Sequential Expert Advice: Superiority of Closed-Door Meetings*

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Abstract

Two career-concerned experts sequentially give advice to a Bayesian decision maker (D). We find that secrecy dominates transparency, yielding superior decisions for D. Secrecy empowers the expert moving late to be pivotal more often. Further, (i) only secrecy enables the second expert to partially communicate her information and its high precision to D and swing the decision away from first expert's recommendation; (ii) if experts have high average precision, then the second expert is effective only under secrecy. These results are obtained when experts only recommend decisions. If they also report the quality of advice, fully revealing equilibrium may exist.

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Running Head: Sequential expert advice

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1 Introduction

Many decisions are based on advice given sequentially by multiple experts. Parliamentarians debate over issues of national importance – whether to go to war, what health reforms to implement, whether to tighten immigration policy, agree to a trade treaty, or whether to put to referendum the decision about breaking away from a club such as the European Union. Similarly, in modern corporations CEOs may consult their deputies for opinions on crucial decisions such as business expansion, joint venture, r&d, etc.

In many cases, the advice provided may not be able to adequately transmit all the relevant information. For instance, members of a committee may convey information through voting (see footnote 3). While votes reflect opinions, they do not convey the quality of information on which the opinions are based. Relevant information may also not be transmitted due to psychological, or behavioral reasons. For example, self-certification of the quality of recommendations may not always be realistic: an expert can hardly be expected to declare even privately that her advice is not of great reliability. Our primary focus in this paper will be on a scenario where two experts sequentially provide *cheap talk* advice in two stages. The advice is constrained by the messages available.[1]

We then go on and relax this constraint and focus on two alternative procedures of advice – detailed recommendation and deliberation. Detailed recommendation captures the case where experts are allowed to express their views in full – the advice as well as any qualification to it.[2] Under deliberation, experts have the option of revising their recommendations in light of the opinion of others. Deliberations are sequential in nature with commentators giving their views, endorsing or countering prevailing opinions. Such a procedure may allow experts

[1]Caillaud and Tirole (2007) propose that processing information may be costly for the decision maker. High processing cost naturally calls for constraining the messages.

[2]Secrecy of advice or any of its limitations are guaranteed, for instance, at top level intelligence services for a country's national security. It is also plausible to consider communication of key information (say the hiding place of Osama Bin Laden, or the planned attack by terrorists, or whether there has been any give-and-take by the countries' top officials/politicians in influencing election, etc.) to be a cheap talk, because the original source might not want to leave any trail of having supplied the expert the confidential information.

to transfer all their information. In monetary policy committees, select members debate over the inflation target or interest rate.[3] The head of states such as the Prime Minister, or the leader of a major political party, may rely on their trusted advisors, who give their conflicting views about the suitability of important decisions in closed-door meetings in a more discussion and deliberative style. A judge may conduct cases *in-camera* (or *in-chambers*), i.e., hear evidence and arguments in private as opposed to open court trial.[4]

We ask whether a decision maker, in order to select a decision corresponding with an unknown *state*, should make the experts' recommendations public, by disclosing who made what recommendations when (transparency), or maintain secrecy by informing the public of only the summary decision. The true state will eventually become known. One principal assumption will be that the experts have "career concerns," an idea in organizational economics introduced by Holmstrom (1999): they care mainly about the perception of outsider(s), i.e. the public, about their ability in predicting the true state. In the examples of parliamentary and political debates as well as advice by corporate managers there is no explicit payment involved per each advice. Instead, giving opinions are seen as part of the job.[5]

[3]In the Bank of England's monetary policy committee consisting of nine members, policy decisions on a number of issues (e.g., the setting of rate of interest) are made by a simple majority rule instead of a sophisticated voting rule that is sensitive to the degree of emphasis of the voters' declared votes reflecting all relevant information. See https://www.bankofengland.co.uk/faq#anchor_1516787784054; specifically, "The MPC's final meeting – its second policy meeting – is normally held on the Wednesday. Following further discussion on the appropriate stance for monetary policy, the Governor puts to the meeting the policy that he believes will command a majority and members of the MPC vote. Any member in a minority is asked to say what level of interest rates they would have preferred. If there is an even split between the MPC members present, the Governor has the casting vote. The interest rate decision is published alongside the minutes of the MPC's meetings at 12 noon on the Thursday." The Governor can be put in the position of our decision maker.

[4]See Jan. 4, 2010 report, "Democratic leaders plan secret health reform deliberations"; source: http://www.usnews.com/opinion/blogs/peter-roff/2010/01/04/democratic-leaders-plan-secret-health-reform-deliberations. A recently edited book titled "*Secrecy and Publicity in Votes and Debates*" (2015; edited by Jon Elster) discuss a range of issues involving secret vs. open debates in politics. In Chapter 12 ("Secret Votes and Secret Talk"), one of the authors, John Ferejohn, discusses publicness of votes (leading to decisive public choices) by elected representatives but also talks about background political deliberations that "are either completely or partly veiled from outside scrutiny." See also some of the other chapters, especially, "Secret-Public Voting in FDA Advisory Committees" by P. Urfalino and P. Costa.

[5]Politicians (Congressmen in the USA) appeal to a higher level audience – heads of important committees in the House or the Senate, electorate who may win him or her a Senate seat in future election, etc. 'Skills' and 'achievements' (e.g., "sponsoring major pieces of legislation, delivering famous speeches, casting decisive votes on important issues" etc.) are reckoned to be important considerations in influencing a politician's

When the decision maker has the final authority to make a yes/no decision, he may base his decision not just on the number of each type of recommendation (or votes) but also on the order of recommendations. This is so especially when the experts can see and, hence, learn from each other's recommendation. In choosing to take the same decision following the same recommendations, but in different orders, the decision maker may be wasting valuable information. In this regard, sequentiality of advice introduces a new dynamic not prevalent in simultaneous decision making with an exogenous rule, e.g., in one-shot voting.

In the two-stage sequential advice game with constrained messages, one of our main results is that a Bayesian decision maker would prefer secrecy over transparency (Proposition 4). Interactions among three principal forces shape the experts' information revelation incentives: a prior bias, a lead opinion bias, and conformity bias. The first and second biases are exogenous and impact on the experts' beliefs about the likely state. We shall focus on the case where the common prior strictly favors one of two possible states, i.e., there is a *prior bias*. The *lead opinion bias* suggests how seriously the second expert should view the first expert's recommendation when her own signal indicates otherwise. As the experts' average precision levels improve, so does the lead opinion bias. The third bias, if and when it exists (and it can arise only endogenously), is induced by the beliefs of the outsider. Typically, when an expert's recommendation (actual or perceived) does not match the realized state, the outsider updates his beliefs towards the expert having low predictive skills. If such downward revision were to be greater when the alternative to status quo is found to have been wrongly predicted, one would expect experts to sometimes recommend in favor of the status quo even if they expect it to occur with probability less than one-half. This we call the *conformity bias*. It inclines the experts towards recommending the decision favored by the prior.

With transparency, at times the second expert is able to overturn a recommendation made against the favored state. But under secrecy, the second expert may also be able to

career prospects (see Diermer, Keane and Merlo, 2005).

overturn a recommendation made in support of the favored state. For small prior biases, the lead opinion bias comes into play. Under transparency, when the lead opinion bias is large the second expert herds and thus becomes redundant (Proposition 1). Under secrecy, however, an endogenous conformity bias acts against the lead opinion bias, making the second expert's recommendation relevant over a larger range of parameters (Proposition 3 and inequality (18)). When the conformity bias is absent, under secrecy the second expert may be able to sometimes communicate, through *partial herding*, all relevant information – her signal about the state as well as its quality when the quality is high (Proposition 2). In fact, this mixed equilibrium (type revelation combined with herding) also yields the highest payoff for the decision maker among all the equilibria identified under secrecy (Proposition 5). Surprisingly, all these gains from secrecy accrue despite the constraints of a limited message set.

The merit of secret advice is enhanced when the restriction on message sets is removed. Under detailed advice where experts make their recommendations as well as qualify their reliability (i.e., of high or low quality), sometimes the experts are able to reveal all their private information leading to efficient decisions (Proposition 6).[6] This, however, is not always true. At times, even with expanded messages full revelation of information may break down; see the discussion on non-congruence of incentives under secrecy in Section 7.

■ **Related literature.** Our paper follows the sequential cheap-talk advice literature started by Scharfstein and Stein (1990), and studied extensively by Ottaviani and Sorensen (2001; 2006a,b,c). These papers focused on how financial experts, who care about their reputation in predicting assets' returns or an unknown state, tend to herd in their recommendations, or conform to some prior expectation of the unknown state. While these papers address an important class of problems, what has not been considered before is whether the transparency of advice is indeed an ideal protocol for good decision making. Studying within the same

[6] A similar result obtains when experts engage in back-and-forth deliberations, possibly changing their advice in light of the other expert's earlier advice.

sequential advice framework, we argue that conducting the sequential advice in closed-door meetings, which is very plausible in many political and organizational decision contexts, yields clearly superior decisions.

Also related are the papers of Levy (2007a,b), and Visser and Swank (2007) who have studied information transmission by experts but in the context of voting. There are important differences between these two papers and our model: first of all, sequencing of expert advice in our analysis, as opposed to simultaneous voting, allows the second expert to learn from the first expert's action. Second, our decision maker does not commit to a decision rule and instead updates his prior and optimally selects a decision.

Levy analyzes a committee decision model using voting. Three experts, motivated by career concerns, simultaneously and independently vote on an action each, and the decision is determined by a given voting rule (unanimity or majority rule). The main argument is that with secretive voting experts are more likely to conform to pre-existing biases either in the voting rule or in the prior, while transparency often leads to contrarian voting. One of Levy's main findings is that under the unanimity rule, secretive voting may *sometimes* induce better decisions than a transparent procedure.[7,8]

Visser and Swank study a different model where career-concerned experts with private signals about the suitability of a public project engage in simultaneous information exchange, followed by voting. Smart experts observe the accurate information whereas dumb experts observe completely uninformative signal, and the exerts do not know their types. The authors find that transparency aligns experts' interests better with the first-best (or public) objective. Under secrecy, experts tend to easily conform to implement the decision that would signal to outsiders that there has been wide agreement. Thus there is a group bias towards conformity.

There is also a considerable literature on deliberations and communication by experts in

[7]The question of transparency has been analyzed in other applications also by Sibert (2003), Gersbach and Hahn (2008), Seidmann (2011), among others.

[8]Earlier, Prat (2005) also advocated secrecy in a principal-agent contracting model. He shows that making an agent's action observable can hurt the principal as the agent might ignore valuable information of her own and instead choose an action to conform to behaviors expected of a more able agent.

decision making, specifically in voting and mechanism design settings but where experts do not necessarily have career concerns,[9] and on information revelation in multi-round communication games.[10] Much of the tension in information revelation derives either from divergence in preferences of the parties directly interested in decisions, or due to heterogeneity in information when preferences are homogenous (known as common-interest games). McLennan (1998) analyzes the latter in the context of jury voting. Our setup, however, is not a common interest game. We elaborate on this in Section 7.

In the next two sections we present the decision maker's problem, the advice protocols and a technical result on partition of expert types. The core analysis is developed in Sections 4–7. Section 8 concludes and the proofs are relegated to an Appendix and a Supplementary file.

2 Decision maker's problem

A decision maker, D, has to solicit recommendations (advice) from two experts. There is an outside observer O, to be referred to as the public or the "market", whose evaluation of the experts' abilities confers the only benefits (payoffs) on the experts.

Formally, two experts make their recommendations to D sequentially about a payoff relevant state $\omega \in \{a, b\}$. Throughout e is a generic label for an expert, with the first mover referred to as i and second mover as j. The two experts, D and O share a common prior that favors state a: $\Pr(a) = q$, where $q \in (\frac{1}{2}, 1)$ will be referred to as the ***prior bias***.[11]

Each expert privately observes a signal $s_e \in \{\alpha, \beta\}$. Let

$$\Pr(s_e = \alpha \mid \omega = a) = \Pr(s_e = \beta \mid \omega = b) = t_e$$

be the quality of expert e's signal, that we call e's precision level (or ability) $t_e \in \{\xi, \lambda\}$,

[9]See, for example, McLennan (1998), Wolinsky (2002), Caillaud and Tirole (2007), Meade and Stasavage (2008), Jackson and Tan (2013), and Iaryczower, Shi and Shum (2018).

[10]Aumann and Hart (2003), Krishna and Morgan (2004), and Forges and Koessler (2008).

[11]Our results would also go through when the states are equally likely, i.e., $q = \frac{1}{2}$. However, there would be additional equilibria that are not robust to small perturbations in beliefs.

with $\frac{1}{2} < \xi < \lambda < 1$. Experts are privately informed about their abilities that are i.i.d., with $\Pr(t_e = \lambda) = \theta$, $0 < \theta < 1$ for $e = i, j$. Let

$$k \equiv \theta\lambda + (1-\theta)\xi$$

be the prior that any expert will observe the correct signal. The index k will also measure the influence of expert i, i.e., the first mover, on expert j's recommendation and will be referred to as the ***lead opinion bias***.

Define

$$T_i = T_j = \big\{(\alpha, \xi), (\alpha, \lambda), (\beta, \xi), (\beta, \lambda)\big\},$$

where the elements of T_i and T_j represent the private information (types) of experts i and j, and are denoted by τ_i and τ_j.

An expert is randomly drawn by D with probability $\frac{1}{2}$ to move first (at the information set h_0). After observing i's recommendation to D (that is conditional on history $h_1 \in \{A, B\}$), expert j makes her recommendation. Let $\nu_e : T_e \longrightarrow \{A, B\}$ be a reporting rule for expert $e \in \{i, j\}$ and let

$$\mathbf{V}_e = \big\{(\nu_e(\alpha, \xi), \nu_e(\alpha, \lambda), \nu_e(\beta, \xi), \nu_e(\beta, \lambda)) \mid \nu_e(s_e, t_e) \in \{A, B\}\big\}. \tag{1}$$

be the set of all reporting rules for expert e. Pure strategies for experts i and j are then functions $h_0 \longrightarrow \mathbf{V}_e$ and $h_1 \longrightarrow \mathbf{V}_e$, respectively.

D uses a **Bayesian decision rule** $d : V \longrightarrow \{A, B\}$ to choose between actions A and B. After the decision, the *true* state is revealed and D receives a payoff $\pi_D(d, \omega)$, where

$$\begin{aligned} \pi_D(A, a) = \pi_D(B, b) &= 1, \\ \pi_D(B, a) = \pi_D(A, b) &= 0. \end{aligned} \tag{2}$$

Thus, action A (resp. B) is D's ideal decision in state a (resp. b).

All of the above, except realizations of types, states and signals, are common knowledge among experts, D and O.

We now state the two protocols and the payoffs of the experts.

