}{dq_k}. \qquad (50)\end{aligned}$$

Since this proof is very similar to that for Proposition 6, we elaborate only the argument for the case $q_0 < \bar{q}^*$. The proof for the cases with $q_0 > \bar{q}^*$ and $q_0 = \bar{q}^*$ can be similarly derived.

First, suppose that the designer chooses $q_k < \bar{q}^*$. For such a committee, we have $dV_0\left(q_0, q_k, q_{-k}\right)/dq_i > 0$, due to $\frac{d\rho}{dq_i} > 0$. This implies that among all committees with $q_k < \bar{q}^*$, the optimal one satisfies $q_i = 1$, $i \neq k$. However, unlike Proposition 6, we cannot determine whether the optimal q_k is smaller than q_0 or not. If $q_k \in [q_0, \bar{q}^*)$, the sign of the second line of $dV_0\left(q_0, q_k, q_{-k}\right)/dq_k$ is indeterminate, due to the indeterminacy of $\frac{d\rho}{dq_k}$, which is because on the LHS of equation (50), the second term is negative, as $\bar{q}^e > q_k$, and the first term is positive, as $q_k < \bar{q}^*$.

Similar to the argument above, we find that among all committees with $q_k > \bar{q}^*$, the optimal one satisfies $q_i = 0$, for $i \neq k$.

If the designer chooses $q_k = \bar{q}^*$, it is indifferent for her to choose any non-threshold voters, so the homogeneous committee with $q_i = \bar{q}^*$ for all i, will give her the highest payoff. However, for this homogeneous committee, we have that $\frac{d\rho}{dq_k} = 0$ and $dV_0/dq_k < 0$. This means that this committee is dominated by one with $q_k < \bar{q}^*$ and $q_i = 1$, $i \neq k$.

Therefore, we conclude that for a designer with $q_0 < \bar{q}^*$, there is an optimal committee satisfying either $q_n \in (\bar{q}^*, 1)$ and $q_i = 0$, $i < n$, with $k = n$, or $q_1 \in (0, \bar{q}^*)$ and $q_i = 1$, $i > 1$, with $k = 1$.

Proof of Proposition 14

To construct an equilibrium of the game in which every committee member fully reveals his private information, specifying the beliefs of the members in cases where some members do not reveal their signals is crucial. The argument in Milgrom and Roberts (1986) does not apply here. In this proof, I specify the beliefs of the members in these cases and their associated voting strategies as follows:

(1) If the threshold voter k (or a non-threshold voter i with $q_i = q_k$) is the only one that does not reveal his information, then all other members believe that the threshold voter

collected no information. In the following voting stage, every member votes based on his belief, and no one adopts a weakly dominated voting strategy.

(2) If a non-threshold voter i with $q_i \neq q_k$ is the only member that does not reveal his information, then all other members upon observing the aggregate signal s_{-i} with

$$s_{-i} = \frac{\sum_{j\neq i}^{n} \rho_j s_j}{\rho_{-i}},$$

where $\rho_{-i} = \sum_{j\neq i}^{n} \rho_j$, hold a common posterior belief that the signal s_i of voter i has precision $\rho_i > 0$ and satisfies

$$s_i < \frac{(\rho_{-i} + \rho_i)\, \underline{s}_m - \rho_{-i} s_{-i}}{\rho_i}, \text{ if } q_i < q_k, \text{ or } s_i > \frac{(\rho_{-i} + \rho_i)\, \underline{s}_M - \rho_{-i} s_{-i}}{\rho_i}, \text{ if } q_i > q_k,$$

where

$$\underline{s}_m = \frac{1}{2} + \frac{1}{\rho_{-i} + \rho_i} \ln \frac{q_m (1-\gamma)}{(1-q_m)\,\gamma}, \text{ with } q_m = \min_{1\leq j\leq n} \{q_j : q_j > 0\}, \text{ and}$$
$$\underline{s}_M = \frac{1}{2} + \frac{1}{\rho_{-i} + \rho_i} \ln \frac{q_M (1-\gamma)}{(1-q_M)\,\gamma}, \text{ with } q_M = \max_{1\leq j\leq n} \{q_j : q_j < 1\}.$$

(Since $q_k \in (0,1)$, q_m and q_M always exist in a committee.) Thus, if $q_i < q_k$, then all non-extreme voters believe that the *status quo* should be chosen; if $q_i > q_k$, then all non-extreme voters believe that the *status quo* should be overturned. In the following voting stage, every member votes based on his belief, and no one adopts a weakly dominated voting strategy.

