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Committee Design with Endogenous Participation

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Abstract

We investigate the optimal design of a committee in a model with the endogenous participation of experts who have private information about their own abilities. We study three different dimensions of committee design: members' wages, the number of seats, and the communication system. We show that, surprisingly, higher wages lead to lower quality experts. By contrast, transparency improves the quality of experts on the committee. We provide a complete characterization of optimal committees. They are characterized by low wages and can be transparent or opaque. An increase in the significance of the decision requires a larger optimal committee, but does not call for different wages or for another communication system. Finally, we prove that the optimal committee design represents the best possible mechanism for the principal.

Keywords: Committee decision-making, information aggregation, adverse selection, efficiency wages, transparency, career concerns.

JEL: D71, D82, J45.

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1 Introduction

Many decisions are taken by committees rather than individuals. Examples include boards of directors, monetary-policy committees, parliamentary committees, search committees in academia, and juries in trials. In this paper, we revisit the question of the optimal design of expert committees. While it has been recognized in the literature that the committee design may have important consequences for the amount of information collected by its members (see Persico (2004)), we focus on how the committee design affects potential members' decisions to join the committee and how this influences the performance of decision-making.

More specifically, we propose a two-period model of a principal ("she") who delegates a decision to an expert committee.[1] Each individual candidate ("he") has private information about his individual competence and decides whether to apply for a position on the committee. If an expert works on the committee, he will earn the wage offered by the principal. In addition, his term on the committee may reveal information about his ability, which will affect his future wage.

We use this model to assess the optimal committee design along three distinct dimensions: the remuneration of experts on the committee, the number of seats, and the communication system, which can be transparent or opaque. These characteristics determine how much information outsiders can learn about the competence of the committees' experts. As a result, different committee designs entail different future wage distributions and thereby affect experts' decisions to apply in the first place.

Our analysis generates the following findings. First, we show that higher wages continuously increase the number of less able experts on the committee. This results from the fact that highly able experts find working on the committee more profitable than their less competent colleagues as it enables them to demonstrate their competence to the market. By contrast, less competent experts only find working on the committee attractive if wages are high. Hence, we identify a continuous relationship between wages and the expected quality of experts on the committee.

[1] The literature on careerist experts can be traced back to Holmström (1999). Ottaviani and Sørensen (2001) build on Scharfstein and Stein (1990) to examine herding in sequential debate. Further analyses of expert committees are Gersbach and Hahn (2008), Hahn (2011, 2012), Levy (2005, 2007), Ottaviani and Sørensen (2006), Swank et al. (2008), and Visser and Swank (2007).

Second, we show that the principal prefers the lowest possible wage for which experts apply. By selecting this wage, she can attract specifically experts of high competence and minimize the wage bill. Thus, our model might provide a rationale for the comparably modest financial incentives offered to members of some expert committees.[2] For example, central bankers' wages are lower than the respective pay in the private sector. Axel Weber earned less than 400,000 Euros as president of the German Bundesbank.[3] When he moved to UBS, he immediately received 2 million francs (around 1.6 million Euros) and 200,000 shares as welcome payment. On top of that, he has since obtained the same money and shares annually.[4]

Third, we show that transparent committees attract more able experts than opaque ones for fixed pay and committee size. This is intuitive because transparent committees make more precise information about experts' expertise available, which tends to deter less able experts from applying.

Fourth, we are able to characterize the optimal committee designs of all transparent and opaque designs. An optimally designed committee always features a low wage to attract only experts of high competence. Somewhat surprisingly, the optimal committee can be either transparent or opaque. The optimal transparent committee leads to exactly the same payoffs for the principal as the optimal opaque committee.

Fifth, we assess how the importance of the decision, i.e. the magnitude of the payoffs that the principal obtains in case of a successful decision, affects the optimal committee design. We prove that a more important decision calls for a larger committee but does not affect optimal wages or the communication system.

Finally, we show that an optimally designed committee represents an optimal mechanism out of all mechanisms with voluntary participation of experts. In this sense, our focus on the majority rule and outcome-independent wages for experts is not restrictive.

[2] The remuneration of members of boards of directors may be rather generous. However, this does not necessarily contradict our analysis because other motives than the ones considered here may influence the size of these remuneration packages. It is also conceivable that experience rather than unknown ability matters more in these cases.

[3] See `http://www.focus.de/finanzen/banken/bundesbank-379-514-euro-fuer-den-praesidenten_aid_379030.html`.

[4] See `http://www.bloomberg.com/news/2011-07-01/axel-weber-to-be-nominated-for-election-to-ubs-board-to-succeed-villiger.html`, `http://www.hftreview.com/pg/newsfeeds/hftreview/item/50029/results-of-the-annual-general-meeting-of-ubs-ag`.

Our paper contributes to the general literature on the optimal design of committees. This literature considers the impact of decision-making rules, committee size, and communication systems on performance when committees are used to aggregate preferences, information, or both.[5] In contributions dealing with the impact of transparency on committee performance, transparency may distort committee members' decisions because the individual members' votes not only affect the outcome but can also be used to signal information about themselves to outsiders or the principal.[6]

Recent works on committees with endogenous information acquisition have studied the impact of committee design on members' incentives to acquire costly information. In particular, larger committees may be harmful as they induce members to free-ride on their colleagues' efforts.[7] The present paper differs from this literature in that it considers the adverse-selection problem arising from the endogenous participation of experts with private information rather than the moral-hazard problem that occurs when agents' decision to acquire costly information is unobservable.

As our paper highlights a relationship between wages and experts' ability, it contributes to the literature on efficiency wages (see Malcomson (1981) and Akerlof (1982)). More specifically, we study a problem of adverse selection where potential employees have private information about their own quality that is not available to the employer (see Stiglitz (1976) and Weiss (1980)).[8] In the literature on efficiency wages, a higher wage increases the efficiency of workers. We complement this literature by identifying the new effect that adverse selection may cause higher wages to be harmful for efficiency when employees use the employment under consideration as a stepping stone for their career.

[5]The first formal analysis of the advantages of group decision-making goes back to Condorcet (1785). A classic book on committees is Black (1958). For a lucid review of papers on information aggregation by committees, see Austen-Smith and Feddersen (2009). Optimal decision rules have been studied, e.g. by Ben-Yashar and Nitzan (1997).

[6]See Levy (2007), Gersbach and Hahn (2008, 2009), Visser and Swank (2007), and Seidmann (2011). Fox and Weelden (2012) analyze the impact of transparency on the performance of an individual expert.

[7]See Mukhopadhaya (2003), Persico (2004), Martinelli (2007), Gerardi and Yariv (2008), Koriyama and Szentes (2009), Gershkov and Szentes (2009), and Gersbach and Hahn (2011) for analyses of committees where members' skills or accuracy of information are endogenous. See Gerling et al. (2005) for a survey.

[8]Other influential models with asymmetric information in worker-firm relationships include Azariadis (1983), Grossman and Hart (1983), Chari (1983), and Green and Kahn (1983). This literature considers the tradeoff between insurance and incentives.

Our paper is organized as follows. In Section 2 we outline the basic setup and define our notion of equilibrium. The two subsequent sections examine transparent and opaque committees respectively. We compare these two classes of committees in Section 5, where we also analyze the optimal committee design out of all transparent and opaque designs. In Section 6, we introduce an example to illustrate some of our findings. Section 7 discusses several extensions to our framework and Section 8 concludes.

2 Model

2.1 Set-up

The model comprises two periods $t = 1, 2$. A principal delegates a decision $d \in \{0, 1\}$ to a committee of experts. At the beginning of period 1, experts from a large pool can apply for the committee. They only serve in period 1; in period 2, all experts are employed from outside the committee.