[***Transparency* or $\wp = t$**] O *observes* d*, the state of the world* ω *and the sequence of moves (which expert moves first and which second) as well as the recommendations made by the experts. In particular,* O *observes a realization of the outcome,* $(\nu_i, \nu_j, \mathsf{d}, \omega)$*, and Bayes-updates his beliefs regarding the experts' abilities denoted by* $\Pr(t_i \mid \nu_i, \nu_j, \mathsf{d}, \omega)$*. The expected abilities of* i *and* j*, as well as their payoffs, are*

$$\begin{aligned} E^{\wp=t}(t_i|\nu_i, \nu_j, \mathsf{d}, \omega) &= \Pr(t_i = \lambda \mid \nu_i, \nu_j, \mathsf{d}, \omega)\lambda + \Pr(t_i = \xi \mid \nu_i, \nu_j, \mathsf{d}, \omega)\xi, \\ E^{\wp=t}(t_j|\nu_i, \nu_j, \mathsf{d}, \omega) &= \Pr(t_j = \lambda \mid \nu_i, \nu_j, \mathsf{d}, \omega)\lambda + \Pr(t_j = \xi \mid \nu_i, \nu_j, \mathsf{d}, \omega)\xi. \end{aligned} \tag{3}$$

[***Secrecy* or $\wp = s$**] O *only observes the decision maker's decision and the true realization of the state,* (d, ω)*, and Bayes-updates expert* e*'s ability to* $\Pr(t_e \mid \mathsf{d}, \omega)$*. The expected ability of* e *is*

$$E^{\wp=s}(t_e|\mathsf{d}, \omega) = \Pr(t_e = \lambda \mid \mathsf{d}, \omega)\lambda + \Pr(t_e = \xi \mid \mathsf{d}, \omega)\xi. \tag{4}$$

This is also each expert's payoff.

D does not offer any explicit monetary rewards to the experts. The market pays the experts based on their expected absolute abilities. These expectations depend on what the market can observe, i.e., on the protocol of advice.

Let $\mu_i^{\wp} = \Pr(\omega = a|\tau_i)$ and $\mu_j^{\wp} = \Pr(\omega = a, \tau_i|\nu_i, \tau_j)$ denote expert i and j's beliefs about ω, and in the case of j also about i's type, conditional on the expert's private information. Let $\mu_D^{\wp} = \Pr(\omega = a|\nu_i, \nu_j)$ denote D's updated belief conditional on the recommendations. O's beliefs are denoted by $\mu_O^{\wp=t} = \Pr(t_e = \lambda|\nu_i, \nu_j, \mathsf{d}, \omega)$ and $\mu_O^{\wp=s} = \Pr(t_e = \lambda|\mathsf{d}, \omega)$ under transparency and secrecy, respectively.

This ends the description of the two games, conditional on the protocols – transparency and secrecy. We build our equilibrium solution starting from perfect Bayesian equilibrium.

DEFINITION 1. *A* perfect Bayesian equilibrium (PBE) *of the game induced under the protocol* $\wp$ *is a profile of (pure) strategies and beliefs,*

$$\left(v_i^*(.),\, v_j^*(.),\, d^*(.,.);\; \mu_i^{\wp},\, \mu_j^{\wp},\, \mu_D^{\wp}, \mu_O^{\wp}\right),$$

for all histories such that the strategies are sequentially rational given beliefs, and the beliefs are derived applying Bayes' rule wherever possible.

Recall that $E_i^{\wp}$ and $E_j^{\wp}$ ($E_i^{\wp} = E_j^{\wp}$ in the case of secrecy) are the expectations over expert abilities t_i, t_j, respectively, that the outsider O estimates.[12] Note that $E_i^{\wp}$ and $E_j^{\wp}$ also define the experts' terminal payoffs in the game. These expectations are derived through $\mu_O^{\wp}$, which in turn is a part of equilibrium. Thus, our Bayesian game is quite different from standard games where players' payoffs in the terminal nodes are taken as given (or fixed), rather than endogenously determined in equilibrium.

Communication games always have babbling equilibria under which recommendations are ignored. We will restrict our attention primarily to a class of 'decisive equilibria':

DEFINITION 2. *An equilibrium of the sequential advice game, in short $\mathcal{E}$, induced under the protocol* $\wp$ *is a* PBE of $\wp$ *where the first expert does not babble.*

Under signal revealing strategies, i.e., an expert recommends A (B) when her signal is α (β), we say that the expert reports truthfully. We now state a stronger version of $\mathcal{E}$.

DEFINITION 3. *A strong sequential advice equilibrium, in short $\mathcal{SE}$, of the game induced under the protocol $\wp$ is an equilibrium $\mathcal{E}$ of $\wp$ where the first expert reports truthfully.*

D's problem is to choose an optimal protocol to maximize his ex-ante expected payoff from eventual decision making. Given the multiplicity of equilibria in communication games, we take a mechanism design approach.

[12]Expected abilities of the first and second movers are the same under secrecy because the order of moves remains hidden.

Definition 4. D *prefers a protocol* $\wp$ *over* $\wp'$ *if for every profile of parameters* $(q, \theta, \xi, \lambda)$*, there exists some* PBE *in the game induced by* $\wp$ *under which the payoff of* D *is (weakly) greater than his payoff under all* PBE *in the game induced by* $\wp'$*, and strictly greater for some parameters.*

This ends the description of the decision maker's two-step decision problem.[13] It may be noted that D does not get to directly choose payoffs for the experts. Once a protocol is chosen, the experts' incentives are induced by O's beliefs which are influenced by D's decision rule.

The following assumption will be maintained throughout the paper.[14]

Assumption 1. $1/2 < q < \xi < \lambda < 1$.

That is, even the low-ability expert's signal is more informative than the unrefined (prior) information. Assumption 1, along with the definition of k, implies the following fact:

Fact 1. $\frac{\lambda}{1-\lambda} > \frac{k}{1-k} > \frac{\xi}{1-\xi} > \frac{q}{1-q} > 1$.

3 Bias, beliefs, and partitioning k and q

We say that signal α (β) favors the corresponding state a (b), if conditional on the signal (and possibly other observables) the expert assigns to state a (b) a probability greater than $\frac{1}{2}$. In the Appendix we show that, both signals of the first expert i favor their respective states. This observation, which results due to Fact 1, plays a crucial role in the existence of $\mathcal{SE}$. In all $\mathcal{SE}$, the second expert j is able to decipher i's signal but not her ability. Hence j's beliefs about i's ability is k.

[13]The reader may be concerned that in the protocol chosen there may be an equilibrium which is worse than all equilibria in the other protocol and strictly worse under some parameter values. This won't happen in our environment because the worst equilibrium in both protocols is the babbling equilibrium.

[14]The assumption helps reducing the set of equilibria. Our qualitative results do not change if $q \geq \xi$.

Due to Fact 1, if j's signal matches that of i, then j's signal favors its corresponding state (see (A.2)). Similarly, when j is of ability λ, signal α favors a even when i's signal is revealed to be β. This is because $\lambda > k$ and $q > \frac{1}{2}$ (see (A.3)).

When j is of low ability (ξ) and i's revealed signal is α, then signal β *does not* favor b, irrespective of q and k. This is because $\xi < k$ and $q > \frac{1}{2}$ (see (A.4)).

There are two cases, however, where the relative weights of q and k matter. Let s_i be the deduced signal of expert i, s_j and t_j the signal and ability of expert j. Signals favor the corresponding states only when the posteriors of j, conditional on (s_i, s_j, t_j), satisfy:

$$\Pr(a \mid \beta, \alpha, \xi) = \frac{q\xi(1-k)}{q\xi(1-k) + (1-q)(1-\xi)k} \geq \frac{1}{2} \quad \text{if and only if} \quad k \leq k(\xi), \tag{5}$$

$$\Pr(b \mid \alpha, \beta, \lambda) = \frac{(1-q)\lambda(1-k)}{q(1-\lambda)k + (1-q)\lambda(1-k)} \geq \frac{1}{2} \quad \text{if and only if} \quad k \leq k(\lambda), \tag{6}$$

where

$$k(\xi) = \frac{q\xi}{q\xi + (1-q)(1-\xi)} \equiv \Pr(a \mid \alpha, \xi) \text{ and } k(\lambda) = \frac{(1-q)\lambda}{q(1-\lambda) + (1-q)\lambda} \equiv \Pr(b \mid \beta, \lambda). \tag{7}$$

Note that $k(\xi)$ and $k(\lambda)$ are j's posteriors of a and b, *solely* conditional on signal and ability. $k(\xi)$ and $k(\lambda)$ do not depend on i's revealed signal. Thus, (5) has a simple interpretation. If i's signal were to be revealed as β then a low ability j's signal α would favor state a only if the lead opinion bias k were to be less than $k(\xi)$. One can interpret (6) similarly.

Note that $k(\xi)$ increases, and $k(\lambda)$ decreases, as q increases. Hence, whether or not signals favor their respective states depend on both k and q. Given $q > \frac{1}{2}$ it is easy to see that $\xi < k(\xi)$ and $k(\lambda) < \lambda$. But, $k(\lambda)$ may exceed or be less than $k(\xi)$ as listed below:[15]

[15] It is easy to rule out $k(\lambda) \leq \xi < k(\xi) < \lambda$. Panels 1-3 in Figure 4 in the Appendix display these orderings.

$$k(\lambda) \le \xi < \lambda \le k(\xi), \tag{8}$$

$$\xi \le k(\lambda) \le k(\xi) < \lambda, \tag{9}$$

$$\xi < k(\xi) < k(\lambda) < \lambda. \tag{10}$$

The partitions (8) through (10) will result depending on values of q. These values are defined below and the relationship is stated in Lemma 1. Let

$$r \equiv \left(\frac{\lambda}{1-\lambda}\right) / \left(\frac{\xi}{1-\xi}\right).$$

DEFINITION 5. *The **prior bias**, q, will be called <u>small</u>, <u>medium</u> or <u>large</u> if, respectively,*

$$\frac{q}{1-q} < \sqrt{r}, \qquad \sqrt{r} \le \frac{q}{1-q} < r, \qquad \textit{or} \qquad \frac{q}{1-q} \ge r.$$

LEMMA 1.

(i) *[**Panel 1**] Inequalities (8) will hold if and only if the prior bias, q, is <u>large</u>;*

(ii) *[**Panel 2**] Inequalities (9) hold if and only if the prior bias is <u>medium</u>;*

(iii) *[**Panel 3**] Inequalities (10) hold if and only if the prior bias is <u>small</u>.*

Lemma 1 can be visualized better with the help of a three-panel classification of Figure 4 in the Appendix.

4 Transparency: Revelation hurdles

D's objective is to maximize the probability that the decision chosen corresponds with the state. An expert's payoff derives from O's beliefs about the expert's ability. Under transparency, O gets to see not only the realized state but also who recommended what and when. Since O is only interested in the expert's ability, this information is sufficient for forming beliefs; D's decision becomes redundant.

We highlight the following two strategies from the strategy set $\mathbf{V}_e$ in (1). The complete list is included in the Appendix.

Truthful recommendation. An expert recommends according to her signal:

$$\mathbf{V}_e^s = \{(A, A, B, B)\}.$$

Babbling. An expert babbles if her recommendation is completely uninformative:

$$\mathbf{V}_e^b = \{(A, A, A, A), (B, B, B, B)\}.$$

With only two possible signals, the contrarian strategy (B, B, A, A) is equivalent to truthful recommendation.[16] Hence, without loss of generality, we drop this recommendation profile from the strategy sets.

In the Supplementary file, we characterize the set of equilibrium strategies for the experts. They imply that the following types of equilibria exist: (i) both experts babble; (ii) first expert babbles and second expert recommends truthfully; (iii) first expert recommends truthfully and second expert always babbles; and (iv) first expert recommends truthfully and second expert recommends truthfully only if the first recommendation is B. Under babbling D's posterior is the same as his prior and therefore his payoff is q. Under (ii) and (iii), D's payoff is k. Since $k > q$, we ignore (i). Since D's payoffs are the same under (ii) and (iii), we

[16]Sometimes *contrarian* is used differently to mean the second expert recommending contrary to the first expert's recommendation. From the context the meaning should be clear.

ignore (ii). Equilibria (iii) and (iv) are $\mathcal{SE}$ and will be of special interest to us. We collect our main results in the following proposition.

PROPOSITION 1 (Transparency: Equilibrium characterization). *Under transparency an $\mathcal{SE}$ equilibrium exists. The experts' strategies in $\mathcal{SE}$ equilibria are as follows:*

1. *In all $\mathcal{SE}$:*
   (i) *If $v_i = A$, then $v_j(v_i) \in \mathbf{V}_j^b$.*
   (ii) *If $v_i = B$ and k is small (i.e., $k \leq k(\xi)$), then $v_j(v_i) \in \mathbf{V}_j^s \cup \mathbf{V}_j^b$. If $v_i = B$ and k is large (i.e., $k > k(\xi)$), then $v_j(v_i) \in \mathbf{V}_j^b$.*
2. *In all $\mathcal{SE}$, following a recommendation of A by the first expert, D chooses A. Following a recommendation of B, D's decision will depend on the continuation equilibrium. For the babbling equilibrium, D chooses B. For the truthful recommendation equilibrium, $d(B, B) = B, \ \ d(B, A) = A$.*

The results in Proposition 1 are derived by eliminating various candidates for equilibrium. Since there are many such candidates, it is tedious to go through them case by case. For the purpose of illustration, we discuss why and when the second expert's signal revealing strategy, (A, A, B, B), and partial type revelation strategies like (A, A, A, B), are ruled out.

Let (A, A, B, B) be the second expert's strategy. In equilibrium, O forms his expectations about the second expert's ability based on this strategy. Given an observed state, let γ be the expectation of this ability when the recommendation is right and γ' be the expectation when the recommendation is wrong. It turns out that γ and γ' do not depend on the states observed. Furthermore, when the recommendation is right O's beliefs are updated in favor of high ability and vice versa when the recommendation is wrong. So $\gamma > \gamma'$. Thus, the expected payoff of type (β, ξ) in recommending B is $\Pr(a \mid v_i, \beta, \xi)\gamma' + \Pr(b \mid v_i, \beta, \xi)\gamma$. If instead she were to deviate from her proposed equilibrium strategy and recommend A, her payoff would be $\Pr(a \mid v_i, \beta, \xi)\gamma + \Pr(b \mid v_i, \beta, \xi)\gamma'$. Then, as $\gamma > \gamma'$, incentive compatibility would require that $\Pr(a \mid \nu_i, \beta, \xi) \leq \Pr(b \mid \nu_i, \beta, \xi)$. Similarly, for type (β, λ), one would require $\Pr(a \mid \nu_i, \beta, \lambda) \leq \Pr(b \mid \nu_i, \beta, \lambda)$.

Now consider part (i) of the Proposition and suppose the first expert i's recommendation is A, i.e. $\nu_i = A$. Under $\mathcal{SE}$, i always recommends her signal. So the second expert j knows that the first expert's signal is α. But suppose j is of type (β, ξ), and as shown in Section 3 (or (A.4)), $\Pr(a \mid A, \beta, \xi) = \Pr(a \mid \alpha, \beta, \xi) > \frac{1}{2}$. So $\Pr(a \mid A, \beta, \xi) > \Pr(b \mid A, \beta, \xi)$ and incentive compatibility is violated.

For part (ii) of the Proposition, if i recommends B then incentive compatibility of the second expert of type (α, ξ) would require that $\Pr(a \mid B, \alpha, \xi) \geq \Pr(b \mid B, \alpha, \xi)$. Or, $\Pr(a \mid \beta, \alpha, \xi) \geq \frac{1}{2}$. By (5), this would hold if and only if $k \leq k(\xi)$.

Thus we see that under transparency, "herd behavior" causes signal revealing equilibria to be ruled out.[17]

Next, consider the strategy (A, A, A, B). If the expert were to recommend B then O would believe that the expert is of ability λ, irrespective of the revealed state of nature. The expert's payoff would then be λ. A recommendation of A, on the other hand, would make O believe that the expert's ability is λ with probability less than one. This would give the expert a payoff of less than λ. But then the low-ability expert would mimic the report of the high-ability expert. That is, the proposed strategy would violate incentive compatibility. The reader may now note that other types of strategies like (A, B, A, B), (B, A, B, B) etc. can be similarly ruled out.[18]

[17] Observe that herd behavior occurs when the lead opinion bias is "high" relative to the prior bias. That is, when $k > k(\xi)$. Since $k(\xi)$ is continuously increasing in q, $k(\xi) = \xi$ when $q = \frac{1}{2}$ (see from (7)), and $k > \xi$, we conclude that $k > k(\xi)$ for low values of q. As such, signal revelation is impossible for very low values of q.