(3) If there are more than one voter concealing their information, then each member, no matter he reveals his information or not, believes that other members not revealing their information collected no information. In the following voting, every member votes based on his belief as in the two cases above.

Now I show that given the beliefs of the members above in the cases where not everyone reveals his information, it is incentive compatible for every member to reveal his information in stage 3. We first examine the incentive of the threshold voter to conceal his information. It is obvious that given that other members always reveal their information, if the threshold voter also reveal his information, the collective decision is always his optimal decision based on the fully aggregated information; there is no room to strictly improve his payoff by concealing his information. Thus, it is incentive compatible for the threshold voter to reveal his signal.

Suppose a non-threshold voter i with $q_i \neq q_k$ observes signal s_{i0} with

$$s_{i0} = \frac{\rho_i s_i + \rho_0 s_0}{\rho_{i0}},$$

where $\rho_{i0} = \rho_i + \rho_0$ and $\rho_i \geq 0$. If he conceals his information, then his expected payoff from the collective decision is

$$\begin{cases} \frac{-(1-q_i)\gamma f_1(s_{i0}|\rho_{i0})}{\gamma f_1(s_{i0}|\rho_{i0})+(1-\gamma)f_0(s_{i0}|\rho_{i0})}, & \text{if } q_i < q_k; \\ \frac{-q_i(1-\gamma)f_0(s_{i0}|\rho_{i0})}{\gamma f_1(s_{i0}|\rho_{i0})+(1-\gamma)f_0(s_{i0}|\rho_{i0})}, & \text{if } q_i > q_k. \end{cases} \tag{51}$$

If he reveals his signal, then his expected payoff is

$$\begin{aligned} &\frac{-(1-q_i)\gamma f_1(s_{i0}|\rho_{i0})}{\gamma f_1(s_{i0}|\rho_{i0}) + (1-\gamma) f_0(s_{i0}|\rho_{i0})} F_1\left(\frac{\rho \underline{s}_k - \rho_{i0} s_{i0}}{\rho - \rho_{i0}}|\rho - \rho_{i0}\right) \\ &\quad + \frac{-q_i(1-\gamma) f_0(s_{i0}|\rho_{i0})}{\gamma f_1(s_{i0}|\rho_{i0}) + (1-\gamma) f_0(s_{i0}|\rho_{i0})}\left[1 - F_0\left(\frac{\rho \underline{s}_k - \rho_{i0} s_{i0}}{\rho - \rho_i}|\rho - \rho_{i0}\right)\right], \end{aligned} \tag{52}$$

where $\rho - \rho_{i0}$ is the aggregate precision of the signals acquired by all other members that i expects. Suppose $q_i < q_k$. If $\rho - \rho_{i0} = 0$, then the expected payoff is reduced to

$$\begin{cases} \frac{-(1-q_i)\gamma f_1(s_{i0}|\rho_{i0})}{\gamma f_1(s_{i0}|\rho_{i0})+(1-\gamma)f_0(s_{i0}|\rho_{i0})}, & \text{if } s_{i0} < \underline{s}_k; \\ \frac{-q_i(1-\gamma)f_0(s_{i0}|\rho_{i0})}{\gamma f_1(s_{i0}|\rho_{i0})+(1-\gamma)f_0(s_{i0}|\rho_{i0})}, & \text{if } s_{i0} \geq \underline{s}_k. \end{cases} \tag{53}$$

Since $q_i < q_k$, we have $\underline{s}_i < \underline{s}_k$. By comparing (51) and (53), we can see that if $s_{i0} < \underline{s}_k$, member i is indifferent between concealing and revealing his information, while if $s_{i0} \geq \underline{s}_k$, member i gets strictly better off from revealing his information, as in this case $s_{i0} > \underline{s}_i$, which implies

$$\frac{-(1-q_i)\gamma f_1(s_{i0}|\rho_{i0})}{\gamma f_1(s_{i0}|\rho_{i0}) + (1-\gamma) f_0(s_{i0}|\rho_{i0})} < \frac{-q_i(1-\gamma) f_0(s_{i0}|\rho_{i0})}{\gamma f_1(s_{i0}|\rho_{i0}) + (1-\gamma) f_0(s_{i0}|\rho_{i0})}.$$

If $\rho - \rho_{i0} > 0$, then it is easy to verify that the expected payoff (52) reaches its maximum at $\underline{s}_k = \underline{s}_i$ and is decreasing in $\underline{s}_k$ for $\underline{s}_k > \underline{s}_i$. The expected payoff of member i from concealing his information is equal to that from revealing his information with $\underline{s}_k = \infty$. Thus, for every finite $\underline{s}_k$, which is assumed in this paper, revealing information is optimal for i. The case where $q_i > q_k$ can be similarly proved. Therefore, it is incentive compatible for every non-threshold voter i with $q_i \neq q_k$ to reveal his information.