Each candidate i in the pool is of one of two types $\tau_i \in \{H, L\}$, where H stands for high and L for low competence. Each expert's type is his private information. The commonly known prior of an expert being of type H is $q \in (0, 1)$. All experts on the committee receive signals $s_i \in \{0, 1\}$ about the state of the world $\sigma \in \{0, 1\}$. Conditional on the state of the world, these signals are independent. For simplicity, we assume that both states are a priori equally likely. The signal $s_i \in \{0, 1\}$ of an expert of type τ is correct, i.e. $s_i = \sigma$, with probability $p_\tau \in [1/2, 1]$. Experts of type H receive more accurate signals than the L-types, i.e. $p_H > p_L$. Experts serving on the committee cast simultaneous votes $d_i \in \{0, 1\}$ on the two alternatives, and the option that receives the majority of votes is implemented. In case of a draw, the decision $d \in \{0, 1\}$ is taken using a fair coin flip. After the decision has been taken, the state of the world and the decision become publicly known. In the following, we will often omit the index i for the expert whenever this does not cause confusion.

When an expert is not serving on the committee, he receives a market wage that is given by $w + \kappa\Delta$, where κ is the endogenously determined probability that the market assigns to the eventuality of the expert being of type H. Thus, w is the wage that a member who is manifestly of type L would earn and $w + \Delta$ is the respective wage for type H. Beliefs κ will be updated as new information about an expert's competence becomes available. We assume that H-types receive higher wages, i.e. the exogenous skill premium Δ satisfies $\Delta > 0$. In the first period, an expert either serves on the committee or is employed elsewhere where he receives the market wage. In the second period, an expert always receives the market wage.

Experts are risk-neutral and have a per-period utility function $u(c_t) = c_t$, where c_t denotes consumption, which equals current labor income. Utility in period $t = 2$ is discounted by some discount factor $\delta > 0$. We explicitly allow for $\delta > 1$, which would have the interpretation that the second period in our model actually captures a long-term future consisting of more than one period.

The committee is characterized by the triple (N, b, S). The integer N denotes the size of the committee, which we assume to be odd for simplicity.[9] Parameter b denotes the wage for committee members, measured as a premium over w. We explicitly allow for b to be negative. $S \in \{O, T\}$ stands for the communication system, which may be opaque (O) or transparent (T). Under system O, only the decision of the committee becomes known. Under system T, the individual voting records are publicized in addition.

The principal receives benefits B if the decision is correct ($d = \sigma$) and a utility of zero otherwise ($d \neq \sigma$). Moreover, the principal has to pay the wage bill for the experts who work on the committee. Hence, the principal's payoffs are $B - \hat{N}(w+b)$ if the decision is correct and $-\hat{N}(w+b)$ if the committee's decision is wrong. Variable $\hat{N} \in \{0, 1, 2, ...N\}$ is used to denote the number of experts who work on the committee. $\hat{N}$ may differ from N if less than N experts have applied for the committee. We introduce three technical assumptions on w, B and b. First, we restrict the principal's choice of b to values at least as large as $\underline{b} := q\Delta - \delta(1-q)\Delta$. We will show that for lower levels of b, experts would never apply, irrespective of the communication system S and the size N. Second, we assume $w \geq -\underline{b}$. This inequality guarantees that the lowest possible wage $w + \underline{b}$ is always positive.[10] Third, we postulate $B > (w + \underline{b})/(p_H - 1/2)$. If this condition were

[9]As shown in Section 7.5, an even number of experts would never be optimal for the principal.

[10]If we did not introduce this assumption, the principal would be able to make money by selling seats on the committee. This would make large committees desirable.

violated, the principal would prefer to have no committee over all possible committees $(N, b, S) \in \{1, 3, 5, ...\} \times \mathbb{R} \times \{O, T\}$.

At the beginning of the first period, all experts decide whether to apply for the committee. Each of the applicants has identical probability of being selected. If less than N candidates applied, the remaining seats would remain vacant ($\hat{N} < N$). The number of vacant seats is common knowledge. We assume that it is not commonly known which experts have applied for the committee. Moreover, the pool of experts is large. These two assumptions imply that not serving on the committee is not informative about an expert's competence, i.e. $\kappa = q$ in this case. This feature of our model is meant to capture the effect that experts working on the committee are in a more exposed position. As a result, more information about their ability will become public compared to the other experts.

In the following, we summarize the sequence of events.

1. At the beginning of period 1, Nature determines experts' types $\tau \in \{H, L\}$. A fraction q in the pool of experts are of type H, the remaining experts are of type L.[11]

2. Given the committee parameters (N, b, S) and his individual competence $\tau \in \{H, L\}$, each expert decides whether to apply for the committee.

3. Out of the group of applicants, N candidates are selected. Each applicant has equal probability of being selected.

4. Nature determines the state of the world σ.

5. Nature determines the signals of all committee members.

6. Committee members vote simultaneously.

7. Members serving on the committee receive a wage $w + b$. The other experts receive $w + q\Delta$.

8. The state of the world as well as the decision become commonly known. Under transparency, individual voting records are published in addition.

[11]Thus we assume that an appropriate law of large numbers holds such that the probabilities of individual experts being of a certain type correspond to the aggregate shares in the population (see Judd (1985) and Uhlig (1996)).

9. At the beginning of period 2, the committee is dissolved. Experts who did not work on the committee in the first period continue to earn a market wage of $w + q\Delta$. Former committee members obtain the wage $w + \kappa\Delta$, where in this case κ is the Bayesian update of the probability of the expert being of type H. Under opacity, κ depends on the correctness of the overall decision. Under transparency, κ depends on the individual votes as well.

2.2 Equilibrium concept

The equilibrium concept we apply is a straightforward extension of a perfect Bayesian equilibrium with three additional refinements. More precisely, an equilibrium consists of a rule how beliefs κ about the competence of individual experts are formed as well as strategies of experts. These strategies prescribe an application probability for both types $\tau \in \{H, L\}$ and a voting behavior that is conditional on types $\tau \in \{H, L\}$ and signals $s \in \{0, 1\}$. The strategies and beliefs have to satisfy the following standard conditions:

1. Whenever possible, the market's beliefs κ about an expert's competence are adjusted with the help of Bayes' law as information about the decision taken by the committee or the individual votes becomes available. The beliefs correspond to the prior q initially.

2. At the voting stage, no beneficial deviation exists for each expert, given the strategies of the other experts and the markets' beliefs κ. Moreover, an expert of type τ will apply for the committee with certainty if his utility as a committee member is strictly higher than as a non-member, given the strategies of the other experts and beliefs κ.[12] He will never apply if his utility on the committee is strictly lower. Members who are indifferent between working on the committee or not may choose a mixed strategy and apply with a probability in the interval $[0, 1]$.

Next we have to specify the three additional restrictions mentioned above. We focus on equilibria in which (i) votes are informative, i.e. each expert votes in line with his signal and (ii) all experts' strategies are identical. We also introduce a third restriction

[12]We state this explicitly because the probability of being accepted as a committee member goes to zero as the number of candidates who apply becomes large.

in the spirit of trembling-hand perfection. We define an ε-perturbation of our game as a modification where all type-H experts apply for the committee with a minimum probability $\varepsilon \in (0, 1)$, i.e. their choice of application probability is restricted to $[\varepsilon, 1]$.[13] We only consider equilibria of the unperturbed game for which the experts' strategies and the resulting expected payoffs for the principal are the limits of equilibrium strategies and resulting payoffs for some sequence of ε-perturbed games with $\varepsilon \to 0$.

A few words are in order regarding the third restriction. As will become clear in the proof, the third restriction rules out equilibria where pessimistic out-of-equilibrium beliefs about the ability of experts who apply for the committee lead all experts to refrain from applying in the first place. Alternatively, we could obtain the same results as in this paper by making the assumption frequently made in the mechanism-design literature that the equilibrium preferred by the principal or mechanism designer is chosen (for a survey of this literature, see Jackson (2001)). Finally, we also could rule out all equilibria eliminated by our third restriction with the Pareto criterion, as these equilibria lead to a lower utility for experts of both types and the principal.