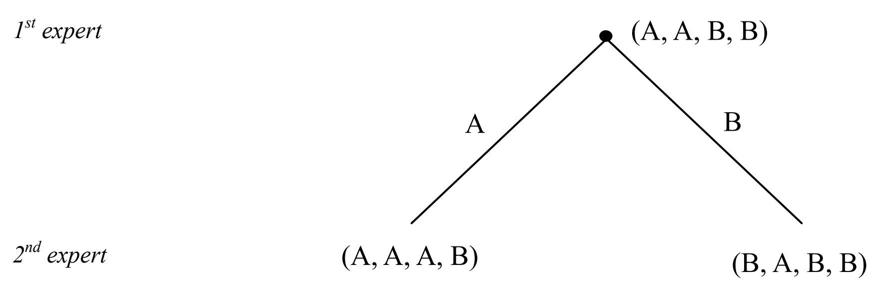
[18] Such strategies are elements of $\mathbf{V}_e^{st}$ and $\mathbf{V}_e^{t}$ as defined in the Appendix. The argument provided in this paragraph, which rules out ability revelation, is not conditional on the values of q or k. Nor is it contingent on experts moving sequentially or simultaneously.

5 Secrecy and revelation

In this section we present two classes of equilibria under secrecy. Now the experts cannot be judged directly by their recommendations but O will have to make inferences about their collective type based on D's decision accuracy.

■ **Herding and partial type revelation.** We first present an equilibrium (see Figure 1), where the second expert's advice is shaped *only* by the lead opinion bias and the prior bias. We call this a partial type revealing equilibrium because only the second expert is able to reveal her type to D (and not to O) and that too in certain cases. For example if the first expert were to recommend B, the second expert's *high* type gets revealed only if she were to recommend A (i.e. if she were to get signal α). A recommendation of B, neither reveals the signal nor ability.

Figure 1: Partial type revelation strategies



Proposition 2 (Partial type revelation). *Let* q *be small, i.e.* $q/(1-q) < \sqrt{r}$*, and* $k \in [k(\xi), k(\lambda)]$*. The following recommendation strategies can be supported as an* $\mathcal{SE}$ *under secrecy:*

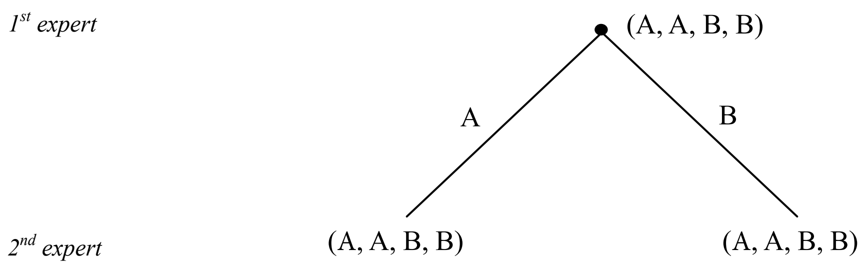
$$\nu_j(A) = (A, A, A, B), \;\; \nu_j(B) = (B, A, B, B),$$

with the decision maker choosing his decision according to the following rule: $d(A, B) = B, \;\; d(A, A) = A, \;\; d(B, A) = A, \;\; d(B, B) = B.$

A simple intuition is that only a high ability expert, when moving second, can risk submitting a different recommendation to one by the first expert to credibly convey to D about the high quality of her recommendation and prompt D to make a better decision. By shielding the identity of the pivotal expert from O, D is able to eliminate any perverse incentive of the second expert of falsely signaling to be one of high ability: such false signaling will only lower the chance of a correct decision, damaging the experts' perceived ability. Interestingly, the "herd behavior" by the low (but not the high) ability second expert facilitates the high-ability type to stand out.

■ **Signal revelation.** The second class consists of signal revealing equilibria. The experts' strategies are depicted in Figure 2.

Figure 2: Signal revelation



In equilibrium, both experts recommend their signals. Given these signal revealing strategies, for recommendation profiles (A, A), (A, B), (B, A) and (B, B), D knows that the corresponding signals are (α, α), (α, β), (β, α) and (β, β). D's posteriors are then:

$$\begin{aligned}
\Pr(a \mid A, A) &= \frac{qk^2}{qk^2+(1-q)(1-k)^2} > \frac{1}{2}\,, \\
\Pr(a \mid A, B) &= q > \frac{1}{2}\,, \\
\Pr(a \mid B, A) &= q > \frac{1}{2}\,, \\
\Pr(a \mid B, B) &= \frac{q(1-k)^2}{q(1-k)^2+(1-q)k^2} < \frac{1}{2}\,.
\end{aligned}$$

These probabilities are calculated using Tables A.2 and A.3 in the Appendix.[19] For the

[19] For example, consider $\Pr(\omega = a \mid A, B)$. Since experts reveal their signals, $\Pr(\omega = a \mid A, B) = \Pr(\omega =$

symmetric case, $q = \frac{1}{2}$, we would have $P(a \mid A, B) = P(a \mid B, A) = \frac{1}{2}$. In this knife-edge case, D's decision rule can take more forms than those specified in Lemma 2 below. Some of these rules align the incentives of the second expert with that of D to always reveal her signals.[20] However, such decision rules are not a part of equilibrium when $q > \frac{1}{2}$. Hence, signal revelation by the second expert, irrespective of the first recommendation, is not robust. With $q > \frac{1}{2}$, which is our main focus, D's beliefs then immediately imply the following result.

LEMMA 2 (D's decision under signal revelation). *Let the recommendations reveal signals.* D *selects* B *if and only if both experts recommend* B*; otherwise* D *selects* A.

Recommendations are not observed by O. Hence O forms beliefs solely on the basis of D's decisions and the observed states. These beliefs then determine the payoffs of the representative expert. Let x' and x'' denote an expert's payoffs when D's decision matches states a and b respectively. Let y'' and y' denote an expert's payoffs when D's decision *does not* match states a and b respectively.[21] Unlike under transparency, or under the partial type revelation equilibrium under secrecy, x' and x'' (or y'' and y') are not equal. Moreover, it turns out that $x' - y'' > 0$ and $x'' - y' > 0$ (see the proof of Proposition 3). We say that there is *conformity bias* when:

$$x' - y'' > x'' - y'.$$

That is, an expert has more net gain (i.e., perceived ability from accuracy of recommendation *less* perceived ability from being wrong) by recommending the prior-favored decision (A) than by recommending the longshot (B). The conformity bias therefore generally inclines an expert in favor of recommending A over B.[22]

$a \mid \alpha, \beta)$. This probability is a ratio where the numerator is the sum of all column entries in row two of Table A.2. In the denominator we have this sum plus the sum of all column entries in row two of Table A.3. This ratio is q. The other probabilities can be derived similarly.

[20] This happens when D randomizes with equal probability between A and B, whenever the two experts recommend differently.

[21] These payoffs are explicitly derived in the proof of Proposition 3.

[22] This is not to say that in the presence of conformity bias an expert would necessarily recommend A over B. The recommendation would also depend on an expert's posteriors of the states as we will see below.

Let c be the measure of conformity bias:

$$c \equiv \frac{x' - y''}{x'' - y'}. \tag{11}$$

Since payoffs are generated by O's beliefs, c results from a certain kind of bias in O's equilibrium beliefs. Given Lemma 2, it turns out that (see the proof of Proposition 3),

$$\begin{aligned} \Pr(\xi \mid d = A, \omega = b) &= 1 - \tfrac{\theta(1-\lambda k)}{1-k^2}, \\ \Pr(\xi \mid d = B, \omega = a) &= 1 - \tfrac{\theta(1-\lambda)}{1-k}. \end{aligned}$$

Since $\lambda < 1$, we have $\Pr(\xi \mid A, b) < \Pr(\xi \mid B, a)$. In other words, the downward adjustment of O's beliefs about experts' skills when D is unable to match state b is smaller than when D is unable to match state a, which confirms the presence of conformity bias.

We now turn to see how the above conformity bias influences signal revelation. For the basic intuition it suffices to consider the case of the second expert j when i reveals her signal as β by recommending B.

The expected payoff of type (β, t_j) in recommending B is $\Pr(a \mid \beta, \beta, t_j)y'' + \Pr(b \mid \beta, \beta, t_j)x''$. If instead she were to deviate and recommend A, her payoff would be $\Pr(a \mid \beta, \beta, t_j)x' + \Pr(b \mid \beta, \beta, t_j)y'$. Incentive compatibility would then require that

$$\Pr(b \mid \beta, \beta, t_j)(x'' - y') \geq \Pr(a \mid \beta, \beta, t_j)(x' - y'').$$

Note that $\Pr(b \mid \beta, \beta, t_j) = \frac{(1-q)t_j k}{q(1-t_j)(1-k)+(1-q)t_j k}$ and $\Pr(a \mid \beta, \beta, t_j) = \frac{q(1-t_j)(1-k)}{q(1-t_j)(1-k)+(1-q)t_j k}$. Using these posteriors in the above inequality we obtain:

$$k \geq \frac{q(1-t_j)(x' - y'')}{(1-q)t_j(x'' - y') + q(1-t_j)(x' - y'')}. \tag{12}$$

Similarly, type (α, t_j) has to recommend A. Her incentive compatibility constraint is given by:

$$\Pr(a \mid \beta, \alpha, t_j)(x' - y'') \geq \Pr(b \mid \beta, \alpha, t_j)(x'' - y').$$

Using $\Pr(a \mid \beta, \alpha, t_j)(x' - y'') = \frac{qt_j(1-k)}{qt_j(1-k)+(1-q)(1-t_j)k}$ and $\Pr(b \mid \beta, \alpha, t_j) = \frac{(1-q)(1-t_j)k}{qt_j(1-k)+(1-q)(1-t_j)k}$, we obtain:

$$\frac{qt_j(x' - y'')}{qt_j(x' - y'') + (1-q)(1-t_j)(x'' - y')} \geq k. \tag{13}$$

Thus, when i reveals her signal as β the second expert recommends her signal if and only if (12) and (13) hold. That is, for every $t_j \in \{\xi, \lambda\}$:

$$\frac{qt_j(x' - y'')}{qt_j(x' - y'') + (1-q)(1-t_j)(x'' - y')} \geq k \geq \frac{q(1-t_j)(x' - y'')}{(1-q)t_j(x'' - y') + q(1-t_j)(x' - y'')}. \tag{14}$$

To check the feasibility of (14), we rewrite it as:

$$\frac{t_j}{1-t_j} \geq \max\left\{\frac{1-k}{k}\frac{q}{1-q}\frac{x'-y''}{x''-y'}, \frac{k}{1-k}\frac{1-q}{q}\frac{x''-y'}{x'-x''}\right\}.$$

It turns out that $\frac{x'-y''}{x''-y'} > 1$.[23] Furthermore, since $\frac{\lambda}{1-\lambda} > \frac{\xi}{1-\xi}$ we can write (14) as:

$$\frac{\xi}{1-\xi} \geq \frac{k}{1-k}\frac{1-q}{q}\frac{x''-y'}{x'-x''}$$

or,

$$k \leq \frac{q\xi(x' - y'')}{q\xi(x' - y'') + (1-q)(1-\xi)(x'' - y')} \equiv \bar{k}(\xi). \tag{15}$$

Below we show that (15) is necessary and sufficient for the existence of a signal revealing equilibrium.

[23] See the proof of Proposition 3.

Proposition 3 (Signal revelation). *Under secrecy, there exists an $\mathcal{SE}$ where the second expert's strategies are as follows: For all $v_i \in \{A, B\}$,*

(i) *if $\xi \leq k \leq \bar{k}(\xi)$, then $v_j(v_i) \in \mathbf{V}_j^s$;* **(Revelation)**

(ii) *if $k > \bar{k}(\xi)$, then $v_j(v_i) \in \mathbf{V}_j^b$.* **(Babbling)**

The first expert, by definition of $\mathcal{SE}$, will recommend truthfully according to her signal.

In part (i) of Proposition 3, the antecedent requires that $\xi \leq k \leq \bar{k}(\xi)$. We first show that this restriction is not vacuous. Rewriting (15) using (11), i.e., in terms of conformity bias c, we obtain:

$$\bar{k}(\xi) \equiv \frac{q\xi c}{q\xi c + (1-q)(1-\xi)},$$

which is increasing in c. This suggests an increase in conformity bias is likely to expand the range of signal revelation. But a caution is needed because conformity bias is endogenously determined.

In the proof of Proposition 3, we show that

$$c = \frac{1+k}{2-k}. \tag{16}$$

So,

$$\bar{k}(\xi) = \frac{q\xi(\frac{1+k}{2-k})}{q\xi(\frac{1+k}{2-k}) + (1-q)(1-\xi)}. \tag{17}$$

As $\frac{1+k}{2-k} > 1$, we have

$$\bar{k}(\xi) > \frac{q\xi}{q\xi + (1-q)(1-\xi)} \equiv k(\xi). \tag{18}$$

Now when $\frac{q}{1-q} \geq r$, i.e. q is large, part (i) of Lemma 1 tells us that (8) holds. So, $\xi < \lambda \leq k(\xi) < \bar{k}(\xi)$. As $\xi \leq k \leq \lambda$, we have $\xi \leq k < \bar{k}(\xi)$ for all k and therefore the antecedent in part (i) of Proposition 3 is not vacuous. We also have the following result.

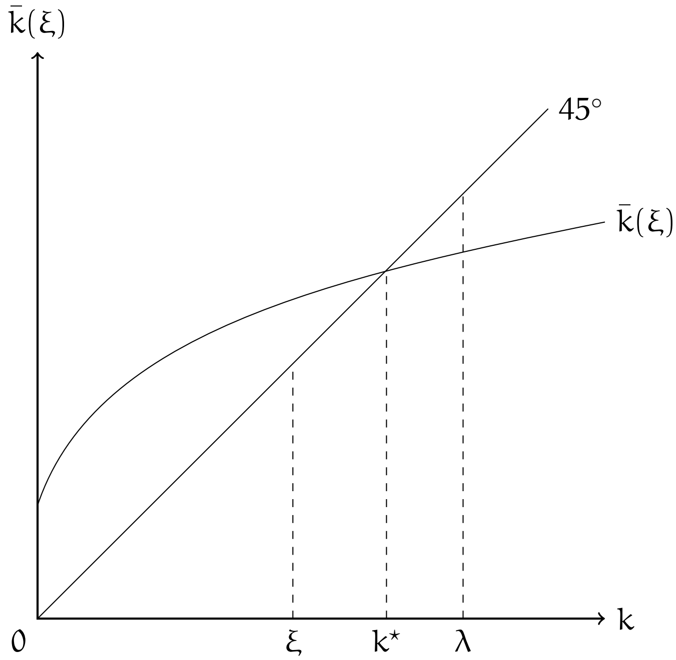


Figure 3: $\bar{k}(\xi), k^\star$ & signal revelation; $\xi > 1/2$ at $(4.5, 0)$, $\lambda < 1$ at $(7.5, 0)$ and $k^\star$ at $(6.15, 6.15)$

Corollary 1. *Let* q *be large, i.e.* $\frac{q}{1-q} \geq r$*, and the protocol be secrecy. Then for every* $k \in [\xi, \lambda]$*, there is a signal revelation equilibrium.*

■ **More on conformity bias and cutoff** k**.** From (16), we see that conformity bias increases as the lead opinion bias, k, increases. The intuition behind this observation is as follows. A high k means that ex ante the expert is believed to be of high ability with a high probability (θ is large). Furthermore since the prior favors state a ($q > \frac{1}{2}$), the experts' recommendation of A is expected to match state a with a higher probability than the recommendation of B matching state b. Ex post, if D's decision *fails* to match state a, O assigns a greater probability to the experts being of low abilities as compared to when the decision does not match state b. This greater adversarial belief about the experts' types (following failure to match state a) will be especially accentuated due to k being high. As a result, the experts will be induced towards recommending A over B (see our earlier discussions on conformity bias).