Since it is incentive compatible for every member to reveal his acquired information in stage 3, the problem facing the members in stage 1 is identical to the problem facing them in stage 1 of the public information case. Thus, every member collects the same amount of information as he does in public information case. This completes the proof.

Committee Design: Voting without Communication

In this supplementary material, I study the problem that a committee designer composes a two-member committee to make a collective decision. Same as in the main model of this paper, the designer chooses the composition and voting rule of the committee. The departure of this problem from the main model is that the information collected by the members, including the precisions and realizations of the signals, is private, and there is no free public signal. The members aggregate their information through voting. Instead of conducting a comprehensive analysis of this problem, I show only that it is typically not optimal for the designer to compose a homogeneous committee whose members are perfectly aligned with her. I consider only the case where the cost of information is convex.

I first analyze arbitrarily composed committees. Let q_1 and q_2 denote the preferences of the two committee members, 1 and 2, respectively. The voting rule is $k = 2$, i.e., unanimity is required to overturn the *status quo*. Suppose that the precisions of their private signals are respectively $\rho_1 > 0$ and $\rho_2 > 0$, and each member forms a correct belief about the precision of the other member's signal. Then, an equilibrium of the voting game can be characterized by a pair of cut-off values $(\bar{s}_1, \bar{s}_2)$, which satisfy

$$\frac{q_i(1-\gamma)}{(1-q_i)\gamma} = \frac{f_1(\bar{s}_i|\rho_i)[1-F_1(\bar{s}_j|\rho_j)]}{f_0(\bar{s}_i|\rho_i)[1-F_0(\bar{s}_j|\rho_j)]}\text{ , for } i, j = 1, 2,\ i \neq j, \tag{54}$$

such that member i votes for overturning the *status quo* if and only if $s_i \geq \bar{s}_i$, $i = 1, 2$. Because $f_1(s_i|\rho_i)/f_0(s_i|\rho_i)$ satisfies the monotone likelihood ratio property (MLRP) and $\frac{f_1(s_i|\rho_i)/[1-F_1(s_i|\rho_i)]}{f_0(s_i|\rho_i)/[1-F_0(s_i|\rho_i)]}$ is increasing in s_i, there exists a unique pair $(\bar{s}_1, \bar{s}_2)$ satisfying (54). (See Li et al. (2001) for detailed discussion.) The equilibrium values of $\bar{s}_1$ and $\bar{s}_2$ depend on ρ_1, ρ_2, q_1, q_2, and γ.

In this model, ρ_1 and ρ_2 are endogenous. I impose the following assumption to ensure the existence of an equilibrium of this committee game with information acquisition. In this assumption, $\bar{\rho}_j$ is the maximum precision that member j is willing to choose; choosing a precision higher than $\bar{\rho}_j$ is so costly that j's payoff is lower than that he can obtain without any information. Since $[1-F_0(\bar{s}_j|\rho)]/[1-F_1(\bar{s}_j|\rho)]$ is decreasing in $\bar{s}_j$ and has maximum equal to 1, the assumption is not empty.

Assumption 5 *Each committee member has a free private signal s_0 with precision $\rho_0 > 0$. The preferences of the members are non-extreme, i.e., $q_1, q_2 \in (0,1)$, and satisfy*

$$\rho_0 > 2\left|\ln\frac{q_i(1-\gamma)[1-F_0(\bar{s}_j|\rho)]}{(1-q_i)\gamma[1-F_1(\bar{s}_j|\rho)]}\right|,$$

for all $\rho \in [\rho_0, \bar{\rho}_j]$, where $\bar{\rho}_j = \rho_0 + C^{-1}(2\min\{q_j(1-\gamma), (1-q_j)\gamma\})$, and all $\bar{s}_j \in (-\infty, \frac{1}{2} + \frac{1}{\rho}\ln\frac{q_j(1-\gamma)}{(1-q_j)\gamma}]$, $i, j = 1, 2$ and $i \neq j$.