In the following, we will analyze the influence of changes in the committee parameters N, b, and S on the experts' application decisions and thus the committee's composition. Moreover, we will identify optimal committees, i.e. triples (N, b, S) that guarantee the highest level of expected payoffs to the principal. We will consider transparent committees first and then proceed to examine opaque committees. Finally, we will be in a position to compare transparent and opaque committees and to identify the optimal committee of all transparent and opaque committees.

3 Transparency

We start the analysis of transparent committees by showing that our three additional restrictions can typically single out a unique equilibrium.

[13] Note that we only consider trembles that induce type-H experts to apply. This can be justified by the observation that these experts always benefit more from working on the committee than the experts of type L. The observation follows from the facts that we consider informative votes and that the probability of a correct signal is higher for type H. Introducing trembles where experts can apply for the committee only with a maximum probability $1 - \varepsilon$ would not affect our results.

Proposition 1

For each transparent committee with $b > \underline{b}$, i.e. a triple (N, b, S) with $S = T$, a unique equilibrium exists.

The proof is given in Appendix A. This appendix also shows that, for $b = \underline{b}$, infinitely many equilibria exist, all of which lead to the same expected payoffs for all players and the principal. As a consequence, it is not restrictive for our analyses of optimal committee design to focus on one of these equilibria.[14]

In Appendix A, we characterize the equilibrium under transparency as follows:

Proposition 2

Consider a transparent committee of size N.

1. *For $b \in [\underline{b}, \overline{b})$, where $\underline{b} = q\Delta - \delta(1-q)\Delta$ and*

$$\overline{b} := q\Delta + \delta \frac{(1-q)q^2(p_H - p_L)^2}{(qp_H + (1-q)p_L)(1 - qp_H - (1-q)p_L)}\Delta > \underline{b}, \tag{1}$$

   experts of type H apply with certainty, while experts of type L apply only with a positive probability. This probability is zero for $b = \underline{b}$, one as b goes to $b = \overline{b}$ and increases strictly in between.

2. *For $b \geq \overline{b}$, both types of experts apply with certainty.*

In every case, sufficient candidates apply to fill every available seat. Thus, $\hat{N} = N$ holds.

The proposition has the noteworthy implication that a higher wage leads to a lower quality of experts on the committee. This has the following interpretation: It is generally more attractive for highly competent experts to apply for the committee than for less competent ones because working on a transparent committee makes information about experts' levels of competence publicly available. This enables highly competent experts to earn a high wage in the future. Hence for all wages of at least $\underline{b}$, experts with high ability are willing to work on the committee.

As the wage increases above $\underline{b}$, working on the committee becomes more attractive even for less competent experts. However, a second, indirect effect reduces the number of

[14] We focus on the equilibrium where experts of type H apply with certainty and type-L experts never apply.

less efficient experts who apply: As more less efficient experts apply for the committee, the gain in reputation that an expert can achieve by working on the committee is diminished. This effect lowers the expected future wages for applicants and thereby reduces the incentive to apply. In fact, when $b \in (\underline{b}, \overline{b})$, the direct effect of a wage increase on the low types' incentive to apply is exactly offset by the indirect effect that works through the deterioration of the committee composition. Under these circumstances, less efficient experts are always indifferent between applying or not applying. For $b \geq \overline{b}$, the remuneration is so high such that both types apply with certainty.

As a higher wage b increases the principal's wage bill and also leads to a lower probability of a correct decision, we obtain the following corollary:

Corollary 1

An optimal transparent committee always involves $b = \underline{b}$.

Thus, the principal always wants to set the wage as low as possible. Note that setting an even lower wage would violate all experts' participation constraints. In this case, no expert would apply and all seats would remain vacant. Interestingly $\underline{b} = q\Delta - \delta(1-q)\Delta$ is smaller than $q\Delta$, which is the premium over w that experts outside the committee earn. Hence highly efficient experts are willing to accept wages that are lower than their outside wages for some time because this will enable them to showcase their competence and thereby receive high wages, $w + \Delta$, in the future.

Next we turn to the question of the optimal size of a transparent committee.

Lemma 1

Consider a transparent committee. Then there is a correspondence $N^*(B, b)$ that maps the principal's benefits B and the wage b into optimal committee sizes. For fixed b, this correspondence increases weakly with B.[15]

For the proof, see Appendix B. Together with Corollary 1, this lemma enables us to characterize the optimal transparent committee:

Lemma 2

An optimal transparent committee is $(N, \underline{b}, T)$ where $N \in N^*(B, \underline{b})$.

[15] By weakly decreasing, we mean that $\max N^*(B', b) \leq \min N^*(B, b)\ \forall B' > B$.

An increase in the importance of the decision, as measured by the principal's benefits in case of a correct decision, B, does not affect the optimal wage $\underline{b}$, which is determined by the highly efficient experts' participation constraints. An increase in the wage for individual experts would lower the quality of applicants, thus leading to a lower committee performance. As a result, more important decisions only call for a larger committee because, in line with the jury theorem by Condorcet (1785), larger committees are more likely to reach a correct decision. Having characterized the optimal committee design under transparency, we turn to opaque committees.

4 Opacity

Under opacity, our restrictions on the equilibria also single out one equilibrium for arbitrary opaque committees:

Proposition 3

For each opaque committee, i.e. a triple (N, b, S) with $S = O$, a unique equilibrium exists.[16]

The proof is given in Appendix C. Interestingly, the equilibria are very similar to those under transparency (for a characterization of the equilibria, see Appendix C):

Proposition 4

Consider an opaque committee of size N. Then there is a value of $\bar{b}_N^O > \underline{b}$ such that

1. *For $b \in [\underline{b}, \bar{b}_N^O)$, experts of type H apply with certainty, while experts of type L only apply with a positive probability. This probability is zero for $b = \underline{b}$, one as b goes to $b = \bar{b}_N^O$ and increases strictly in between.*
2. *For $b \geq \bar{b}_N^O$, both types of experts apply with certainty.*

In every case, all N seats are filled in equilibrium ($\hat{N} = N$).

[16] As with transparency, a multitude of equilibria exist for $b = \underline{b}$. As all of these lead to the same expected payoffs for all players and the principal, we limit our attention to the equilibrium where experts of type H apply with certainty.

As with transparency, we receive the finding that increases in wages generally cause a deterioration in the quality of experts working on the committee. This implies again that wages should be as low as possible:

Corollary 2

An optimal opaque committee always involves $b = \underline{b}$.

It may be surprising that the optimal wage under opacity is exactly the same as that under transparency. This is due to the fact that only experts of type H apply for the optimal wage under both communication systems. This implies that the decision stage reveals no information regarding experts' competence. As a result, the communication system is irrelevant at these wages and both wages must be identical.

Now we are in a position to compare the endogenous committee composition of transparent and opaque committees for a fixed wage and committee size. Moreover, we will assess which committee design is globally optimal.

5 Globally Optimal Committees

Before elaborating on the differences between transparent and opaque committees, we would like to indicate that, in one case, transparency and opacity lead to identical outcomes: that of an individual expert. Naturally, a single expert's individual decision is known also under opacity because the decision taken by the committee is publicly observable. Hence, transparency and opacity are equivalent in this case.

Thus, we focus on a three-member committee in the following. In Appendix E, we prove

Proposition 5

Suppose $N = 3$ and consider an arbitrary but fixed $b \in (\underline{b}, \overline{b})$. Then transparency leads to a strictly higher probability of a committee member being highly competent than opacity. Moreover, transparency entails strictly higher expected payoffs for the principal. For $b \geq \overline{b}$, transparency and opacity imply the same application probabilities and expected payoffs for the principal.