Corollary 1 tells us that the antecedent in (i) of Proposition 3 holds when q is large. We now show that the antecedent holds for smaller values of q. From (17), one can deduce that $\bar{k}(\xi)$ is an increasing concave function of k and that $\xi < \bar{k}(\xi)$. Furthermore, when q is not large, it is also the case that $\bar{k}(\xi) < \lambda$. So $\bar{k}(\xi)$ has a fixed point (see Figure 3). Let $k^\star$ be the fixed point of $\bar{k}(\xi)$. Using (16) in (18) we obtain

$$k^\star = \frac{\sqrt{y(y-1)+1}-1}{y-1}, \quad \text{where } y = \frac{q}{1-q}\frac{\xi}{1-\xi}.$$

So for $k \in [\xi, k^\star]$ the antecedent in (i) of Proposition 3 is satisfied and a signal revealing equilibrium exists.

Corollary 2. *Let $\frac{q}{1-q} < r$ and the protocol be secrecy. A signal revealing equilibrium exists under secrecy if $\xi \leq k \leq k^\star$. $k^\star$ is increasing in the prior bias q.*

Corollary 2 further clarifies Proposition 3. The relevant scenario to study this is one where the first expert has recommended B and a low-ability (ξ) second expert who has observed signal α is considering what to recommend: a high lead opinion bias k incentivizes her to ignore her signal and recommend B but then the high conformity bias c, resulting from the same high k (see (16)), inclines the expert towards recommending truthfully A. So long as k is below $k^\star$, i.e. lead opinion bias not too strong, conformity bias wins over the lead opinion bias. However when q is small so that $k^\star$ is not large, and k becomes sufficiently large, in excess of $k^\star$, the first expert's contrarian recommendation of B can no longer be countered by the low-ability second expert's α signal. Here the lead opinion's influence prevails over conformity bias (in Figure 3, $k > \bar{k}(\xi)$), making signal revelation an impossibility. Thus, a sufficient increase in k may completely nullify the second expert's usefulness.

■ **Comparing equilibria.** When the prior bias q is small, by bringing together Propositions 2 and 3 one can see that there is an overlap of partial type revelation with full signal revelation in the region of k: $[k(\xi), k(\lambda)] \cap [\xi, \bar{k}(\xi)] \neq \emptyset$. Hence, under secrecy there are multiple $\mathcal{SE}$.[24] A natural question then is how do these equilibria rank? In partial type revelation equilibrium there is some amount of herding, whereas in full signal revelation D

[24] Multiplicity of equilibria is not surprising as there is always a babbling equilibrium.

loses out on the important information that the second expert could be of high ability. An answer is provided in the next section.

6 Transparency or secrecy?

To evaluate the relative merits of the two protocols, it is sufficient to consider only one class of equilibria under secrecy, i.e., the one in Proposition 3. Consideration of type revelation equilibrium would only strengthen the main finding of this comparison.

Given that $\bar{k}(\xi) > k(\xi)$ we conclude, from Proposition 1 and Proposition 3, that signal revelation occurs under secrecy over a larger parameter space. The main difference between the two mechanisms comes in the form of revelation incentives of a low (ξ) ability expert who observes the signal α, when preceded by a B-recommendation by the first expert.[25] Under transparency, signal revelation requires:

$$\begin{aligned}
\Pi_j^t(B, A, \alpha, \xi) = \Pr(a \mid \beta, \alpha, \xi)\gamma &+ \Pr(b \mid \beta, \alpha, \xi)\gamma' \\
&\geq \Pr(a \mid \beta, \alpha, \xi)\gamma' + \Pr(b \mid \beta, \alpha, \xi)\gamma = \Pi_j^t(B, B, \alpha, \xi) \\
\text{or,} \quad \Pr(a \mid \beta, \alpha, \xi)\big[\gamma - \gamma'\big] &\geq \Pr(b \mid \beta, \alpha, \xi)\big[\gamma - \gamma'\big],
\end{aligned}$$

where $\gamma = E_j^t(B, A, a) = E_j^t(B, B, b)$, $\gamma' = E_j^t(B, A, b) = E_j^t(B, B, a)$ (this is verified in Lemma S1.2 in the proof of Proposition 1 in the Supplementary file). That is, the second expert will recommend truthfully if her chance of being right is higher than that of being wrong, i.e., $\Pr(a \mid \beta, \alpha, \xi) \geq 1/2$. The term $[\gamma - \gamma']$, which is the gain in one's perceived ability from being an accurate predictor over being inaccurate, is the <u>same</u> whether the revealed state is a or b and thus drops out. In our terminology, this means that there is no conformity bias. The experts are now evaluated by the accuracy of their individual

[25] As we already know, under transparency if the first expert recommends A the only continuation equilibrium possible is that of babbling by the second expert. And under secrecy, the first expert recommending A makes the second expert's recommendation inconsequential for D's decision.

recommendations, so there is no collective blame or benefit-of-doubt, i.e., no conformity bias.

In contrast, under secrecy a similar payoff comparison makes truthful recommendation optimal if (see Proposition 3 proof):

$$\Pr(a|s_i = \beta, s_j = \alpha, \xi)\left[x' - y''\right] \geq \Pr(b|s_i = \beta, s_j = \alpha, \xi)\left[x'' - y'\right]. \tag{19}$$

Here due to conformity bias (i.e., $\left[x' - y''\right] > \left[x'' - y'\right]$), even if the state a is less likely the low-ability expert j chooses to recommend decision A as she gets a higher payoff. This expands the truthful recommendation range of k beyond $k(\xi)$ to $\bar{k}(\xi)$.

Hence, restricting ourselves to only the class of secrecy equilibria in Proposition 3 which is about signal revelation, we have the following result.

Proposition 4 (Choice of protocol). D *prefers secrecy over transparency.*

Table 1 compares D's payoffs under signal revealing equilibrium of secrecy and the best equilibrium under transparency.

Table 1: D's payoffs – secrecy vs. transparency

Prior\lead bias	$[\xi, k(\xi)]$	$(k(\xi), \bar{k}(\xi)]$	$(\bar{k}(\xi), \lambda]$
small/medium: $\frac{q}{1-q} < r$	secrecy$\equiv$ transp; more signal reveln under secrecy, same decisions	secrecy$\succ$ transp; 2nd expert babbles under transparency	secrecy$\equiv$ transp; 2nd expert babbles under both protocols
large: $\frac{q}{1-q} \geq r$	same as above	empty[a]	empty

[a] Cutoffs are endogenous and vary with q. As a result, some of the k-ranges are empty. See Figure 4.

■ **Equilibria within secrecy**. We now turn to the question of ranking of possible equilibria within secrecy, posed at the end of Section 5.

PROPOSITION 5 (Value of information: signal vs. type). *Consider the secret advice protocol and let* q *be small, i.e.* $\frac{q}{1-q} < \sqrt{r}$.

(i) *For the parameter range* $\{k : k(\xi) \leq k \leq k(\lambda)\} \cap \{k : \xi < k \leq \bar{k}(\xi)\}$*,* D*'s payoff from the partial type revelation equilibrium strictly dominates the payoff from the full signal revelation equilibrium.*

(ii) *For all* $k \in \big(k(\xi), k(\lambda)\big)$*, the payoff under partial type revelation equilibrium strictly dominates the payoff when only the first expert reveals her signal.*

The reason for the payoff dominance in part (i) can be understood as follows. Due to (18) and the fact that $k(\xi) > \xi$, the intersection of the two sets is non-empty. In this intersection both types of equilibria exist. On the left-hand branch of Figure 1 the decisions in the two equilibria differ only for the recommendation sequence (A, B), with the final decision being A in the signal revealing equilibrium whereas the decision is B in the partial type revealing equilibrium. When the decisions differ, D not only learns the true signal of the second expert he also learns that it is coming from a high-ability expert in the partial type revealing equilibrium; this lifts up partial type revelation for D. On the right-hand branch, decisions differ again in only one scenario: when low-ability second expert observes signal α she herds under partial type revelation, triggering decision B, whereas under full signal revelation she would have triggered decision A; given that in signal revealing equilibrium A is triggered by the low-ability second expert's α signal against the first expert's average quality (k) β signal, decisions will be poorer on average. Thus, overall, partial type revelation equilibrium yields higher expected payoff for D. Intuition for the dominance in part (ii) is straightforward.

Based on Propositions 2, 4 and 5 we can make another important observation on the value of secrecy:

COROLLARY 3. *Let* $z = \max\{k(\lambda), \bar{k}(\xi)\} < \lambda$*. Suppose* $q/(1-q) < \sqrt{r}$*, and* $k(\xi) < k \leq z$*. Then the second expert can potentially have an impact on the decision only under the secrecy protocol.*

The statement in Corollary 3 is not vacuous because $k(\xi) < k(\lambda)$ (Proposition 2) and $k(\xi) < \bar{k}(\xi)$ ((18)). In the context of transparent (sequential) debates with heterogenous experts of *known* abilities, Ottaviani and Sorensen (2001) already pointed out why having too good a first expert might render the second expert's opinion meaningless. Our above observation goes well beyond Ottaviani-Sorensen, in answering the broader question of transparency vs. secrecy when the experts' abilities are private information. Also in contrast to Ottaviani-Sorensen's experts, our second expert is of the same expected quality as the first expert.

7 Detailed advice under secrecy

Under secrecy, we saw that partial type revelation was possible. But can *both* experts reveal their entire type, i.e., signal and the precision level? We show that this is possible if experts' message space is enlarged from one dimension (communication of signal only) to two (both signal and ability), while retaining the sequential advice format.[26]

The richer message space may be considered a natural extension of our restricted message game. It allows the experts to convey not only what decisions they view to be appropriate but also lend some weight to their recommendations, if necessary even pointing out their limitations by adding disclaimer riders. Such a procedure would be credible especially when the decision maker can ensure full confidentiality of the experts' self-certification of the quality of recommendations. When governments make political decisions that are of significant importance, the last thing it would want is not look into the discussions of the advisors with a critical outlook – balancing the arguments in favor of or against some actions.

Formally, the experts get to send two messages from $\{\alpha, \beta\} \times \{\xi, \lambda\}$. The first message is the expert's claim to observed signal, to be treated also as the expert-recommended decision (α for decision A and β for decision B); the second message conveys the quality of the recommendation. Thus, each expert now has access to messages with the richness to convey the entire content of information. Under this protocol, the first mover makes all her submission before hearing anything from the other expert.

We consider only truth-telling equilibria, so D treats the experts' recommendations and the precision levels as per submitted reports. Call such an equilibrium a *fully revealing*

[26]Under transparency signal revelation is impeded by herd behavior. So to induce signal revelation one could make the experts move simultaneously. However, ability revelation is never possible under transparency (see footnote 18).

equilibrium. Conditional on the posterior formed on the basis of a profile of reports, D makes the optimal choice of d which is a straightforward derivation; see Table 2. When q is large D chooses B only when both experts report having observed signal β. Since this is similar to the sequential advice game with restricted messages studied in Proposition 2, we focus on the case where q is not large. So let $\frac{q}{1-q} < r$.

Table 2: Detailed recommendation

	Report Profile	d	q large	q not large [a]
1.	$\{(\alpha,\lambda),(\alpha,\lambda)\}$	A		
2.	$\{(\alpha,\lambda),(\alpha,\xi)\}$	A		
3.	$\{(\alpha,\xi),(\alpha,\lambda)\}$	A		
4.	$\{(\alpha,\xi),(\alpha,\xi)\}$	A		
5.	$\{(\alpha,\lambda),(\beta,\xi)\}$	A		
6.	$\{(\alpha,\lambda),(\beta,\lambda)\}$	A		
7.	$\{(\alpha,\xi),(\beta,\xi)\}$	A		
8.	$\{(\alpha,\xi),(\beta,\lambda)\}$		A	B
9.	$\{(\beta,\xi),(\alpha,\lambda)\}$	A		
10.	$\{(\beta,\xi),(\alpha,\xi)\}$	A		
11.	$\{(\beta,\lambda),(\alpha,\lambda)\}$	A		
12.	$\{(\beta,\lambda),(\alpha,\xi)\}$		A	B
13.	$\{(\beta,\xi),(\beta,\xi)\}$	B		
14.	$\{(\beta,\xi),(\beta,\lambda)\}$	B		
15.	$\{(\beta,\lambda),(\beta,\xi)\}$	B		
16.	$\{(\beta,\lambda),(\beta,\lambda)\}$	B		

[a] For [6], [7], [10] and [11], D could have equally chosen $d = B$ for $q = 1/2$. The reported decisions apply to $q \geq 1/2$.

We now turn to O's beliefs. Consider the case where q is not large. Conditional on

(d, ω), O's beliefs are:

$$
\begin{aligned}
\Pr(\lambda \mid A, a) &= \frac{\theta\lambda[1+\theta(1-\lambda)]}{\theta\lambda[1+\theta(1-\lambda)]+(1-\theta)[k+(1-\theta)\xi(1-\xi)]}, \\
\Pr(\lambda \mid A, b) &= \frac{\theta(1-\lambda)[1+\theta\lambda)]}{\theta(1-\lambda)[1+\theta\lambda)]+(1-\theta)[(1-k)+(1-\theta)\xi(1-\xi)]}, \\
\Pr(\lambda \mid B, b) &= \frac{\theta\lambda[(1-\theta)+\theta\lambda]}{\theta\lambda[(1-\theta)+\theta\lambda]+(1-\theta)[(1-\theta)\xi^2+\theta\lambda]}, \\
\Pr(\lambda \mid B, a) &= \frac{\theta(1-\lambda)[(1-\theta)+\theta(1-\lambda)]}{\theta(1-\lambda)[(1-\theta)+\theta(1-\lambda)]+(1-\theta)[(1-\theta)(1-\xi)^2+\theta(1-\lambda)]}.
\end{aligned} \tag{20}
$$

Define

$$
g' = \Pr(\lambda \mid A, a), \quad h'' = \Pr(\lambda \mid B, a), \quad g'' = \Pr(\lambda \mid B, b), \quad h' = \Pr(\lambda \mid A, b). \tag{21}
$$

Let

$$
Q = \max\left\{ \left(\frac{1-\xi}{\xi} \Big/ \frac{\xi}{1-\xi} \right), \left(\frac{\xi}{1-\xi} \Big/ \frac{\lambda}{1-\lambda} \right) \right\}.
$$

The proof of the following Proposition, together with a numerical illustration of the sufficient condition, appears in the Supplementary file.

PROPOSITION 6 (Detailed advice). *Let the recommendation protocol be secrecy, and* $q/(1-q) < r$. *A fully revealing equilibrium exists under detailed recommendation if and only if*

$$
\frac{q}{1-q}(g' - h'') \geq (g'' - h') \geq \frac{q}{1-q} \cdot Q \cdot (g' - h''). \tag{22}
$$

Proposition 6 informs us that for a fully revealing equilibrium to exist we need $g' - h'' \geq 0$ and $g'' - h' \geq 0$ (as $Q < 1$).