In the information acquisition stage of the game, if member i believes that member $j \neq i$

chooses precision ρ_j' and cut-off $\bar{s}_j'$, and he chooses precision ρ_i and consequently $\bar{s}_i$ satisfying

$$\frac{q_i(1-\gamma)}{(1-q_i)\gamma} = \frac{f_1(\bar{s}_i|\rho_i)[1-F_1(\bar{s}_j'|\rho_j')]}{f_0(\bar{s}_i|\rho_i)[1-F_0(\bar{s}_j'|\rho_j')]}, \tag{55}$$

according to (54), then the expected payoff of i is

$$-(1-q_i)\gamma\{1-[1-F_1(\bar{s}_i|\rho_i)][1-F_1(\bar{s}_j'|\rho_j')]\} \\ -q_i(1-\gamma)[1-F_0(\bar{s}_i|\rho_i)][1-F_0(\bar{s}_j'|\rho_j')]-C(\rho_i-\rho_0). \tag{56}$$

The first order condition of i's payoff maximization problem is

$$-(1-q_i)\gamma[1-F_1(\bar{s}_j'|\rho_j')]f_1(\bar{s}_i|\rho_i)\left(\frac{\bar{s}_i-1}{2\rho_i}+\frac{d\bar{s}_i}{d\rho_i}\right) \\ +q_i(1-\gamma)[1-F_0(\bar{s}_j'|\rho_j')]f_0(\bar{s}_i|\rho_i)\left(\frac{\bar{s}_i}{2\rho_i}+\frac{d\bar{s}_i}{d\rho_i}\right)-C'(\rho_i-\rho_0)=0.$$

According to (55), the first order condition can be reduced to

$$\frac{(1-q_i)\gamma[1-F_1(\bar{s}_j'|\rho_j')]f_1(\bar{s}_i|\rho_i)}{2\rho_i}-C'(\rho_i-\rho_0)=0. \tag{57}$$

Whether the second order condition of the payoff maximization problem is satisfied depends on the values of $\bar{s}_j'$ and ρ_j'. If member i believes that member j is rational, then $\rho_j' \in [\rho_0, \bar{\rho}_j]$, and $\bar{s}_j' \in (-\infty, \frac{1}{2}+\frac{1}{\rho_j'}\ln\frac{q_j(1-\gamma)}{(1-q_j)\gamma}]$, because member j would believe that $\bar{s}_i \in \mathbb{R}$ and choose $\bar{s}_j'$ following his belief on $\bar{s}_i$ according to (54). Given these ranges of $\bar{s}_j'$ and ρ_j', the expected payoff (56) is concave in ρ_i, thus the second order condition is satisfied. The concavity of the expected payoff also ensures the existence of an equilibrium. Let (ρ_1^*, ρ_2^*) be the equilibrium precision profile and $(\bar{s}_1^*, \bar{s}_2^*)$ the equilibrium cut-offs associated with the precisions, then according to (54) and (57), they satisfy

$$\frac{(1-q_i)\gamma[1-F_1(\bar{s}_j^*|\rho_j^*)]f_1(\bar{s}_i^*|\rho_i^*)}{2\rho_i^*}-C'(\rho_i^*-\rho_0)=0, \text{ and} \tag{58}$$

$$\frac{q_i(1-\gamma)}{(1-q_i)\gamma} = \frac{f_1(\bar{s}_i^*|\rho_i^*)[1-F_1(\bar{s}_j^*|\rho_j^*)]}{f_0(\bar{s}_i^*|\rho_i^*)[1-F_0(\bar{s}_j^*|\rho_j^*)]}\text{ , for } i,j=1,2,\ i\neq j. \tag{59}$$

Now I examine whether a designer with preference q_0 would like to compose a committee in which $q_1 = q_2 = q_0$. In this analysis, I assume that the value of q_0 satisfies Assumption 5, so the game played by the homogeneous committee has an equilibrium. Moreover, I focus on the symmetric equilibrium of the game. It is easy to verify the existence of a symmetric equilibrium, using (58) by restricting $\bar{s}_j^* = \bar{s}_i^*$ and $\rho_j^* = \rho_i^*$. The expected payoff of the designer from composing a committee with preference profile (q_1, q_2) is

$$
-(1-q_0)\,\gamma\left\{1-[1-F_1(\bar{s}_i^*|\rho_i^*)][1-F_1(\bar{s}_j^*|\rho_j^*)]\right\}-q_0\,(1-\gamma)\,[1-F_0(\bar{s}_i^*|\rho_i^*)][1-F_0(\bar{s}_j^*|\rho_j^*)],
$$