What is the intuition behind our finding that transparency leads to a higher quality of experts on the committee? In the region $b \in (\underline{b}, \bar{b})$, the wage is sufficiently generous to ensure highly efficient experts apply. For less efficient experts, applying for the committee involves the risk of their low ability being revealed to some extent. This is particularly likely if the committee is transparent. In an opaque committee, individual behavior is unobservable and, in addition, it is likely that less efficient experts will benefit from the expertise of one or more highly efficient committee members who may ensure a correct overall decision.[17] As a result, more less efficient experts apply when a committee is opaque than when it is transparent.

The following proposition characterizes globally optimal committees:

Proposition 6

An optimal committee (N, b, S) fulfills the following properties:

- *The wage is as low as possible: $b = \underline{b}$*
- $N \in N^*(B, \underline{b})$.
- *Both possibilities $S \in \{H, L\}$ lead to the same expected payoffs for the principal.*

Proof The Proposition follows directly from our previous results. First, we have already shown that optimal transparent and opaque committees involve $b = \underline{b}$ (see Corollaries 1 and 2). At this wage, transparent and opaque committees are equivalent for same sizes N. In particular, only highly efficient experts apply (see Propositions 2 and 4). Thus, the optimal committee size $N^*(B, \underline{b})$ of transparent committees, which has been derived in Proposition 1, corresponds to the optimal committee size under opacity, which completes the proof. □

Importantly, for an optimally designed committee, the communication system does not matter. This is a consequence of our observation that for $b = \underline{b}$ only highly competent experts apply both under transparency and opacity, which has the implication that the decision stage does not reveal additional information about experts' levels of competence.

[17] Our numerical simulations suggest that transparency also attracts better experts for larger committees. However, a formal proof is not available yet.

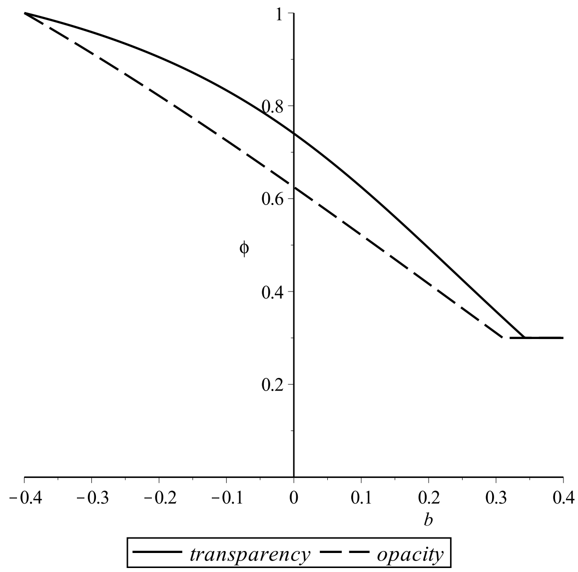

Figure 1: The probability of an expert on the committee being of type H as a function of the wage b. Parameters: $q = 0.3$, $p_H = 0.9$, $p_L = 0.5$, $N = 3$, $w = 2$, $\Delta = 1$, $\delta = 1$.

6 Example

We illustrate some of our results with an example. Consider a committee of fixed size $N = 3$. For the other parameters, we assume $q = 0.3$, $p_H = 0.9$, $p_L = 0.5$, $w = 2$, $\Delta = 1$, and $\delta = 1$. It is now straightforward to compute $\underline{b} = -0.40$ and $\overline{b} \approx 0.34$. As a result, in an optimally designed committee, members earn $w + \underline{b} = 1.6$. This is lower than the outside wage $w + q\Delta = 2.3$, but enables experts to earn $w + \Delta = 3$ after serving on the committee.

The impact of the wage b on the committee composition is illustrated by Figure 1. For $b = \underline{b}$, only highly efficient members apply for the committee both under transparency and opacity. As the wage increases, the committee composition deteriorates under both communication systems, i.e. the probability of highly competent members declines. This illustrates our finding that $b = \underline{b}$ is the optimal wage, irrespective of the communication system. Higher wages lead to an inferior quality of experts on the committee and to a higher wage bill. Thus, they are unequivocally detrimental to the principal.

For sufficiently high wages $b \geq \overline{b}$, both types of experts always apply. As a result, the probability of an expert on the committee being highly efficient is identical to the respective probability for the pool of experts ($q = 0.3$). One can also observe that for fixed wages between $\underline{b}$ and $\overline{b}$, transparency leads to a higher quality of experts on the committee. As has been explained, opaque committees make it more attractive for less able experts to apply because it is more difficult for the market to become aware of their individual expertise. Finally, we note that the level of b where the graph for opacity has a kink is $\overline{b}_3^O$. At this point, the probability of the experts on the committee being of type L cannot drop any further because it is bounded from below by q.

7 Extensions

In this section, we discuss several extensions to our model. More specifically, we consider the possibility that the principal and the market can observe the quality of some experts, a variant of our framework where experts have no superior information about their own expertise, and another variant where the market cannot observe the state of the world. Moreover, we consider the possibility that the market also receives information about the competence of experts who do not serve on the committee. Finally, we allow the principal to use more general mechanisms than the ones considered here.

7.1 Observable expert quality

In this section, we discuss the case where the ability of some experts is commonly known. This could occur, e.g., when these experts have a long track record of working on other committees in the past. Suppose that there were three groups of experts: Experts whose ability is their private information, experts who are commonly known to be of type L, and experts who are commonly known to be of type H. Suppose also that $\underline{b} < 0$, which always holds if experts work for a sufficiently long time after their term on the committee or if the fraction of highly competent experts in the pool q is rather low. Condition $\underline{b} < 0$ ensures that the wage $w + \underline{b}$, which is sufficient to attract H-types from the group of experts with unknown ability, is lower than the wage w necessary to attract L-types from the group of experts of known ability. Under these circumstances, it is clearly optimal for the principal to offer $b = \underline{b}$. This will only attract highly competent experts at the lowest possible cost. Hence our characterization of optimal committees is also valid in this variant of our model.

7.2 Unknown own ability

Which committees would be optimal if experts did not know their own ability? In this case, the optimal wage the principal would choose would be equal to the market wage $w + q\Delta$. At this wage, all experts would be indifferent between applying for the committee or continuing their current employment. Working on the committee would always lead to an expected future wage equal to the current wage. However, it would introduce a mean-preserving spread to experts' future wage, which would be more pronounced under transparency than under opacity and more pronounced in smaller opaque committees than in larger ones. Given experts' risk neutrality, this mean-preserving spread would not affect their utility. Hence an optimal committee would be characterized by a wage $w + q\Delta$ and a number of seats that would be determined by an increasing function of B. As in our basic model, the communication system would not matter at the optimal wage and size.

7.3 Unobservable state of the world

Finally, we discuss a variant of our model where the market cannot observe the state of the world and thus cannot assess the correctness of individual votes or the overall decision. As a consequence, an opaque committee would not deliver any information about the competence of experts. By contrast, transparency would reveal some information in this regard. Experts voting for the minority position would suffer a loss in reputation whereas experts who support the ultimately implemented decision would gain prestige.[18]

Thus, several effects from this paper would also occur in such a variant: Transparent committees could be used as a stage for competent experts to showcase their high ability. This plausibly leads to a pattern of expert ability and wages similar to that of the basic model. In particular, the optimal wage under transparency would be sufficiently low to deter less competent experts but still high enough to attract highly competent experts. In contrast to the finding in this paper, however, this wage would depend on the size of the committee. This follows from the fact that the competence

[18] Swank et al. (2008) investigate the effect that concealing disagreement may be desirable for experts.

assigned to a particular expert will depend on the distribution of votes, which can display different patterns in larger than in smaller committees.

7.4 Learning about the competence of outside experts

We have assumed that no information about the ability of experts who do not work on the committee becomes available to the market. This assumption is meant to capture the fact that experts on the committee are in a more exposed position than the experts working in the outside sector.

Relaxing this assumption would be straightforward. One could assume that, for experts not working on the committee, there is a fixed probability of their competence being revealed.[19] For a given committee composition, this possibility would simultaneously reduce the incentive for highly efficient experts to apply and increase the incentive for less efficient experts to apply. If the probability of experts' competence becoming known was small for experts outside the committee, our results would continue to hold.