■ **Non-congruence of incentives under secrecy.** Under secrecy, since O evaluates the experts' ability through D's decision, it might be argued that the experts and D have common interests. Both would want D's decision to match the state. As a result, the experts would *always* truthfully reveal their types. This intuition, as seen in Proposition 6, is misleading. Below we further elaborate the reasons.

O's beliefs about an expert's ability (and hence the expert's payoff) is a function of D's success (or failure) *as well as* the specific decision chosen by D. Thus, an expert *may* prefer a decision that matches the state with a lower probability ($< \frac{1}{2}$) as long as the expected payoff associated with the decision is relatively large. On the other hand, D's payoff is solely success dependent. Hence, he would prefer the decision that matches the state with a higher probability ($> \frac{1}{2}$). Such perverse incentives, on the part of experts, may rule out fully revealing equilibrium under detailed advice (Proposition 6). The perverse incentives arise due to conformity bias and, as we shall show below, this bias exists even under simultaneous advice.

We will argue that the experts will not always reveal all their information. Suppose the experts move simultaneously and truthfully reveal their two-dimensional types. D's decision is given in Table 2.[27] Let q be large ($\frac{q}{1-q} > r$). Then O's beliefs are as follows:

$$\begin{aligned}
\Pr(\lambda \mid A, a) &= \frac{\theta\lambda+\theta(1-\lambda)k}{k(2-k)}, \\
\Pr(\lambda \mid A, b) &= \frac{\theta(1-\lambda)+\theta\lambda(1-k)}{(1-k)(1+k)}, \\
\Pr(\lambda \mid B, b) &= \frac{\theta\lambda}{k}, \\
\Pr(\lambda \mid B, a) &= \frac{\theta(1-\lambda)}{(1-k)}.
\end{aligned}$$

Consider an expert i. Suppose i gets signal β and let her belief that the state is b be denoted by h. If she recommends A, then from Table 2 we have that $d = A$. If she recommends B, then $d = B$ only if the other expert j also recommends B. Let i believe that j recommends A with probability w (which, due to our supposition, is strictly less than 1). For i to truthfully reveal her type, the following incentive constraint has to be satisfied:

$$\begin{aligned}
&h(wE^s(t_e|A,b) + (1-w)E^s(t_e|B,b)) + (1-h)(wE^s(t_e|A,a) + (1-w)E^s(t_e|B,a)) \\
&\geq hE^s(t_e|A,b) + (1-h)E^s(t_e|A,a). \qquad (23)
\end{aligned}$$

The right-hand side of the inequality gives i's payoff when she recommends A. Note that in this case, irrespective of j's recommendation, $d = A$. On the left-hand side we have i's payoff when she recommends B. With probability w the decision is A because j recommends A. With probability $(1-w)$, j recommends B and so $d = B$. Hence, when the state is b, i's expected payoff is $wE^s(t_e|A,b) + (1-w)E^s(t_e|B,b)$ and when the state is a, i's expected payoff is $wE^s(t_e|A,a) + (1-w)E^s(t_e|B,a)$. The left-hand side can now be derived by recalling that h is i's belief that the state is b. We can simplify (23) to:

$$[hE^s(t_e|B,b) + (1-h)E^s(t_e|B,a)] \geq [hE^s(t_e|A,b) + (1-h)E^s(t_e|A,a)]. \qquad (24)$$

[27] Table 2 holds for both simultaneous and sequential advice.

Using the fact that $E^s(t_e|.,.) = \Pr(\lambda \mid .,.)\lambda + (1 - \Pr(\lambda \mid .,.))\xi$, or $E^s(t_e|.,.) = \Pr(\lambda \mid .,.)(\lambda - \xi) + \xi$, we can write (24) as

$$h\frac{\theta\lambda}{k} + (1-h)\frac{\theta(1-\lambda)}{(1-k)} \geq h\frac{\theta(1-\lambda)+\theta\lambda(1-k)}{(1-k)(1+k)} + (1-h)\frac{\theta\lambda+\theta(1-\lambda)k}{k(2-k)}$$

$$\text{or,} \quad \frac{h}{1-h} \geq \frac{1+k}{2-k}. \tag{25}$$

Recall that i's precise beliefs about the state depend on her type. When i's type is ξ, and substituting for the appropriate value of h, condition (25) becomes:

$$\frac{\xi}{1-\xi} \geq \left(\frac{1+k}{2-k}\right)\frac{q}{1-q}. \tag{26}$$

Hence, as $1+k > 2-k$, (26) is not satisfied when:

$$\left(\frac{1+k}{2-k}\right)\frac{q}{1-q} > \frac{\xi}{1-\xi} > \frac{q}{1-q}. \tag{27}$$

That is, (26) is not satisfied when ξ is small. Using (16) as the definition of conformity bias, we can write (27) as

$$c \cdot \frac{q}{1-q} > \frac{\xi}{1-\xi} > \frac{q}{1-q}. \tag{28}$$

Hence, the possibility of full revelation decreases as conformity bias increases. Or, the incentives of the experts and D are not aligned due to conformity bias.[28] ||

8 Some final remarks

We conclude by noting the following points:

1. The number of experts is limited to two. While tractability is surely a consideration for this restriction, many decisions often involve a small number of experts. Much of the economic insight developed with two experts should remain valid for more than two experts. Under transparency herding is a pervasive force and that should be the case

[28]The following example illustrates the non-alignment of incentives result nicely. Let $q = 0.6$, ξ is marginally higher than q so that for this example $\xi \approx q$, and $\lambda = 0.65$. So $(\frac{q}{1-q})^2 = (\frac{0.6}{0.4})^2 = 2.25$ and $\frac{\lambda}{1-\lambda} = \frac{0.65}{1-0.65} \approx 1.857$, thus $(\frac{q}{1-q})^2 > \frac{\lambda}{1-\lambda}$ so that $\frac{q}{1-q} > r$ (with $\xi \approx q$). Also, assume $\theta = 1/2$, so $k \approx \frac{1}{2} * 0.65 + \frac{1}{2} * 0.6 = 0.625$. With $c \approx \frac{1+0.625}{2-0.625} = \frac{1.625}{1.375} \approx 1.1818$ and ξ marginally exceeding q, condition (28) is satisfied.

in our model with n experts, just like we have shown for two experts. Analysis of the secrecy game with more than two experts will encounter obvious technical hurdles. However, incentives for truthful recommendation (i.e., signal revelation) due to congruity of interests in building collective reputation remains in place.

2. Increasing the number of messages under transparency will not lead to better outcomes for D. This is because a message which reveals the high ability of an expert will be mimicked by the low-ability expert. It may, however, lead to better outcomes under secrecy.

3. The analysis has been restricted to only pure strategies. Consideration of mixed strategies will increase the complexity of analysis.

4. Possible equilibria under secrecy reported in Propositions 2 and 3 are not exhaustive. Despite this, using a plausible criterion of ranking between protocols (Definition 4), we are able to argue that secrecy should be preferred over transparency. We are also able to provide a strict ranking between partial type revelation equilibrium and full signal revelation equilibrium.

5. While detailed advice can give rise to full revelation (of types), it may also fail to transmit the desired information. Moreover, detailed advice may not always seem sensible as explained in the Introduction. In any case, any submission by the experts about the quality of their recommendations can be ignored by D and anticipating this response experts will babble. In such cases, an analysis of constrained, simple binary messages predicts optimality of secret advice that has featured prominently in the debate of secrecy vs. publicity of advice.

The entire edited volume by Elster (2015) has debated on the issue of *secrecy vs. publicity in votes and debates*. Important government and political decisions taken through votes in the Congress or Parliaments, the Fed or the Central Banks and many other arenas can impact on the lives of many ordinary citizens. While in reality, transparency is often advocated to protect the public's interests, especially when experts have conflicts of interest, this work points towards the merit of secret consultations and deliberations when experts are unbiased and focused solely on their reputation concerns. It's a moot point how to finely balance the so-called accountability and the merit of economic efficiency. Hopefully our work contributes to this debate positively, when recent trends in many countries with regard to public decision making favor more open discussions.

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A Appendix

A.1 Section 3 materials

The joint distribution of signal and state, given t_e, is as follows:

Table A.1: Joint distribution of signal and state

	a	b
α	qt_e	$(1-q)(1-t_e)$
β	$q(1-t_e)$	$(1-q)t_e$

An expert infers the state from her signal using Bayes' rule, e.g., $\Pr(\omega = a \mid s_e = \alpha, t_e) = \frac{qt_e}{qt_e+(1-q)(1-t_e)}$. We assume that the distribution of the experts' signals conditional on the state are independent. Below we report the joint distribution over state, signals and expert abilities. Given our assumption on independence (of signals and abilities), we have (we divide the distribution into two tables, and for only the following tables let $q' = (1-q)$):

Table A.2: Joint distribution of state, signals and abilities

	$t_i = \lambda, t_j = \lambda$	$t_i = \lambda, t_j = \xi$	$t_i = \xi, t_j = \lambda$	$t_i = \xi, t_j = \xi$
a, α, α	$q\theta^2\lambda^2$	$q\theta(1-\theta)\lambda\xi$	$q\theta(1-\theta)\lambda\xi$	$q(1-\theta)^2\xi^2$
a, α, β	$q\theta^2\lambda(1-\lambda)$	$q\theta(1-\theta)\lambda(1-\xi)$	$q\theta(1-\theta)\xi(1-\lambda)$	$q(1-\theta)^2\xi(1-\xi)$
a, β, α	$q\theta^2(1-\lambda)\lambda$	$q\theta(1-\theta)(1-\lambda)\xi$	$q\theta(1-\theta)(1-\xi)\lambda$	$q(1-\theta)^2(1-\xi)\xi$
a, β, β	$q\theta^2(1-\lambda)^2$	$q\theta(1-\theta)(1-\lambda)(1-\xi)$	$q\theta(1-\theta)(1-\xi)(1-\lambda)$	$q(1-\theta)^2(1-\xi)^2$

Table A.3: Joint distribution of state, signals and abilities

	$t_i = \lambda, t_j = \lambda$	$t_i = \lambda, t_j = \xi$	$t_i = \xi, t_j = \lambda$	$t_i = \xi, t_j = \xi$
b, α, α	$q'\theta^2(1-\lambda)^2$	$q'\theta(1-\theta)(1-\lambda)(1-\xi)$	$q'\theta(1-\theta)(1-\xi)(1-\lambda)$	$q'(1-\theta)^2(1-\xi)^2$
b, α, β	$q'\theta^2(1-\lambda)\lambda$	$q'\theta(1-\theta)(1-\lambda)\xi$	$q'\theta(1-\theta)(1-\xi)\lambda$	$q'(1-\theta)^2(1-\xi)\xi$
b, β, α	$q'\theta^2\lambda(1-\lambda)$	$q'\theta(1-\theta)\lambda(1-\xi)$	$q'\theta(1-\theta)\xi(1-\lambda)$	$q'(1-\theta)^2\xi(1-\xi)$
b, β, β	$q'\theta^2\lambda^2$	$q'\theta(1-\theta)\lambda\xi$	$q'\theta(1-\theta)\lambda\xi$	$q'(1-\theta)^2\xi^2$

The beliefs of expert i who moves first, conditional on her ability and signal, are given by $\Pr(\omega \mid s_i, t_i)$ as follows (refer Table A.1):

$$
\begin{aligned}
\Pr(a \mid \alpha, t_i) &= \tfrac{qt_i}{qt_i+(1-q)(1-t_i)} && > \tfrac{1}{2}, \\
\Pr(b \mid \alpha, t_i) &= \tfrac{(1-q)(1-t_i)}{qt_i+(1-q)(1-t_i)} && < \tfrac{1}{2}, \\
\Pr(a \mid \beta, t_i) &= \tfrac{q(1-t_i)}{q(1-t_i)+(1-q)t_i} && < \tfrac{1}{2}, \\
\Pr(b \mid \beta, t_i) &= \tfrac{(1-q)t_i}{q(1-t_i)+(1-q)t_i} && > \tfrac{1}{2}\,.
\end{aligned}
\tag{A.1}
$$

The inequalities follow from Assumption 1 and Fact 1. Note that despite the prior bias in favor of state a ($q > \frac{1}{2}$), signal β reverses this belief for either ability of expert.

Next consider expert j who moves second. Suppose she were to deduce the first expert's signal, but not her ability, from the observed recommendation. She would then update her beliefs conditional on (s_i, s_j, t_j), as follows (Assumption 1 and Fact 1 are used to establish the inequalities):

$$
\begin{aligned}
\Pr(a \mid \alpha, \alpha, t_j) &= \tfrac{qt_jk}{qt_jk+(1-q)(1-t_j)(1-k)} && > \tfrac{1}{2}, \\
\Pr(b \mid \alpha, \alpha, t_j) &= \tfrac{(1-q)(1-t_j)(1-k)}{qt_jk+(1-q)(1-t_j)(1-k)} && < \tfrac{1}{2}, \\
\Pr(a \mid \beta, \beta, t_j) &= \tfrac{q(1-t_j)(1-k)}{(1-q)t_jk+q(1-t_j)(1-k)} && < \tfrac{1}{2}, \\
\Pr(b \mid \beta, \beta, t_j) &= \tfrac{(1-q)t_jk}{(1-q)t_jk+q(1-t_j)(1-k)} && > \tfrac{1}{2}.
\end{aligned}
\tag{A.2}
$$

These four probabilities indicate that when the second expert's signal matches that of the first, then irrespective of ability, her posterior on state a (b) is higher than that on b (a) when she sees signal α (β).

When the first expert's signal is deduced as β and the second expert of ability λ receives signal α, we have:

$$
\begin{aligned}
\Pr(a \mid \beta, \alpha, \lambda) &= \tfrac{q\lambda(1-k)}{q\lambda(1-k)+(1-q)(1-\lambda)k} && > \tfrac{1}{2}, \\
\Pr(b \mid \beta, \alpha, \lambda) &= \tfrac{(1-q)(1-\lambda)k}{q\lambda(1-k)+(1-q)(1-\lambda)k} && < \tfrac{1}{2}.
\end{aligned}
\tag{A.3}
$$

When the first expert's signal is deduced as α and the second expert of ability ξ receives signal β, we have:

$$\begin{aligned}
\Pr(a \mid \alpha, \beta, \xi) &= \tfrac{q(1-\xi)k}{q(1-\xi)k+(1-q)\xi(1-k)} > \tfrac{1}{2}, \\
\Pr(b \mid \alpha, \beta, \xi) &= \tfrac{(1-q)\xi(1-k)}{q(1-\xi)k+(1-q)\xi(1-k)} < \tfrac{1}{2}.
\end{aligned} \tag{A.4}$$

A.2 List of strategies (relevant for Section 4 analysis)

$\mathbf{V}_e$ can be partitioned into the following class of strategies:

Partial type revelation. Strategies reveal the expert's ability only if she were to get signal s but not $s' \neq s$: $\mathbf{V}_e^{st} = \{v \mid v \in \mathbf{V}_i;\ \#A(v) = 1 \text{ or } \#B(v) = 1\}$.[29]

Type revealing. Strategies reveal the expert's ability: $\mathbf{V}_e^{t} = \{(A, B, A, B), (B, A, B, A)\}$.

Contrarian recommendation. Experts of both abilities recommend different from their signal: $\mathbf{V}_e^{c} = \{(B, B, A, A)\}$.

Revelation-Contrarian. Experts of only one ability recommend their signal while the other ability recommend contrarian: $\mathbf{V}_e^{sc} = \{(A, B, B, A), (B, A, A, B)\}$.