where (ρ_1^*, ρ_2^*) and $(\bar{s}_1^*, \bar{s}_2^*)$ satisfy (58) and (59). Starting from a committee with $q_1 = q_2 = q_0$, if the designer marginally moves q_1 away from q_0, the marginal change of her payoff is

$$
\frac{(1-q_0)\,\gamma f_1(\bar{s}_2^*|\rho_2^*)\,[1-F_1(\bar{s}_1^*|\rho_1^*)]}{2\rho_2}\left(\frac{d\rho_1^*}{dq_1}+\frac{d\rho_2^*}{dq_1}\right),
$$

which is derived using the symmetry of the equilibrium and (59). It is clear that the designer has incentive to choose $q_1 \neq q_0$ if $\frac{d\rho_1^*}{dq_1}+\frac{d\rho_2^*}{dq_1}\neq 0$. I prove that this is typically true.

To proceed, we look at how ρ_1 and ρ_2 change with q_1. From the F.O.C. of member 1 in (58), we have

$$
\begin{aligned}
&2\left[C''(\rho_1^*-\rho_0)\,\rho_1^*+C'(\rho_1^*-\rho_0)\right]\frac{d\rho_1^*}{dq_1}=-\gamma\,[1-F_1(\bar{s}_2^*|\rho_2^*)]\,f_1(\bar{s}_1^*|\rho_1^*)\\
&+(1-q_1)\,\gamma\left\{\begin{array}{l}
-f_1(\bar{s}_2^*|\rho_2^*)f_1(\bar{s}_1^*|\rho_1^*)\left[\frac{\left(\bar{s}_2^*-1\right)}{2\rho_2^*}\frac{d\rho_2^*}{dq_1}+\frac{\partial\bar{s}_2^*}{\partial\rho_2^*}\frac{d\rho_2^*}{dq_1}+\frac{\partial\bar{s}_2^*}{\partial\rho_1^*}\frac{d\rho_1^*}{dq_1}+\frac{\partial\bar{s}_2^*}{\partial q_1}\right]\\
+[1-F_1(\bar{s}_2^*|\rho_2^*)]\,f_1(\bar{s}_1^*|\rho_1^*)\left[\begin{array}{l}
\frac{1}{2\rho_1^*}\frac{d\rho_1^*}{dq_1}-\frac{\left(\bar{s}_1^*-1\right)^2}{2}\frac{d\rho_1^*}{dq_1}\\
-(\bar{s}_1^*-1)\,\rho_1^*\left(\frac{\partial\bar{s}_1^*}{\partial\rho_1^*}\frac{d\rho_1^*}{dq_1}+\frac{\partial\bar{s}_1^*}{\partial\rho_2^*}\frac{d\rho_2^*}{dq_1}+\frac{\partial\bar{s}_1^*}{\partial q_1}\right)
\end{array}\right]
\end{array}\right\}.
\end{aligned}
$$

Similarly, from the F.O.C. of member 2 in (58), we have

$$
\begin{aligned}
&2\left[C''(\rho_2^*-\rho_0)\,\rho_2^*+C'(\rho_2^*-\rho_0)\right]\frac{d\rho_2^*}{dq_1}=\\
&(1-q_2)\,\gamma\left\{\begin{array}{l}
-f_1(\bar{s}_1^*|\rho_1^*)f_1(\bar{s}_2^*|\rho_2^*)\left[\frac{\left(\bar{s}_1^*-1\right)}{2\rho_1^*}\frac{\partial\rho_1^*}{\partial q_1}+\frac{\partial\bar{s}_1^*}{\partial\rho_1^*}\frac{d\rho_1^*}{dq_1}+\frac{\partial\bar{s}_1^*}{\partial\rho_2^*}\frac{d\rho_2^*}{dq_1}+\frac{\partial\bar{s}_1^*}{\partial q_1}\right]\\
+[1-F_1(\bar{s}_1^*|\rho_1^*)]\,f_1(\bar{s}_2^*|\rho_2^*)\left[\begin{array}{l}
\frac{1}{2\rho_2^*}\frac{d\rho_2^*}{dq_1}-\frac{\left(\bar{s}_2^*-1\right)^2}{2}\frac{d\rho_2^*}{dq_1}\\
-(\bar{s}_2^*-1)\,\rho_2^*\left(\frac{\partial\bar{s}_2^*}{\partial\rho_2^*}\frac{d\rho_2^*}{dq_1}+\frac{\partial\bar{s}_2^*}{\partial\rho_1^*}\frac{d\rho_1^*}{dq_1}+\frac{\partial\bar{s}_2^*}{\partial q_1}\right)
\end{array}\right]
\end{array}\right\}.
\end{aligned}
$$