7.5 General Class of Mechanisms

Our exercise can also be interpreted as a mechanism-design problem where the designer is restricted to a certain class of mechanisms, namely committees characterized by $(N, b, S) \in \{1, 3, 5, ...\} \times [\underline{b}, \infty) \times \{O, T\}$. This raises the question how superior mechanisms that respect the experts' participation constraints and draw on an arbitrary (not necessarily odd) number of experts could be designed.

An optimal mechanism from all mechanisms with voluntary participation can be obtained when four sufficient conditions are fulfilled. First, the mechanism stipulates the lowest possible wage for which experts of arbitrary expertise would participate under any mechanism. The corresponding wage, $w + b_{min}$, can be computed by considering the case where the mechanism guarantees the maximum possible market wage of $w+\Delta$ in the second period. Consequently, it solves $w + b_{min} + \delta(w + \Delta) = (1 + \delta)(w + q\Delta)$.

[19] As experts are risk-neutral, this would be equivalent to the market receiving partially informative signals about the experts' competence.

The solution is $b_{min} = \underline{b}$. Second, at this lowest possible wage, only highly efficient experts are attracted. Third, experts' signals about the state of the world are aggregated efficiently. At this point, we note that this property is guaranteed by the majority rule when only highly efficient experts are present.[20] Fourth, the mechanism cannot be improved upon by adding or removing experts. At this point, we refer to Appendix F, which proves that even numbers of experts are never optimal for the principal as she can secure the same probability of a correct decision by removing one expert.

As the optimal committee design in Proposition 6 satisfies all four necessary conditions, we obtain

Proposition 7

Provided that expert participation is voluntary, mechanisms better than the optimal committee designs identified in Proposition 6 cannot be found.

8 Conclusions

In this paper, we have examined the optimal design of expert committees when members' decisions to participate are endogenous. More specifically, we have studied three determinants of committee performance: the remuneration of its members, the committee's size, and the communication system: transparency or opacity.

Experts' incentives to work on the committee are determined not only by the remuneration offered by the principal but also by the prestige they can gain from working on the committee because prestige affects their future income. The potential gain or loss in prestige is affected by the committee design. More specifically, we have derived the following results. First, while one would typically expect the quality of experts to increase with remuneration, we obtain the exact opposite: Higher wages attract a larger number of mediocre experts irrespective of whether the committee works under opacity or transparency. Second, due to this effect, the principal will always find it beneficial to choose the lowest wage for which experts participate. Third, we have shown that

[20] Note that the majority rule would not aggregate information efficiently in the presence of experts of different types. This can be immediately seen by considering a three-member committee comprising two experts of type L with $p_L = 1/2$ and one expert of type H with $p_H = 1$. Clearly, letting the highly efficient expert decide alone would be superior to a decision reached by the majority rule.

transparent committees typically attract more able experts because these committees make more information about experts' competence publicly available than opaque ones. Fourth, we have characterized the optimal design out of all possible committee designs considered. It stipulates low wages, can be either transparent or opaque, and has a size that depends positively on the significance that the principal attaches to the correctness of the decision. Finally, we have demonstrated that our focus on committees with performance-independent pay, transparent or opaque communication system, and decisions made by the majority rule is not restrictive: No alternative mechanism with voluntary participation could deliver a higher level of expected payoffs to the principal.

A Proof of Propositions 1 and 2

To derive the equilibrium under transparency, we proceed in several steps. First, we will derive the market's beliefs about the competence of experts. Second, based on these results, we will derive a condition that determines whether an expert of a particular type will apply. Third, we will show that the gains from applying are always higher for H-types than for experts of type L and that the gains from applying are an increasing function of the expected quality of the experts who apply. Fourth, equipped with these results, we will examine all candidate equilibria and, for each parameter constellation, will be able to rule out all but one. Finally, we will complete the proof by showing that the assumption of informative voting is indeed consistent with optimal expert behavior.

Step 1: Market's beliefs Assume for the moment that votes are informative and that, for the experts who apply for the committee, the probability of high competence is $\phi \in [0,1]$. Then Bayes' law dictates that

$$\kappa(C_i) = \frac{\phi p_H}{\phi p_H + (1-\phi)p_L}, \tag{2}$$

$$\kappa(W_i) = \frac{\phi(1-p_H)}{\phi(1-p_H) + (1-\phi)(1-p_L)}, \tag{3}$$

where $\kappa(C_i)$ describes the market's beliefs about expert i's competence, conditional on a (C)orrect vote, and $\kappa(W_i)$ is the corresponding probability for a (W)rong vote. We note that $\kappa(C_i) \geq \kappa(W_i)$ holds for all $\phi \in [0,1]$, where the inequality is strict for $\phi \in (0,1)$.

Step 2: Gains from applying Consider an expert of type $\tau \in \{H, L\}$. The expert will find it strictly profitable to apply if

$$G_\tau^T(\phi) := w + b + \delta\left\{w + \left[p_\tau \kappa(C_i) + (1-p_\tau)\kappa(W_i)\right]\Delta\right\} - (w + q\Delta)(1+\delta) > 0. \tag{4}$$

Here we have taken into account that the expert receives an outside wage of $w + q\Delta$ in both periods when not working on the committee. If the expert joins the committee, his wage in period 1 will be $w + b$. In the second period, he will earn the market wage $w + \kappa(C_i)\Delta$ if he votes correctly, which happens with probability p_τ, and the market wage $w + \kappa(W_i)\Delta$ if he casts a wrong vote, which happens with probability $1 - p_\tau$.

Step 3: Properties of $\mathbf{G}_\tau^T(\phi)$ We will demonstrate two properties of $G_\tau^T(\phi)$ which will be crucial for the rest of the analysis. First, $G_H^T(\phi) \geq G_L^T(\phi)$ holds, which follows from (4), $p_H > p_L$, and $\kappa(C_i) \geq \kappa(W_i)$. As $\phi \in (0,1)$ implies that $\kappa(C_i) \geq \kappa(W_i)$ holds strictly, $G_H^T(\phi)$ is strictly larger than $G_L^T(\phi)$ in this case. Second, we claim that $G_\tau^T(\phi)$ strictly increases with ϕ, $\forall \tau \in \{H, L\}$. This can be immediately seen from

$$\begin{aligned} \frac{\partial \kappa(C_i)}{\partial \phi} &= \frac{p_L p_H}{(\phi p_H + (1-\phi)p_L)^2} > 0, \\ \frac{\partial \kappa(W_i)}{\partial \phi} &= \frac{(1-p_H)(1-p_L)}{(\phi(1-p_H) + (1-\phi)(1-p_L))^2} > 0. \end{aligned}$$

Step 4: Candidate equilibria In the following, we check all candidate equilibria in ϵ-perturbations of our game, i.e. we impose the restriction that the application probability of type H must not be smaller than some fixed $\varepsilon \in (0,1)$. For this purpose, we distinguish between different ranges for ϕ with $\phi > 0$.[21]

(a) $\underline{\phi \text{ is such that } G_H^T(\phi) < 0.}$ In this case, due to $G_H^T(\phi) \geq G_L^T(\phi)$, $G_L^T(\phi) < 0$ must hold as well. As a result, L-types never apply and H-types apply with the lowest possible probability ε. This implies that only experts of type H apply in an ε-perturbed game and thus $\phi = 1$. Such a constellation corresponds to an equilibrium if $G_H^T(1) < 0$. Using (4), we observe that this equivalent to $b < \underline{b} = q\Delta - \delta(1-q)\Delta$. By letting $\varepsilon \to 0$, we obtain an equilibrium where both types of experts never apply. However, this equilibrium exists only if $b < \underline{b}$, which we have ruled out by assumption.