Truthful recommendation. $\mathbf{V}_e^{s} = \{(A, A, B, B)\}$.

Babbling. An expert's recommendation is completely uninformative: $\mathbf{V}_e^{b} = \{(A, A, A, A), (B, B, B, B)\}$.

A.3 The proofs

Proof of Lemma 1. Note that

$$k \leq k(\xi) \quad \text{if and only if} \quad \frac{\xi}{1-\xi} \geq \frac{k}{1-k}\frac{1-q}{q},$$

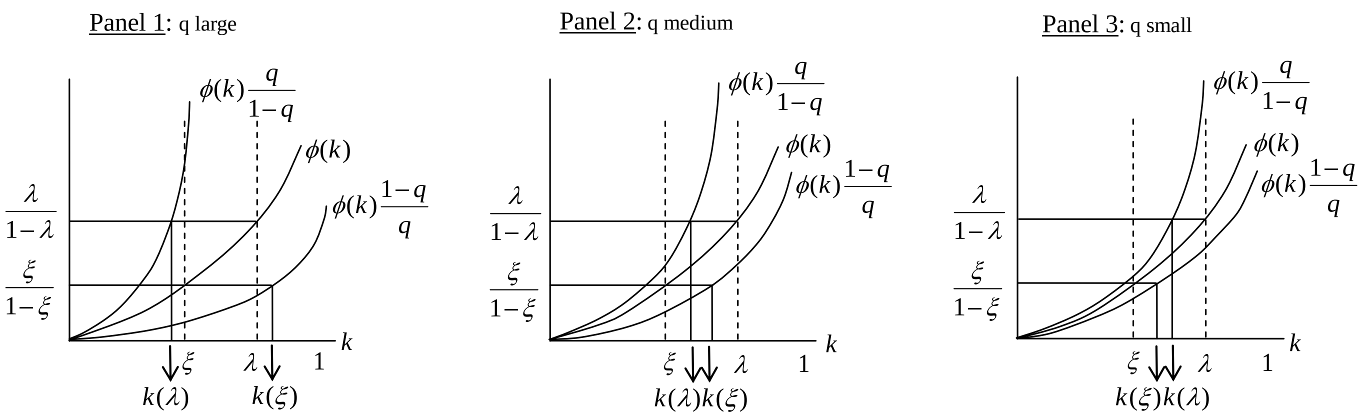
and

$$k \leq k(\lambda) \quad \text{if and only if} \quad \frac{\lambda}{1-\lambda} \geq \frac{k}{1-k}\frac{q}{1-q}.$$

[29] The cardinality of $\mathbf{V}_e^{st}$ is eight.

Now let $\phi(k) = \frac{k}{1-k}$. Since $\frac{q}{1-q} > 1$, in Figure 4 the graph of $\frac{q}{1-q}\phi(k)$ ($\frac{1-q}{q}\phi(k)$) lies above (below) $\phi(k)$.[30] Now (i) follows from Panel 1, (ii) from Panel 2, and (iii) from Panel 3 of Figure 4. ■

Figure 4: Partitioning k & q



Proof of Proposition 1. A long, relatively straightforward proof is included in the Supplementary file.

Proof of Proposition 2. When $q/(1-q) < \sqrt{r}$, we have, from part (iii) of Lemma 1, $k(\xi) \leq k \leq k(\lambda)$. This is equivalent to (see Panel 3 of Figure 4):

$$\text{(A.5)} \qquad \frac{\xi}{1-\xi}\frac{q}{1-q} \leq \frac{k}{1-k} \leq \frac{1-q}{q}\frac{\lambda}{1-\lambda}\,.$$

D's beliefs for the proposed strategies would be as follows, using Tables A.2 and A.3 (the tuple (AB) etc. are ordered pairs where the first coordinate denotes the first expert's advice):

$$\text{(A.6)} \qquad \begin{aligned} \Pr(a \mid AB) &= \tfrac{q\theta(1-\lambda)k}{q\theta(1-\lambda)k+(1-q)\theta\lambda(1-k)} \leq \tfrac{1}{2}\,, \\ \Pr(a \mid AA) &= \tfrac{qk[k+(1-\theta)(1-\xi)]}{qk[k+(1-\theta)(1-\xi)]+(1-q)(1-k)[1-k+(1-\theta)\xi]} > \tfrac{1}{2}\,, \\ \Pr(a \mid BA) &= \tfrac{q\theta\lambda(1-k)}{q\theta\lambda(1-k)+(1-q)\theta(1-\lambda)k} > \tfrac{1}{2}\,, \\ \Pr(a \mid BB) &= \tfrac{q(1-k)[1-k+(1-\theta)\xi]}{q(1-k)[1-k+(1-\theta)\xi]+(1-q)k[k+(1-\theta)(1-\xi)]} < \tfrac{1}{2}. \end{aligned}$$

[30]Keeping ξ and λ constant, k increases from ξ to λ as θ varies from 0 to 1. The function $\phi(k)$ is increasing and convex with $\phi(0) = 0$ and $\lim_{k\to 1}\phi(k) = \infty$. Therefore, $k(\xi)$ and $k(\lambda)$ exist such that $\frac{\xi}{1-\xi} = \phi(k(\xi))\frac{1-q}{q}$ and $\frac{\lambda}{1-\lambda} = \phi(k(\lambda))\frac{q}{1-q}$.

The first and third inequalities follow given the RHS inequality of (A.5), and the second and fourth inequalities follow given the LHS inequality of (A.5).

Let $d(v_i, v_j)$ be D's decision. Given D's beliefs (A.6), we have

$$d(A, B) = B, \quad d(A, A) = A, \quad d(B, A) = A, \quad d(B, B) = B.$$

Thus, if D's decision is A, then O knows that the recommendation profile is either (AA) or (BA). Conditional on observing D's decision d and state ω, O's beliefs about the experts' abilities are as follows:

$$\text{(A.7)} \qquad \begin{aligned} \Pr(t=\lambda \mid A, a) &= \tfrac{\theta\lambda}{\theta\lambda+(1-\theta)k}, & \Pr(t=\lambda \mid A, b) &= \tfrac{\theta(1-\lambda)}{\theta(1-\lambda)+(1-\theta)(1-k)}, \\ \Pr(t=\lambda \mid B, b) &= \tfrac{\theta\lambda}{\theta\lambda+(1-\theta)k}, & \Pr(t=\lambda \mid B, a) &= \tfrac{\theta(1-\lambda)}{\theta(1-\lambda)+(1-\theta)(1-k)}, \end{aligned}$$

where $t = \lambda$ is the event of a randomly chosen expert being of ability λ.[31] Let $\rho = \frac{\theta\lambda}{\theta\lambda+(1-\theta)k}$, $\rho' = \frac{\theta(1-\lambda)}{\theta(1-\lambda)+(1-\theta)(1-k)}$.

Let us consider the second expert's payoff:

$$\Pi_j^s(v_i, v_j, s_j, t_j) = \Pr(a|v_i, s_j, t_j)E_j^s(v_i, v_j, d(v_i, v_j), a) + \Pr(b|v_i, s_j, t_j)E_j^s(v_i, v_j, d(v_i, v_j), b),$$

where

$$\text{(A.8)} \qquad \begin{aligned} E_j^s(A, A, A, a) &= \rho(\lambda-\xi)+\xi = E_j^s(B, A, A, a), \\ E_j^s(A, A, A, b) &= \rho'(\lambda-\xi)+\xi = E_j^s(B, A, A, b), \\ E_j^s(B, B, B, b) &= \rho(\lambda-\xi)+\xi = E_j^s(A, B, B, b), \\ E_j^s(B, B, B, a) &= \rho'(\lambda-\xi)+\xi = E_j^s(A, B, B, a). \end{aligned}$$

So, consider the second expert of ability t_j with signal s_j who sees a recommendation A. Then,

[31] To illustrate how the beliefs are derived, let us consider $\Pr\left(t = \lambda \mid A, a\right)$. Note that $d = A$ if and only if the recommendation profile is (AA) or (BA). Given $\omega = a$, the probability of the event (AA) is $k[k + (1-\theta)(1-\xi)]$ and that of (BA) is $(1-k)\theta\lambda$, so $\Pr\left(d = A \mid a\right) = \theta\lambda + (1-\theta)k$.

The probability of the event that the recommendation profile is (AA) or (BA) and a randomly selected expert is of ability λ, given $\omega = a$, is $\Pr\left((AA\cup BA)\cap\lambda\lambda \mid a\right)+\frac{1}{2}\left[\Pr\left((AA\cup BA)\cap\lambda\xi \mid a\right)+\Pr\left((AA\cup BA)\cap\xi\lambda \mid a\right)\right] = \left[\theta\lambda\,\theta\lambda+\theta(1-\lambda)\,\theta\lambda\right]+\frac{1}{2}\left[\left\{\theta\lambda\,(1-\theta)\xi+\theta\lambda\,(1-\theta)(1-\xi)\right\}+\left\{(1-\theta)\xi\,\theta\lambda+(1-\theta)(1-\xi)\,\theta\lambda\right\}\right] = \theta\lambda$. So, $\Pr\left(t=\lambda \mid A, a\right) = \frac{\theta\lambda}{\theta\lambda+(1-\theta)k}$. The other beliefs follow similarly.

$$\Pi_j^s(A, A, s_j, t_j) = [\Pr(a|\alpha, s_j, t_j)\rho + \Pr(b|\alpha, s_j, t_j)\rho'](\lambda - \xi) + \xi,$$
$$\Pi_j^s(A, B, s_j, t_j) = [\Pr(a|\alpha, s_j, t_j)\rho' + \Pr(b|\alpha, s_j, t_j)\rho](\lambda - \xi) + \xi.$$

Since $\rho > \rho'$ and $\Pr(a|\alpha, \alpha, t_j) > 1/2$ (by (A.2)), following a recommendation of A it is optimal for both abilities of the second expert to recommend A, when she gets signal α. Due to (A.4), $\Pr(a|\alpha, \beta, \xi) > 1/2$. So, it is optimal for the second expert of ability ξ who gets signal β to herd and recommend A. Due to (6) and the condition that $\frac{\lambda}{1-\lambda} \geq \frac{q}{1-q}\frac{k}{1-k}$, we have $\Pr(b|\alpha, \beta, \lambda) > 1/2$. So, following an A-recommendation it is optimal for the second expert of ability λ, who gets signal β, to truthfully recommend B.

Now consider the second expert of ability t_j with signal s_j who sees a recommendation B. Then,

$$\Pi_j^s(B, B, s_j, t_j) = [\Pr(a|\beta, s_j, t_j)\rho' + \Pr(b|\beta, s_j, t_j)\rho](\lambda - \xi) + \xi,$$
$$\Pi_j^s(B, A, s_j, t_j) = [\Pr(a|\beta, s_j, t_j)\rho + \Pr(b|\beta, s_j, t_j)\rho'](\lambda - \xi) + \xi.$$

Again due to (A.2), $\Pr(b|\beta, \beta, t_j) > 1/2$. So, following a recommendation of B, it is optimal for the second expert to recommend B when she gets signal β. Due to (A.3), following a recommendation of B, it is optimal for the second expert to truthfully recommend A when she is of ability λ and gets signal α. Finally, consider the second expert of ability ξ who gets a signal α. From (5), she will herd and recommend B if and only if

$$\frac{(1-q)(1-\xi)k}{q\xi(1-k) + (1-q)(1-\xi)k} \geq \frac{1}{2} \quad \Leftrightarrow \quad \frac{k}{1-k} \geq \frac{q}{1-q}\frac{\xi}{1-\xi},$$

which is satisfied given (A.5).

Let us now consider the first expert and suppose she recommends A. Given the second expert's recommendation strategy, the first expert knows that if the second expert were to get signal α, then irrespective of her ability she would recommend A; if she were to get signal β and her ability were ξ she would recommend A, and if her ability were λ she would recommend B. Hence, if $\omega = a$, then the probability of the second expert recommending A would be $k + (1-\theta)(1-\xi)$, and of recommending B would be $\theta(1-\lambda)$. And if $\omega = b$, then the probability of the second expert recommending A would be $(1 - k) + (1-\theta)\xi$ and of recommending B would be $\theta\lambda$. Hence, the first expert's expected payoff from recommending A is:

$$\Pi_i^s(A,s_i,t_i) = \Pr(a|s_i,t_i)\left\{[k+(1-\theta)(1-\xi)]\rho+\theta(1-\lambda)\rho'\right\}+\Pr(b|s_i,t_i)\left\{[(1-k)+(1-\theta)\xi]\rho'+\theta\lambda\rho\right\}.$$

Similarly, if the first expert were to recommend B, then conditional on $\omega = a$ the second expert would recommend A with probability $\theta\lambda$ and recommend B with probability $(1-k)+(1-\theta)\xi$; conditional on $\omega = b$ the second expert would recommend A with probability $\theta(1-\lambda)$ and B with probability $k+(1-\theta)(1-\xi)$. Thus,

$$\Pi_i^s(B,s_i,t_i) = \Pr(a|s_i,t_i)\left\{\theta\lambda\rho+[(1-k)+(1-\theta)\xi]\rho'\right\}+\Pr(b|s_i,t_i)\left\{\theta(1-\lambda)\rho'+[k+(1-\theta)(1-\xi)]\rho\right\}.$$

Hence, $\Pi_i^s(A,s_i,t_i) - \Pi_i^s(B,s_i,t_i) = \Pr(a|s_i,t_i)\{(1-\theta)(\rho-\rho')\} - \Pr(b|s_i,t_i)\{(1-\theta)(\rho-\rho')\}$. Therefore, as $\rho-\rho'>0$ and $\theta<1$, we have

$$\Pi_i^s(A,s_i,t_i) \geq \Pi_i^s(B,s_i,t_i) \quad \text{if and only if} \quad \Pr(a|s_i,t_i) \geq \Pr(b|s_i,t_i).$$

Since $\Pr(a|\alpha,t_i) > \Pr(b|\alpha,t_i)$ and $\Pr(b|\beta,t_i) > \Pr(a|\beta,t_i)$ for any $t_i \in \{\xi,\lambda\}$, the first expert recommends A when she gets signal α and recommends B when she gets signal β.

Thus, under the stated condition (A.5), the proposed equilibrium will exist. It follows from Lemma 1 that for *small* q, condition (A.5) is met. ■

Proof of Proposition 3. (i) For the first part of the proof we shall assume that the experts recommend their signals in equilibrium and then show that such an equilibrium indeed exists under the stated parameter restrictions. Recall, given that the experts recommend their signals, D selects B only if two recommendations are in favor of B; otherwise D selects A (Lemma 2). Therefore when $d = A$, O knows that one of three pairs of signals, (α,α), (α,β), (β,α), could have resulted. When $d = B$, O knows that (β,β) resulted. O's relevant posteriors are then calculated, using Tables A.2 and A.3, as follows:[32]

$$\begin{aligned}
\Pr(t=\lambda \mid A,a) &= \frac{\theta[\lambda+(1-\lambda)(\theta\lambda+(1-\theta)\xi)]}{\theta[\lambda+(1-\lambda)(\theta\lambda+(1-\theta)\xi)]+(1-\theta)[\xi+(1-\xi)(\theta\lambda+(1-\theta)\xi)]} = \frac{\theta[\lambda+(1-\lambda)k]}{k(2-k)},\\
\Pr(t=\lambda \mid A,b) &= \frac{\theta[(1-\lambda)+\lambda(1-\theta\lambda-(1-\theta)\xi)]}{\theta[(1-\lambda)+\lambda(1-\theta\lambda-(1-\theta)\xi)]+(1-\theta)[(1-\xi)+\xi(1-\theta\lambda-(1-\theta)\xi)]} = \frac{\theta(1-\lambda k)}{1-k^2},\\
\Pr(t=\lambda \mid B,b) &= \frac{\theta\lambda}{\theta\lambda+(1-\theta)\xi} = \frac{\theta\lambda}{k},\\
\Pr(t=\lambda \mid B,a) &= \frac{\theta(1-\lambda)}{\theta(1-\lambda)+(1-\theta)(1-\xi)} = \frac{\theta(1-\lambda)}{1-k}.
\end{aligned}$$

[32]To alert the reader, here the first conditioning variable is the decision d.