Suppose that $\frac{d\rho_1^*}{dq_1}+\frac{d\rho_2^*}{dq_1}=0$. Using the fact that $\frac{\partial\bar{s}_i^*}{\partial\rho_j^*}=\frac{\partial\bar{s}_j^*}{\partial\rho_i^*}$, $i,j=1,2$, in the symmetric equilibrium, we add up the two equations above and obtain,

$$
\begin{aligned}
0=&-\gamma\,[1-F_1(\bar{s}_2^*|\rho_2^*)]\,f_1(\bar{s}_1^*|\rho_1^*)\\
&-(1-q_1)\,\gamma\left(\frac{\partial\bar{s}_1^*}{\partial q_1}+\frac{\partial\bar{s}_2^*}{\partial q_1}\right)f_1(\bar{s}_1^*|\rho_1^*)\left\{f_1(\bar{s}_2^*|\rho_2^*)+[1-F_1(\bar{s}_2^*|\rho_2^*)]\,(\bar{s}_1^*-1)\,\rho_1^*\right\}.
\end{aligned}
\tag{60}
$$

To learn about $\frac{\partial \bar{s}_1^*}{\partial q_1} + \frac{\partial \bar{s}_2^*}{\partial q_1}$, we use (59) and obtain

$$\begin{aligned} & (1-\gamma)\left[1-F_0(\bar{s}_2^*|\rho_2^*)\right] f_0\left(\bar{s}_1^*|\rho_1^*\right) \\ & -q_1\left(1-\gamma\right)\left(\frac{\partial \bar{s}_1^*}{\partial q_1}+\frac{\partial \bar{s}_2^*}{\partial q_1}\right) f_0\left(\bar{s}_1^*|\rho_1^*\right)\left\{f_0(\bar{s}_2^*|\rho_2^*)+\left[1-F_0(\bar{s}_2^*|\rho_2^*)\right]\bar{s}_1^*\rho_1^*\right\} \\ = & -\gamma\left[1-F_1(\bar{s}_1^*|\rho_1^*)\right] f_1\left(\bar{s}_1^*|\rho_1^*\right) \\ & -\left(1-q_1\right)\gamma\left(\frac{\partial \bar{s}_1^*}{\partial q_1}+\frac{\partial \bar{s}_2^*}{\partial q_1}\right) f_1\left(\bar{s}_1^*|\rho_1^*\right)\left\{f_1(\bar{s}_2^*|\rho_2^*)+\left[1-F_1(\bar{s}_2^*|\rho_2^*)\right]\left(\bar{s}_1^*-1\right)\rho_1^*\right\}. \end{aligned} \tag{61}$$

Equations (60) and (61) jointly imply that

$$\frac{(1-q_1)}{q_1}\frac{\left[1-F_0(\bar{s}_2^*|\rho_2^*)\right]}{\left[1-F_1(\bar{s}_1^*|\rho_1^*)\right]} = -\frac{f_0(\bar{s}_2^*|\rho_2^*)+\left[1-F_0(\bar{s}_2^*|\rho_2^*)\right]\bar{s}_1^*\rho_1^*}{f_1(\bar{s}_2^*|\rho_2^*)+\left[1-F_1(\bar{s}_2^*|\rho_2^*)\right]\left(\bar{s}_1^*-1\right)\rho_1^*}. \tag{62}$$

One should note that (62) is independent of γ. Thus, the relationship between $\rho_1^* = \rho_2^*$ and $\bar{s}_1^* = \bar{s}_2^*$ in (62) does not depend on γ. However, the relationship between $\rho_1^* = \rho_2^*$ and $\bar{s}_1^* = \bar{s}_2^*$ in (59) and (58) is governed by γ. Therefore, (62) typically does not hold, which implies that $\frac{d\rho_1^*}{dq_1} + \frac{d\rho_2^*}{dq_1} = 0$ does not hold typically, and the designer has incentive to change q_1.

The proof for the case of $k = 1$ can be similarly proved. Thus, I omit it in this supplementary material.