(b) $\underline{\phi \text{ is such that } G_H^T(\phi) = 0}$ First, assume that $G_L^T(\phi) < 0$ holds in addition. In such a candidate equilibrium, experts of type L never apply. Highly competent experts apply with some probability in $[\varepsilon, 1]$. As a consequence, $\phi = 1$ must hold. However, with the help of (2)-(4), we can easily see that $G_H^T(1) = G_L^T(1)$, which leads to a contradiction. Second, let us suppose that $G_L^T(\phi) = 0$ holds on top of $G_H^T(\phi) = 0$. According to our previous results, $G_H^T(\phi) = G_L^T(\phi)$ implies $\phi = 1$. Hence, experts of the low type do not apply and experts of type H apply with some probability in $[\varepsilon, 1]$. It is immediate to show that condition $G_H^T(1) = 0$ can be rewritten as $b = \underline{b}$.

[21] Because H-types apply with positive probability, $\phi = 0$ can be ruled out.

At this point, it is important to mention that our refinement in the spirit of trembling-hand perfection enables us to eliminate the equilibrium of the unperturbed game in which all experts refrain from applying with certainty. This is so because it is impossible to find a sequence of equilibria of ε-perturbed games with $\varepsilon \to 0$ such that the respective strategies of experts and the resulting payoffs for the principal converge to the strategies and the principal's implied payoffs in the aforementioned equilibrium of the unperturbed game. To see this, note that for all strictly positive probabilities of individual experts of type H applying, all seats on the committee are filled, whereas all seats would remain vacant of the equilibrium of the unperturbed game. As a result, we are left with equilibria of the unperturbed game in which highly efficient experts apply with strictly positive probability. These equilibria occur for $b = \underline{b}$.

(c) ϕ is such that $G_H^T(\phi) > 0$ As H-types strictly prefer to apply and they constitute a fraction q in the pool of potential candidates, $\phi \in [q, 1]$ must hold. We distinguish between three cases. First, $G_L^T(\phi) > 0$ may hold in addition to $G_H^T(\phi) > 0$. This implies $\phi = q$. Condition $G_L^T(q) > 0$ is equivalent to $b > \overline{b}$, where

$$\overline{b} := q\Delta + \delta \frac{(1-q)q^2(p_H - p_L)^2}{(qp_H + (1-q)p_L)(1 - qp_H - (1-q)p_L)}\Delta > \underline{b}. \tag{5}$$

Second, we may have $G_L^T(\phi) < 0$. In this case, $\phi = 1$ and hence $G_L^T(1) < 0$ in addition to $G_H^T(1) > 0$. This leads to a contradiction since $G_L^T(1) = G_H^T(1)$, as can be easily verified from (4). Third, $G_L^T(\phi) = 0$ may hold. Then less competent experts may apply with some probability $\psi \in [0, 1]$. As a result, ϕ is pinned down by $G_L^T(\phi) = 0$, and ψ can be readily computed from $\phi = q/(q+(1-q)\psi)$. As $G_L^T(\phi)$ strictly increases with ϕ, $G_L^T(\phi) = 0$ has at most one solution in the interval $[q, 1]$. For $b \in [\underline{b}, \overline{b}]$, this solution exists, which follows from $G_L^T(q) \leq 0$ and $G_L^T(1) \geq 0$ for $b \in [\underline{b}, \overline{b}]$.[22] Finally, we conclude from (4) and our result that $G_L^T(\phi)$ strictly increases with ϕ that the value of ϕ that solves $G_L^T(\phi) = 0$ is a strictly decreasing function of b.

Step 5: Is informative voting optimal? Until now, we have simply assumed that all experts vote in line with their private signals. This behavior is indeed optimal given

[22]It is easy to check that for $b \notin [\underline{b}, \overline{b}]$, $G_L^T(\phi) = 0$ has no solution in the interval $[q, 1]$.

beliefs (2) and (3), as $p_\tau \geq 1/2\ \forall \tau \in \{H, L\}$ and $\kappa(C_i) \geq \kappa(W_i)$ holds in all equilibria. This completes the proof. $\square$

B Proof of Lemma 1

In this section, we analyze the optimal choice of N, for given b and communication system $S = T$. Using the result that, in equilibrium, all seats are filled ($\hat{N} = N$), we can write the principal's expected payoffs as

$$P_N\left((N+1)/2\right) B - N(b+w), \tag{6}$$

where we use $P_N(n)$ to denote the probability of at least n out of N experts voting correctly, given that each individual expert votes correctly with probability $\overline{p} := \phi p_H + (1-\phi)p_L > 1/2$. Moreover, we introduce $\hat{P}_N(n)$ to denote the probability of exactly n experts voting correctly.

In the following, we will prove that $P_N\left((N+1)/2\right)$ is an increasing and concave function of N, which establishes that the N maximizing (6) is unique in general and increases in B. Here "in general" means that there are knife-edge values for B such that the principal is exactly indifferent between two adjacent odd values of N, both of which maximize her utility. Hence $N^*(B, b)$, interpreted as a function of B, is an increasing step function. $N^*(B, b)$ contains two values only at the points where it jumps from one odd level of N to the next.

Some useful identities To show that $P_N\left((N+1)/2\right)$ is increasing and concave requires three identities:

$$\begin{aligned}
P_N(n+1) + \hat{P}_N(n) &= P_N(n), && (7)\\
P_N(1) + \hat{P}_N(0) &= 1, && (8)\\
P_N\left(\frac{N+3}{2}\right) + \hat{P}_N\left(\frac{N+1}{2}\right) P_2(1) + \hat{P}_N\left(\frac{N-1}{2}\right) \hat{P}_2(2) &= P_{N+2}\left(\frac{N+3}{2}\right). && (9)
\end{aligned}$$

While (7) are (8) clear from the above definitions, (9) is somewhat more involved. The right-hand side of (9) gives the probability of a majority of experts out of $N+2$ experts voting for the correct option. Suppose that we divide the group of $N+2$ members into a large group comprising N experts and a small group containing two experts.[23] Then there will be three different constellations that may result in a majority of the whole group voting correctly. First, $(N+2)/3$ experts in the large group, which comprises N members, may vote correctly. Second, exactly $(N+1)/2$ in the large group and at least one expert in the small group may vote correctly. Third, exactly $(N-1)/2$ members of the large group and two members of the small group may cast correct votes. The left-hand side of (9) calculates the probabilities for these three constellations.

$\mathbf{P_N\left((N+1)/2\right)}$ increases with N This property is intuitively clear because a larger committee should reach a correct decision with higher probability, which is just a manifestation of the jury theorem that goes back to Condorcet (1785). To show this formally, we compute the difference of $P_N\left((N+1)/2\right)$ for two adjacent, odd values of N:

$$\begin{aligned}
&P_{N+2}\left(\frac{N+3}{2}\right) - P_N\left(\frac{N+1}{2}\right)\\
=&\left[P_N\left(\frac{N+3}{2}\right) + \hat{P}_N\left(\frac{N+1}{2}\right)P_2(1) + \hat{P}_N\left(\frac{N-1}{2}\right)\hat{P}_2(2)\right] - P_N\left(\frac{N+1}{2}\right)\\
=&\left[P_N\left(\frac{N+1}{2}\right) - \hat{P}_N\left(\frac{N+1}{2}\right) + \hat{P}_N\left(\frac{N+1}{2}\right)P_2(1) + \hat{P}_N\left(\frac{N-1}{2}\right)\hat{P}_2(2)\right]\\
&\qquad\qquad\qquad - P_N\left(\frac{N+1}{2}\right) \qquad\qquad (10)\\
=&-(1-P_2(1))\hat{P}_N\left(\frac{N+1}{2}\right) + \hat{P}_N\left(\frac{N-1}{2}\right)\hat{P}_2(2)\\
=&-\hat{P}_2(0)\hat{P}_N\left(\frac{N+1}{2}\right) + \hat{P}_N\left(\frac{N-1}{2}\right)\hat{P}_2(2)\\
=&(1-\overline{p})(2\overline{p}-1)\hat{P}_N\left(\frac{N+1}{2}\right),
\end{aligned}$$

where the second line can be obtained from (9), the third line from (7), the fifth line from (8), and the last line uses $\hat{P}_N(n) = \binom{N}{n}\overline{p}^n(1-\overline{p})^{N-n}$. Due to $\overline{p} \in (1/2, 1)$, the term in the last line is strictly positive, which establishes the claim.