Also, $\Pr(t = \xi \mid A, a) = 1 - \Pr(t = \lambda \mid A, a)$, and likewise for the remaining posteriors.

Define

$$\begin{aligned} x' &= \Pr(t = \lambda \mid A, a)\lambda + (1 - \Pr(t = \lambda \mid A, a))\xi, \\ y' &= \Pr(t = \lambda \mid A, b)\lambda + (1 - \Pr(t = \lambda \mid A, b))\xi, \\ x'' &= \Pr(t = \lambda \mid B, b)\lambda + (1 - \Pr(t = \lambda \mid B, b))\xi, \\ y'' &= \Pr(t = \lambda \mid B, a)\lambda + (1 - \Pr(t = \lambda \mid B, a))\xi. \end{aligned}$$

Now, these are O's expectations of expert abilities conditional on D's decision and the observed state. Note that

$$\begin{aligned} x' - y'' = [\Pr(\lambda \mid A, a) - \Pr(\lambda \mid B, a)](\lambda - \xi) = \tfrac{\lambda(1-k)-(1-\lambda)k}{k(1-k)(2-k)}(\lambda - \xi), \\ x'' - y' = [\Pr(\lambda \mid B, b) - \Pr(\lambda \mid A, b)](\lambda - \xi) = \tfrac{\lambda(1-k)-(1-\lambda)k}{k(1-k)(1+k)}(\lambda - \xi). \end{aligned}$$

As $k > \frac{1}{2}$, we have $k(1-k)(2-k) < k(1-k)(1+k)$ and hence:

$$x' - y'' > x'' - y' > 0.$$

Also,

$$\frac{x' - y''}{x'' - y'} = \frac{1+k}{2-k} > 1.$$

Let the first expert i, reveal her signal. Consider the second expert j. If she sees a first period recommendation of A then she knows that $d = A$, so she is indifferent between recommending A and recommending B. Thus, recommending her signal is a best response for j. If she sees a first period recommendation of B, then we have already seen in the main text that j reveals her signal if and only if,

$$k \leq \bar{k}(\xi).$$

In the main text we had also shown that $k(\xi) < \bar{k}(\xi)$. Furthermore, due to (8) through (10), $\xi < k(\xi)$. So, $\xi < \bar{k}(\xi)$. From now on suppose $\xi \leq k \leq \bar{k}(\xi)$.

We now need to show that the first expert i reveals her signal when $\xi \leq k \leq \bar{k}(\xi)$. Let the second expert j recommend her signal. Let i observe signal α. If she recommends A then irrespective of what the second expert recommends, $d = A$. So expert i receives a payoff:[33]

$$\Pi_i^s(A,\alpha,t_i) = \Pr(a|\alpha,t_i)x' + \Pr(b|\alpha,t_i)y' = \frac{qt_i}{H(t_i)}x' + \frac{(1-q)(1-t_i)}{H(t_i)}y',$$

where $H(t_i) \equiv qt_i + (1-q)(1-t_i)$.

If she recommends B then d depends on whether j observes α or β. This payoff can be written as:

$$\begin{aligned}
\Pi_i^s(B,\alpha,t_i) = \Pr(a|\alpha,t_i)\big[&\sum_{t_j=\lambda,\xi}\Pr(s_j=\alpha|a,t_j)\cdot\Pr(t_j)x' + \sum_{t_j=\lambda,\xi}\Pr(s_j=\beta|a,t_j)\cdot\Pr(t_j)y''\big]\\
&+\Pr(b|\alpha,t_i)\big[\sum_{t_j=\lambda,\xi}\Pr(s_j=\alpha|b,t_j)\cdot\Pr(t_j)y' + \sum_{t_j=\lambda,\xi}\Pr(s_j=\beta|b,t_j)\cdot\Pr(t_j)x''\big]\\
&=\Pr(a|\alpha,t_i)\big[\{\Pr(\alpha|a,\lambda)\theta+\Pr(\alpha|a,\xi)(1-\theta)\}x' + \{\Pr(\beta|a,\lambda)\theta+\Pr(\beta|a,\xi)(1-\theta)\}y''\big]\\
&+\Pr(b|\alpha,t_i)\big[\{\Pr(\alpha|b,\lambda)\theta+\Pr(\alpha|b,\xi)(1-\theta)\}y' + \{\Pr(\beta|b,\lambda)\theta+\Pr(\beta|b,\xi)(1-\theta)\}x''\big]\\
&=\Pr(a|\alpha,t_i)\big[\{\lambda\theta+\xi(1-\theta)\}x' + \{(1-\lambda)\theta+(1-\xi)(1-\theta)\}y''\big]\\
&+\Pr(b|\alpha,t_i)\big[\{(1-\lambda)\theta+(1-\xi)(1-\theta)\}y' + \{\lambda\theta+\xi(1-\theta)\}x''\big]\\
&=\frac{qt_i}{H(t_i)}\big[kx'+(1-k)y''\big] + \frac{(1-q)(1-t_i)}{H(t_i)}\big[kx''+(1-k)y'\big].
\end{aligned}$$

Substituting terms and with some algebra we obtain:

$$\Pi_i^s(A,\alpha,t_i) \geq \Pi_i^s(B,\alpha,t_i) \Leftrightarrow qt_i\big[(1-k)(x'-y'')\big] \geq (1-q)(1-t_i)\big[k(x''-y')\big]$$

$$\text{(A.9)}\quad \text{or,}\qquad \frac{t_i}{1-t_i} \geq \frac{k}{1-k}\frac{1-q}{q}\frac{x''-y'}{x'-y''}.$$

Let i observe signal β. Then,

$$\begin{aligned}
\Pi_i^s(B,\beta,t_i) \;=\;& \Pr(a|s_i=\beta,t_i)\big[\sum_{t_j=\lambda,\xi}\Pr(s_j=\alpha|a,t_j)\cdot\Pr(t_j)x' + \sum_{t_j=\lambda,\xi}\Pr(s_j=\beta|a,t_j)\cdot\Pr(t_j)y''\big]\\
&+\Pr(b|s_i=\beta,t_i)\big[\sum_{t_j=\lambda,\xi}\Pr(s_j=\alpha|b,t_j)\cdot\Pr(t_j)y' + \sum_{t_j=\lambda,\xi}\Pr(s_j=\beta|b,t_j)\cdot\Pr(t_j)x''\big]\\
=\;& \Pr(a|\beta,t_i)\big[\{\Pr(\alpha|a,\lambda)\theta+\Pr(\alpha|a,\xi)(1-\theta)\}x' + \{\Pr(\beta|a,\lambda)\theta+\Pr(\beta|a,\xi)(1-\theta)\}y''\big]\\
&+\Pr(b|\beta,t_i)\big[\{\Pr(\alpha|b,\lambda)\theta+\Pr(\alpha|b,\xi)(1-\theta)\}y' + \{\Pr(\beta|b,\lambda)\theta+\Pr(\beta|b,\xi)(1-\theta)\}x''\big]
\end{aligned}$$

[33] $\Pr(a|\alpha,t_i) = \frac{\Pr(\alpha|a,t_i)\cdot\Pr(a,t_i)}{\Pr(\alpha|a,t_i)\cdot\Pr(a,t_i)+\Pr(\alpha|b,t_i)\cdot\Pr(b,t_i)} = \frac{qt_i\cdot\Pr(t_i)}{qt_i\cdot\Pr(t_i)+(1-q)(1-t_i)\cdot\Pr(t_i)} = \frac{qt_i}{qt_i+(1-q)(1-t_i)}$.

$$
\begin{aligned}
&= \Pr(a|\beta,t_i)\big[\{\lambda\theta+\xi(1-\theta)\}x'+\{(1-\lambda)\theta+(1-\xi)(1-\theta)\}y''\big] \\
&\quad +\Pr(b|\beta,t_i)\big[\{(1-\lambda)\theta+(1-\xi)(1-\theta)\}y'+\{\lambda\theta+\xi(1-\theta)\}x''\big] \\
&= \frac{q(1-t_i)}{J(t_i)}[kx'+(1-k)y'']+\frac{(1-q)t_i}{J(t_i)}[(1-k)y'+kx''],
\end{aligned}
$$

where $J(t_i)\equiv(1-q)t_i+q(1-t_i)$. On the other hand,

$$
\Pi_i^s(A,\beta,t_i)=\Pr(a|\beta,t_i)x'+\Pr(b|\beta,t_i)y'=\frac{q(1-t_i)}{J(t_i)}x'+\frac{(1-q)t_i}{J(t_i)}y'.
$$

It is easy to check that

$$
\begin{aligned}
&\Pi_i^s(B,\beta,t_i)\ge\Pi_i^s(A,\beta,t_i)\Leftrightarrow(1-q)t_i\big[k(x''-y')\big]\ge q(1-t_i)\big[(1-k)(x'-y'')\big] \\
&\text{or,}\quad \frac{t_i}{1-t_j}\ge\frac{1-k}{k}\frac{q}{1-q}\frac{x'-y''}{x''-y'}.
\end{aligned}
\tag{A.10}
$$

Combining (A.9) and (A.10) we have that i recommends her signal if and only if,

$$
\frac{t_i}{1-t_i}\ge\max\left\{\frac{1-k}{k}\frac{q}{1-q}\frac{x'-y''}{x''-y'},\frac{k}{1-k}\frac{1-q}{q}\frac{x''-y'}{x'-x''}\right\}.
$$

But, as shown in the text, this is equivalent to (15), i.e., $k\le\bar{k}(\xi)$, which holds by supposition. This ends the proof of part (i).

(ii) When $k>\bar{k}(\xi)$ we will construct an $\mathcal{SE}$ under which the second expert babbles. In fact, such an $\mathcal{SE}$ exists for all parameters k. Let

$$
\begin{aligned}
x &\equiv \frac{\theta\lambda}{\theta\lambda+(1-\theta)\xi}\lambda+\frac{(1-\theta)\xi}{\theta\lambda+(1-\theta)\xi}\xi, \\
y &\equiv \frac{\theta(1-\lambda)}{\theta(1-\lambda)+(1-\theta)(1-\xi)}\lambda+\frac{(1-\theta)(1-\xi)}{\theta(1-\lambda)+(1-\theta)(1-\xi)}\xi.
\end{aligned}
$$

Here x is the expected accuracy of an expert's signal (i.e., market evaluation of expert skill) who has made a correct recommendation based on her signal alone, and y is similarly defined for an expert who has made an inaccurate recommendation based only on her own signal. Due to Assumption 1,

$$
x>k>y.
$$

To calculate equilibrium beliefs about the experts' abilities, suppose the experts follow their respective strategies as specified above (the optimality of strategies to be verified later). Then, for recommendation pairs (A,A) and (A,B), the decision maker will choose $d=A$

(Lemma 2). If the first expert recommends B (i.e. for recommendation pairs (B, A) and (B, B)), the decision maker will select $d = B$ based only on the first expert's recommendation; the second recommendation is uninformative. Hence for O the beliefs are as follows:

$$\begin{aligned}
\Pr(t = \lambda \mid A, a) = \quad \Pr(t = \lambda \mid B, b) &= \quad \tfrac{\theta\lambda}{\theta\lambda + (1-\theta)\xi}\,, \\
\Pr(t = \xi \mid A, a) = \quad \Pr(t = \xi \mid B, b) &= \quad \tfrac{(1-\theta)\xi}{\theta\lambda + (1-\theta)\xi}\,, \\
\Pr(t = \lambda \mid A, b) = \quad \Pr(t = \lambda \mid B, a) &= \quad \tfrac{\theta(1-\lambda)}{\theta(1-\lambda) + (1-\theta)(1-\xi)}\,, \\
\Pr(t = \xi \mid A, b) = \quad \Pr(t = \xi \mid B, a) &= \quad \tfrac{(1-\theta)(1-\xi)}{\theta(1-\lambda) + (1-\theta)(1-\xi)}\,.
\end{aligned}$$

Again, the beliefs are applicable to both experts, given that neither the experts' identities nor the timing of moves are revealed.

Now consider expert i who moves first. Let her observe α. If she recommends A, she receives

$$\Pi_i^s(A, \alpha, t_i) = \frac{qt_i}{qt_i + (1-q)(1-t_i)}x + \frac{(1-q)(1-t_i)}{qt_i + (1-q)(1-t_i)}y.$$

If she recommends B, her payoff is

$$\Pi_i^s(B, \alpha, t_i) = \frac{(1-q)(1-t_i)}{qt_i + (1-q)(1-t_i)}x + \frac{qt_i}{qt_i + (1-q)(1-t_i)}y.$$

Since $qt_i > (1-q)(1-t_i)$ and $x > y$, we have $\Pi_i^s(A, \alpha, t_i) > \Pi_i^s(B, \alpha, t_i)$. Now suppose she observes β. If she recommends B, her payoff is

$$\Pi_i^s(B, \beta, t_i) = \frac{(1-q)t_i}{(1-q)t_i + q(1-t_i)}x + \frac{q(1-t_i)}{(1-q)t_i + q(1-t_i)}y.$$

If she recommends A, she receives

$$\Pi_i^s(A, \beta, t_i) = \frac{q(1-t_i)}{(1-q)t_i + q(1-t_i)}x + \frac{(1-q)t_i}{(1-q)t_i + q(1-t_i)}y.$$

As $\frac{t_i}{1-t_i} > \frac{q}{1-q}$, and $x > y$, we have $\Pi_i^s(B, \beta, t_i) > \Pi_i^s(A, \beta, t_i)$. Hence, it is strictly optimal for i to recommend her signal, irrespective of her ability. Now, given a first period recommendation of A, the second expert j knows that $d = A$ (Lemma 2). Her payoff remains unchanged whether she recommends A or B. Similarly, if the first recommendation is B, j's recommendation is immaterial and $d = B$. Hence again, j's payoff remains unchanged whether she recommends A or B. So it is optimal for j to babble. This ends the proof of part (ii). ■

Proof of Proposition 4. Under the transparency protocol, in the proof of Proposition 1 in the Supplementary file we show that that the following PBE exist (i.e., a case of multiple equilibria): (i) both experts babble; (ii) one expert babbles and one recommends truthfully; (iii) the first expert recommends truthfully and the second expert babbles if the first recommendation is A and recommends truthfully if the first recommendation is B, provided that either the bias q is large, or the bias q is medium/small and $k \in [\xi, k(\xi)]$. The payoff to D under (i) is q, under (ii) is k, and under (iii) is $q[k+(1-k)k]+(1-q)k^2$ (this one follows applying the equilibrium strategies in Proposition 1). By Assumption 1, $k > q$. Since $2q > 1$ and $k < 1$, we have $q[k+(1-k)k]+(1-q)k^2 > k$.

Thus for large q, or medium/small q and $k \in [\xi, k(\xi)]$, the maximum equilibrium payoff of D is $q[k+(1-k)k]+(1-q)k^2$. When q is medium/small and $k > k(\xi)$, D's maximum equilibrium payoff is k.