$\mathbf{P_N\left((N+1)/2\right)}$ is concave To show concavity, we demonstrate that the second-order differences of $P_N\left((N+1)/2\right)$ are strictly negative. For this purpose we draw

[23] For $N = 1$, the group we label "large" would be smaller than the group we label "small." However, this is immaterial for our argument.

on the results for the first-order difference, i.e. (10), and observe that the second-order difference is negative if $\hat{P}_{N+2}\left(\frac{N+3}{2}\right) < \hat{P}_N\left(\frac{N+1}{2}\right)$ for all odd numbers of N. This condition is equivalent to

$$\begin{aligned}
\binom{N+2}{\frac{N+3}{2}}\overline{p}^{\frac{N+3}{2}}(1-\overline{p})^{\frac{N+1}{2}} &< \binom{N}{\frac{N+1}{2}}\overline{p}^{\frac{N+1}{2}}(1-\overline{p})^{\frac{N-1}{2}},\\
\Leftrightarrow \binom{N+2}{\frac{N+3}{2}}\overline{p}(1-\overline{p}) &< \binom{N}{\frac{N+1}{2}},\\
\Leftrightarrow \left(\binom{N}{\frac{N+3}{2}}+3\binom{N}{\frac{N+1}{2}}\right)\overline{p}(1-\overline{p}) &< \binom{N}{\frac{N+1}{2}},
\end{aligned}$$

where we have used $\binom{n}{k}=\binom{n-1}{k}+\binom{n-1}{k-1}$ and $\binom{N}{\frac{N+1}{2}}=\binom{N}{\frac{N-1}{2}}$. The last inequality is always fulfilled because $\overline{p}(1-\overline{p})<1/4$ and $\binom{N}{\frac{N+3}{2}}<\binom{N}{\frac{N+1}{2}}$. $\square$

C Proof of Propositions 3 and 4

As in Appendix A, we divide the proof into several steps. Since the proof is almost identical to that in Appendix A, we focus on the major differences in this section and only mention the identical sections briefly.

Step 1: Market's beliefs Again we assume for the moment that votes are informative and that, for the experts who apply for the committee, the probability of high competence is $\phi \in [0,1]$. Then the probability of an expert i being of type H, conditional on the overall decision being (C)orrect or (W)rong, can be stated as

$$\kappa(C) = \frac{\phi q_H}{\phi q_H + (1-\phi)q_L}, \tag{11}$$

$$\kappa(W) = \frac{\phi(1-q_H)}{\phi(1-q_H)+(1-\phi)(1-q_L)}, \tag{12}$$

where we have introduced q_τ $\forall \tau \in \{H, L\}$ as the probability of the committee reaching a correct decision, conditional on the ability τ of expert i. We note that $q_H > q_L$ holds for all $\phi \in [0,1]$. This is easy to see. Expert i's vote only influences the overall decision in the case of a draw among the other experts. Then a highly able expert casts a correct vote with a higher probability than a less able one ($p_H > p_L$). Our finding that $q_H > q_L$ has the implication that $\kappa(C) \geq \kappa(W)$ holds for all $\phi \in [0,1]$, where the inequality is strict for $\phi \in (0,1)$.

Step 2: Gains from applying Consider an expert of type $\tau \in \{H, L\}$. The expert will find it strictly profitable to apply if

$$G_\tau^O(\phi) := w + b + \delta \{w + [q_\tau \kappa(C) + (1 - q_\tau)\kappa(W)] \Delta\} - (w + q\Delta)(1 + \delta) > 0. \quad (13)$$

The interpretation for this expression is analogous to the one for (4). Importantly, $G_\tau^O(\phi)$ fulfills properties identical to those we have identified for $G_\tau^T(\phi)$. First, we have already noted that $\kappa(C) \geq \kappa(W)$. Together with $q_H > q_L$, this entails $G_H^O(\phi) \geq G_L^O(\phi)$, where the inequality is strict for $\phi \in (0, 1)$. Second, $G_\tau^O(\phi)$ strictly increases with ϕ $\forall\{H, L\}$, which is proved in Appendix D. Third, we observe that $G_L^O(1) = G_H^O(1) = G_H^T(1)$. For $\tau \in \{H, L\}$, this implies that $G_\tau^O(1) < 0$ iff $b < \underline{b}$ and $G_\tau^O(1) = 0$ iff $b = \underline{b}$. Fourth, in Appendix A, $\overline{b}$ was introduced as the level of b for which $G_L^T(q) = 0$ holds. Analogously, we define $\overline{b}_N^O$ to be the level of b such that $G_L^O(q) = 0$.

Step 3: Wrapping up As $G_\tau^O(\phi)$ fulfills the same crucial properties that hold for $G_\tau^T(\phi)$, the equilibria are essentially the same. This can be seen by reconsidering Step 4 in Appendix A and replacing $G_\tau^T(\phi)$ by $G_\tau^O(\phi)$ for $\tau \in \{H, L\}$ and $\overline{b}$ by $\overline{b}_N^O$ everywhere. This procedure produces the following results. For $b \geq \overline{b}_N^O$, both types apply with certainty (note that $G_L^T(q)$ and $G_L^T(q)$ are positive in this case). For $b = \underline{b}$, only experts of type H apply. For $b \in (\underline{b}, \overline{b}_N^O)$, H-types apply with certainty, whereas committee members of type L apply randomly. Type L's probability of application, ψ, is implicitly given by $G_L^O(\phi) = 0$ and $\phi = q/(q+(1-q)\psi)$. We stress the only difference between the equilibria under transparency and opacity: As $G_\tau^O(\phi) \neq G_\tau^T(\phi)$ in general, probabilities ϕ and ψ may be different from the ones computed in the transparency scenario for a given level of b. □

D Proof that $\mathrm{G}_\tau^O(\phi)$ is an increasing function of ϕ

In this appendix, we show that $G_\tau^O(\phi)$ is an increasing function of ϕ. For this purpose, we refer to (13) to note that the claim is equivalent to

$$\frac{\partial}{\partial \phi} [q_\tau \kappa(C) + (1 - q_\tau)\kappa(W)] > 0, \qquad \forall \phi \in (0, 1). \quad (14)$$

Inequality (14) holds if, for all $\phi \in (0,1)$, four conditions are met: (i) $\frac{\partial q_\tau}{\partial \phi} \geq 0\ \forall \tau \in \{H, L\}$, (ii) $\kappa(C) > \kappa(W)$, (iii) $\frac{\partial \kappa(C)}{\partial \phi} > 0$, and (iv) $\frac{\partial \kappa(W)}{\partial \phi} > 0$. In the following, we show that each of these conditions holds.

(i) The property $\frac{\partial q_\tau}{\partial \phi} > 0\ \forall \tau \in \{H, L\}$ is intuitively clear: While keeping the competence of one expert fixed at τ, an increase in the probability of all other members being highly competent and thus voting for the correct option leads to an increase in the probability of a correct overall decision.[24] Formally, it is straightforward to show this by proving that the probability of a correct overall decision increases if the probability of an individual member voting correctly increases for fixed probabilities of correct votes by the other experts.[25]

(ii) Property $\kappa(C) \geq \kappa(W)$ has already been derived.

(iii) Condition $\frac{\partial \kappa(C)}{\partial \phi} > 0$ is somewhat tedious to ascertain. To prove it, it will be useful to introduce ρ_n as the probability of n experts out of N experts being of type H, provided that the probability of an individual expert being of type H is ϕ. Probability ρ_n can be written as $\rho_n = \binom{N}{n}\phi^n(1-\phi)^{N-n}$. In addition, let $P(H_i|n) = n/N$ be the probability that an individual expert i is highly competent, conditional on n experts out of N experts being highly competent. Finally, we introduce $P(C|n)$ to denote the probability of a correct decision, conditional on n experts being of type H and $N-n$ experts of type L. Importantly, both $P(H_i|n)$ and $P(C|n)$ are independent of ϕ. Now an alternative way of stating the probability of an expert being of type H, conditional on the overall decision being correct (C), is

$$\kappa(C) = \frac{\sum_{n=0}^{N} P(H_i|n)P(C|n)\rho_n}{\sum_{n=0}^{N} P(C|n)\rho_n}, \tag{15}$$

Note that $\pi_n := \frac{P(C|n)\rho_n}{\sum_{n=(N+1)/2}^{N} P(C|n)\rho_n}$ is a probability mass function for a distribution of n on $0, ..., N$. The corresponding cumulative distribution function is $C(n) := \sum_{l=0}^{n} \pi_l$.

[24] Only in the case where the expert is the only member serving on the committee would q_τ be independent of ϕ for $\phi \in (0,1)$.

[25] Recall that an expert's vote only matters if there is a draw among the other experts. In this event, a higher probability of a correct vote of this expert translates into a higher probability of a correct overall decision.

We will show that an increase in ϕ leads to a new distribution that first-order stochastically dominates the original distribution in a strict sense, i.e. for the new cumulative distribution function $\tilde{C}(n)$, we have $\tilde{C}(n) < C(n)\ \forall n = 0, ..., N-1$. Together with the observation that $P(H_i|n)$ strictly increases with n, this proves the claim.[26]

It remains to be shown that an increase in ϕ actually renders a new distribution that first-order stochastically dominates the original distribution in the strict sense specified above. For this purpose, it suffices to show that the derivative of $C(n)$ with respect to ϕ is strictly negative for all $n = 0, ..., N-1$:

$$\frac{\partial C(n)}{\partial \phi} = \frac{\left(\sum_{k=0}^{n} P(C|k)\frac{\partial \rho_k}{\partial \phi}\right)\left(\sum_{l=0}^{N} P(C|l)\rho_l\right) - \left(\sum_{k=0}^{n} P(C|k)\rho_k\right)\left(\sum_{l=0}^{N} P(C|l)\frac{\partial \rho_l}{\partial \phi}\right)}{\left(\sum_{k=0}^{N} P(C|k)\rho_k\right)^2}.$$

This expression is strictly negative for $n = 0, ..., N-1$ if the numerator is smaller than zero:

$$\left(\sum_{k=0}^{n} P(C|k)\frac{\partial \rho_k}{\partial \phi}\right)\left(\sum_{l=n+1}^{N} P(C|l)\rho_l\right) - \left(\sum_{k=0}^{n} P(C|k)\rho_k\right)\left(\sum_{l=n+1}^{N} P(C|l)\frac{\partial \rho_l}{\partial \phi}\right) < 0. \tag{16}$$

At this point, it is useful to observe

$$\frac{\partial \rho_k}{\partial \phi} = \frac{k - N\phi}{\phi(1-\phi)}\rho_k, \tag{17}$$

which directly follows from $\rho_k = \binom{N}{k}\phi^k(1-\phi)^{N-k}$. With equation (17), inequality (16) can be restated as

$$\left(\sum_{k=0}^{n} \frac{k - N\phi}{\phi(1-\phi)} P(C|k)\rho_k\right)\left(\sum_{l=n+1}^{N} P(C|l)\rho_l\right) - \left(\sum_{k=0}^{n} P(C|k)\rho_k\right)\left(\sum_{l=n+1}^{N} \frac{l - N\phi}{\phi(1-\phi)} P(C|l)\rho_l\right) < 0.$$

Re-arranging yields

$$\sum_{k=0}^{n}\sum_{l=n+1}^{N} \frac{k-l}{\phi(1-\phi)} P(C|k)P(C|l)\rho_k\rho_l < 0.$$

Because $k - l < 0$ for all summands, we obtain the claim.

[26] This is intimately related to the result that a decision-maker with non-decreasing utility function prefers a lottery over any other lottery that is first-order stochastically dominated by it (see Mas-Colell et al. (1995, p. 195)).

(iv) To show $\frac{\partial \kappa(W)}{\partial \phi} > 0$, we can rely on several of our previous findings. The probability of an expert being of type H, conditional on the overall decision being wrong (W), can be formulated as

$$\kappa(W) = \frac{\sum_{n=0}^{N} P(H_i|n)(1 - P(C|n))\rho_n}{\sum_{n=0}^{N}(1 - P(C|n))\rho_n}. \tag{18}$$

Because the remaining steps are essentially identical to those we have presented to show (iii) (one simply has to substitute $1 - P(C|n)$ for each $P(C|n)$), the details are omitted. □

E Proof of Proposition 5

To prove the claim of the proposition, it is sufficient to show that $G_L^T(\phi) > G_L^O(\phi)$ for $N = 3$, $\phi \in (0, 1)$, and fixed b. With the help of (4) and (13), it is tedious but straightforward to show that, for $N = 3$,

$$G_L^T(\phi) - G_L^O(\phi) = \frac{3\,(1-\phi)\,\phi^2\,(p_H - p_L)^2}{\overline{p}\,(1-\overline{p})\,(1+2\overline{p})\,(3-2\overline{p})}\delta\Delta, \tag{19}$$

where $\overline{p} = \phi p_H + (1 - \phi)p_L$. Because $\overline{p} \in (1/2, 1)$, $\phi \in (0, 1)$ as well as $p_H > p_L$, this expression is strictly positive. □

F An Even Number of Experts is Inefficient

Let us focus on the voting stage of our model with highly competent experts only. Moreover, assume that the decision supported by the majority of experts is taken. In case of a draw, it is taken by a fair coin flip. This method of aggregating signals is efficient in the sense that no alternative method leading to a higher probability of a correct decision can be found.

We now prove that, if the number of experts is even, reducing the number of experts by one leads to the same probability of a correct decision.[27] As a result, an optimal mechanism cannot involve the participation of an odd number of experts because each expert requires a payment of at least $w + \underline{b}$. This is strictly positive by assumption.

[27]This result is also stated without proof in Gersbach and Hahn (2008, pp. 665-666).

We use the probabilities $P_N(n)$ and $\hat{P}_N(n)$ introduced in Appendix B with the modification that the probability that an expert votes correctly is p_H rather than $\overline{p}$.

Consider an odd number N. Then the probability of a correct outcome is

$$P_N\left(\frac{N+1}{2}\right) = P_N\left(\frac{N+3}{2}\right) + \hat{P}_N\left(\frac{N+1}{2}\right), \tag{20}$$

where we have applied (7). If we add one additional committee member, the probability of a correct outcome will be

$$P_N\left(\frac{N+3}{2}\right) + \hat{P}_N\left(\frac{N+1}{2}\right) p_H + \frac{1}{2}\hat{P}_N\left(\frac{N+1}{2}\right)(1-p_H) + \frac{1}{2}\hat{P}_N\left(\frac{N-1}{2}\right) p_H. \tag{21}$$

The difference between (20) and (21) is

$$\frac{1}{2}\hat{P}_N\left(\frac{N+1}{2}\right)(1-p_H) - \frac{1}{2}\hat{P}_N\left(\frac{N-1}{2}\right) p_H. \tag{22}$$

As $(1-p_H)\hat{P}_N\left(\frac{N+1}{2}\right) = p_H \hat{P}_N\left(\frac{N-1}{2}\right)$, which is a direct consequence of $\hat{P}(n) = \binom{N}{n} p_H^n (1-p_H)^{N-n}$ and $\binom{N}{(N+1)/2} = \binom{N}{(N-1)/2}$, expression (22) is zero. $\square$

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