Under the secrecy $\mathcal{SE}$ in Proposition 3 the payoff of D is $q[k^2+2k(1-k)]+(1-q)k^2$, same as $q[k+(1-k)k]+(1-q)k^2$, when q is either large, or medium/small and $k \in [\xi, \bar{k}(\xi)]$. When q is medium/small and $k > \bar{k}(\xi)$, the first expert recommends her signal and the second expert babbles. The payoff of D then is k.

Thus, for large q, the *identified* equilibrium under secrecy gives D a payoff that is equal to the maximum equilibrium payoff of D under transparency. The same holds true when q is medium/small and $k \in [\xi, k(\xi)]$ or $k \in (\bar{k}(\xi), \lambda]$. This is because, due to (18), we have that $k(\xi) < \bar{k}(\xi)$.

When q is medium/small and $k \in (k(\xi), \bar{k}(\xi)]$, the *identified* equilibrium under secrecy gives D a payoff that is strictly greater than the maximum equilibrium payoff of D under transparency. This is because, $q[k+k(1-k)]+(1-q)k^2 > k$.

Hence, by Definition 4, D prefers secrecy over transparency. ■

Proof of Proposition 5. (i) Recall that

$$k(\xi) = \frac{q\xi}{q\xi + (1-q)(1-\xi)}, \quad k(\lambda) = \frac{(1-q)\lambda}{(1-q)\lambda + q(1-\lambda)}$$

and k is a function of θ. We change variables and write k as a function of x,[34]

[34]This x should not be confused with the variable x defined in the proof of Proposition 3.

$$k(x) = \frac{(x+2q-1)\xi\lambda}{(2q-1)\lambda + x\xi} \quad \text{for} \;\; x \in [\underline{x}, \bar{x}],$$

where

$$\underline{x} \equiv \frac{(2q-1)^2\lambda(1-\xi)}{(1-q)\lambda(1-\xi) - q\xi(1-\lambda)}, \quad \bar{x} \equiv \frac{(1-q)\lambda(1-\xi) - q\xi(1-\lambda)}{\xi(1-\lambda)}.$$

Note that $k(\underline{x}) = k(\xi)$ and $k(\bar{x}) = k(\lambda)$. The denominator of $\underline{x}$ and the numerator of $\bar{x}$ are the same and the value is positive because $\frac{1-q}{q}\frac{\lambda}{1-\lambda} > \frac{q}{1-q}\frac{\xi}{1-\xi}$ (follows from $k(\xi) < k(\lambda)$) and $\frac{q}{1-q}\frac{\xi}{1-\xi} > \frac{\xi}{1-\xi}$ (as $q > \frac{1}{2}$). Furthermore,

$$k'(x) = \frac{(2q-1)\xi\lambda(\lambda-\xi)}{[(2q-1)\lambda + x\xi]^2} > 0.$$

Hence $\{k : k(\xi) \le k \le k(\lambda)\} = \{k : k(\underline{x}) \le k \le k(\bar{x})\}$ and $x > 0$ for all $x \in [\underline{x}, \bar{x}]$.

We now start our proof by noting that D's payoff from the partial type revealing equilibrium,

$$k^2 + k(1-\theta)(1-\xi) + (1-k)\theta\lambda,$$

dominates the payoff from the signal revealing equilibrium,

$$q[k^2 + 2k(1-k)] + (1-q)k^2,$$

if and only if

(A.11) $$(1-\theta)(1-\xi)k + \theta\lambda(1-k) > 2qk(1-k),$$

or equivalently,

(A.12) $$(2q-1)\frac{\theta\lambda}{(1-\theta)(1-\xi)} + 2q\frac{\xi}{1-\xi} < \frac{k}{1-k}.$$

The following claim (which relates θ to x) will be used in the proof.

Claim 1: $(2q-1)\frac{\theta\lambda}{(1-\theta)(1-\xi)} = x\frac{\xi}{1-\xi}$ if and only if $k = \frac{(x+2q-1)\xi\lambda}{(2q-1)\lambda+x\xi}$.

This is because

$$(2q-1)\frac{\theta\lambda}{(1-\theta)(1-\xi)} = x\frac{\xi}{1-\xi} \quad \Leftrightarrow \quad (2q-1)\theta\lambda = x\xi(1-\theta)$$

$$\Leftrightarrow \quad \theta = \frac{x\xi}{(2q-1)\lambda + x\xi} \quad \Leftrightarrow \quad \theta(\lambda - \xi) = \frac{x\xi(\lambda - \xi)}{(2q-1)\lambda + x\xi}$$

$$\Leftrightarrow \quad \theta(\lambda - \xi) + \xi = \frac{x\xi(\lambda - \xi)}{(2q-1)\lambda + x\xi} + \xi \quad \Leftrightarrow \quad \theta\lambda + (1-\theta)\xi = \frac{(x+2q-1)\xi\lambda}{(2q-1)\lambda + x\xi}$$

$$\Leftrightarrow \quad k = \frac{(x+2q-1)\xi\lambda}{(2q-1)\lambda + x\xi}.$$

Hence, it follows from Claim 1 and (A.12) that D's payoff from the partial type revealing equilibrium dominates that from the signal revealing equilibrium if and only if

$$\text{(A.13)} \qquad (x+2q)\frac{\xi}{1-\xi} < \frac{k}{1-k} \quad \left(\equiv \frac{(x+2q-1)\xi\lambda}{(2q-1)\lambda(1-\xi) + x\xi(1-\lambda)} \right)$$

or, as $x > 0$,

$$\text{(A.14)} \qquad x^2\xi(1-\lambda) - 2x[(1-q)\lambda(1-\xi) - q\xi(1-\lambda)] + (2q-1)^2\lambda(1-\xi) < 0.$$

Call the LHS of (A.14) $f(x)$. So,

$$f(x) = x^2\xi(1-\lambda) - 2x[(1-q)\lambda(1-\xi) - q\xi(1-\lambda)] + (2q-1)^2\lambda(1-\xi).$$

Claim 2: $f'(x) < 0$ for all $x < (1-q)\frac{\lambda}{1-\lambda}\frac{(1-\xi)}{\xi} + q$.

Because

$$f'(x) = 2x\xi(1-\lambda) - 2[(1-q)\lambda(1-\xi) - q\xi(1-\lambda)],$$

$$f'(x) < 0 \quad \Leftrightarrow \quad 2x\xi(1-\lambda) - 2[(1-q)\lambda(1-\xi) - q\xi(1-\lambda)] < 0$$

$$\Leftrightarrow \quad x < (1-q)\frac{\lambda}{1-\lambda}\frac{(1-\xi)}{\xi} + q.$$

We now check whether (A.13), and therefore (A.14), holds at $x = \underline{x}$.

Claim 3:

$$\text{(A.15)} \qquad (\underline{x}+2q)\frac{\xi}{1-\xi} < \frac{k(\underline{x})}{1-k(\underline{x})}.$$

We know that the RHS of (A.15) is equal to $\frac{k(\xi)}{1-k(\xi)} = \frac{q}{1-q}\frac{\xi}{1-\xi}$. So we need to show that

$(\underline{x}+2q)\frac{\xi}{1-\xi} < \frac{q}{1-q}\frac{\xi}{1-\xi}$, or $(\underline{x}+2q) < \frac{q}{1-q}$. Now,

$$
\begin{aligned}
&(\underline{x}+2q) < \frac{q}{1-q} \quad \Leftrightarrow \quad \underline{x} < \frac{q(2q-1)}{1-q} \quad \Leftrightarrow \quad \frac{(2q-1)^2\lambda(1-\xi)}{(1-q)\lambda(1-\xi)-q\xi(1-\lambda)} < \frac{q(2q-1)}{1-q} \\
&\Leftrightarrow \quad (2q-1)(1-q)\lambda(1-\xi) < q(1-q)\lambda(1-\xi) - q^2\xi(1-\lambda) \\
&\Leftrightarrow \quad q^2\xi(1-\lambda) < (q-2q+1)(1-q)\lambda(1-\xi) \quad \Leftrightarrow \quad \frac{q^2}{(1-q)^2} < \frac{\lambda}{1-\lambda}\frac{1-\xi}{\xi} \\
&\Leftrightarrow \quad \frac{q}{1-q} < \sqrt{r}\text{ , which is true.}
\end{aligned}
$$

So (A.13), and therefore (A.14), is satisfied at $x = \underline{x}$. Now by Claim 2, $f'(x)$ is negative for all x such that $\underline{x} < x < (1-q)\frac{\lambda}{1-\lambda}\frac{1-\xi}{\xi} + q$. So (A.13), and (A.14), will be satisfied for all x such that $\underline{x} < x < (1-q)\frac{\lambda}{1-\lambda}\frac{1-\xi}{\xi} + q$. Therefore, if $\bar{x} < (1-q)\frac{\lambda}{1-\lambda}\frac{1-\xi}{\xi} + q$, then (A.13) and (A.14) would hold for all $x \in [\underline{x}, \bar{x}]$. The condition is verified as follows:

$$
\bar{x} = \frac{(1-q)\lambda(1-\xi) - q\xi(1-\lambda)}{\xi(1-\lambda)} = (1-q)\frac{\lambda}{1-\lambda}\frac{1-\xi}{\xi} - q < (1-q)\frac{\lambda}{1-\lambda}\frac{(1-\xi)}{\xi} + q.
$$

This completes the proof of part (i).

(ii) In part (i) we have shown that $k^2+k(1-\theta)(1-\xi)+(1-k)\theta\lambda > q[k^2+2k(1-k)]+(1-q)k^2$, and in the proof of Proposition 4 we have shown that $q[k^2+2k(1-k)]+(1-q)k^2 > k$. So, our claim follows. ■

A.4 Deliberation under secrecy

In Section 7, we studied the question of information revelation when experts submit detailed recommendations. Here we present an alternative protocol where experts are allowed to deliberate through back-and-forth messages.[35] Consider a communication format under secrecy where there are four stages. Experts alternate in stages first recommending an action, an element from $\{A, B\}$, and later on confirming the initial recommendation or altering her position. The experts and D observe all recommendations but O does not. A recommendation profile is a four-dimensional vector with coordinates belonging to $\{A, B\}$. Following the recommendation, D chooses $d \in \{A, B\}$. O observes d and ω and forms expectations

[35]We do not analyze transparency, given what we already know from Section 4 and the negative results (on information revelation) of Ottaviani and Sorensen (2001; 2006a,b,c), Meade and Stasavage (2008), and Fehrler and Hughes (2018).

about the experts' types. These expectations are the payoffs of the experts. This game we call *deliberation*.

We show the existence and characterization of an equilibrium under which *both* experts reveal their entire two-dimensional type in a restricted environment, parallel to Proposition 6 (see the Supplementary file). As a protocol, deliberation enriches our analysis of the secret sequential advice game. While some earlier works do model deliberations (see footnote 9), to our knowledge, there is no general analysis of deliberation as an interactive, back-and-forth communication game (as opposed to simultaneous exchange of views/signals) readily applicable in decision making contexts. Aumann and Hart's (2003) long-drawn message game between two players (one informed and another uninformed), who have to take an action each in an uncertain bimatrix game at the end of the talk (or message) phase, is closest to modelling protracted cheap-talk communications. But both players in their model have intrinsic stakes in the outcomes of the game to be played. Directly related to organizational economics, there is a recognition that diverging opinions could in fact be beneficial for efficient decision making (Landier, Sraer and Thesmar, 2009). In our secret sequential advice protocol, making an effective use of the second expert's differing views (about the suitable action) is in the same spirit of promoting diverse opinions for optimal decisions. But still the sequential advice mechanism fails to draw out any difference of opinions in a full-fledged manner. The deliberation game proposed here can facilitate information aggregation via emerging conflicting/corroborating views, when the experts do not have any intrinsic interests in decisions.

Our main message therefore dispels any negative view of deliberation necessarily compromising decisive actions by creating seeds of doubts, so long as deliberation is done secretly. ||

Supplementary materials

The manuscript contains additional supplementary materials.

References

Aumann, R.J. and Hart, S., "Long Cheap Talk," *Econometrica* 71 (2003), 1619-1660.

Caillaud, B. and Tirole, J., "Consensus Building: How to Persuade a Group," *American Economic Review* 97 (2007), 1877-1900.

Diermeier, D., Keane, M. and Merlo, A., "A Political Economy Model of Congressional Careers," *American Economic Review* 95 (2005), 347-373.

Elster, J. (edited), *Secrecy and Publicity in Votes and Debates* (Cambridge University Press, 2015, ISBN 978-1-107-08336-3).

Fehrler, S. and Hughes, N., "How Transparency Kills Information Aggregation: Theory and Experiment," *American Economic Journal: Microeconomics* 10 (2018), 181-209.

Forges, F. and Koessler, F., "Long Persuasion Games," *Journal of Economic Theory* 143 (2008), 1-35.

Gersbach, H. and Hahn, V., "Should Individual Voting Records of Central Bankers be Published?" *Social Choice Welfare* 30 (2008), 655-683.

Holmstrom, B., "Managerial Incentive Problems: A Dynamic Perspective," *Review of Economic Studies* 66 (1999), 169-182.

Iaryczower, M., Shi, X. and Shum, M., "Can Words Get in the Way? The Effect of Deliberation in Collective Decision-Making," *Journal of Political Economy* 126 (2018), 688-734.

Jackson, M.O. and Tan, X., "Deliberation, Disclosure of Information, and Voting," *Journal of Economic Theory* 148 (2013), 2-30.

Krishna, V. and Morgan, J., "The Art of Conversation: Eliciting Information from Experts through Multistage Communication," *Journal of Economic Theory* 117 (2004), 147-179.

Landier, A., Sraer, D. and Thesmar, D., "Optimal Dissent in Organizations," *Review of Economic Studies* 76 (2009), 761-794.

Levy, G., "Decision Making in Committees: Transparency, Reputation and Voting Rules," *American Economic Review* 97 (2007a), 150-168.

Levy, G., "Decision Making Procedures for Careerist Experts," *American Economic Review Papers and Proceedings* 97 (2007b), 306-310.

McLennan, A., "Consequences of the Condorcet Jury Theorem for Beneficial Information Aggregation by Rational Agents," *American Political Science Review* 92 (1998), 413-418.

Meade, E. and Stasavage, D., "Publicity of Debate and the Incentive to Dissent: Evidence from the US Federal Reserve," *Economic Journal* 118 (2008), 695-717.

Ottaviani, M. and Sorensen, P., "Information Aggregation in Debate: Who Should Speak First?" *Journal of Public Economics* 81 (2001), 393-421.

Ottaviani, M. and Sorensen, P., "Professional Advice," *Journal of Economic Theory* 126 (2006a), 120-142.

Ottaviani, M. and Sorensen, P., "Reputational Cheap Talk," *Rand Journal of Economics* 37 (2006b), 155-175.

Ottaviani, M. and Sorensen, P., "The Strategy of Professional Forecasting," *Journal of Financial Economics* 81 (2006c), 441-466.

Prat, A., "The Wrong Kind of Transparency," *American Economic Review* 95 (2005), 862-877.

Scharfstein, D. and Stein, J., "Herd Behavior and Investment," *American Economic Review* 90 (2000), 465-479.

Seidmann, D., "A Theory of Voting Patterns and Performance in Private and Public Committees," *Social Choice Welfare* 36 (2011), 49-74.

Sibert, A., "Monetary Policy Committees: Individual and Collective Reputations," *Review of Economic Studies* 70 (2003), 649-665.

Visser, B. and Swank, O., "On Committees of Experts," *Quarterly Journal of Economics* 122 (2007), 337-372.

Wolinsky, A., "Eliciting Information from Multiple Experts," *Games and Economic Behavior* 41 (2002), 141-160.