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Deliberations and Choices by Committees

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Abstract

Committee protocols typically involve deliberations in which committee members try to influence and convince each other regarding the "right" choice. Such deliberations do not involve only information exchange, but their aim is also to affect the preferences and the votes of other members. This aspect of committee deliberation is the focus of this paper. Using a model of social influence we demonstrate how the debating and voting procedures affect the voting outcome and how different protocols of consultation by a chair may affect his final decision.

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1 Introduction

Consider two different decision procedures that are part of academic life: recruiting a new faculty and the evaluation of papers. Both are important decisions that require the inputs, vote, and recommendations of several people. There is, however, a fundamental difference between the two. In the first, there is typically a meeting of the recruiting committee in which there is an open deliberation regarding the different candidates. This deliberation process typically goes far beyond providing additional information as it involves expressing preferences and priorities while trying to convince and persuade other committee members regarding the attractiveness of each of the candidates. Referees, on the other hand, write their reports and recommendations directly to the editor and there is no discussion and deliberation among them.[1]

If individuals vote only according to their own preferences and are not influenced by others then the only purpose of a deliberation process is information sharing. But this can be often done without a meeting and without direct deliberation. Typical meetings regarding faculty recruit involve more than information sharing and include debates regarding preferences, opinions, and priorities. On the other hand, there are different types of articles' reviewing processes. For example, editors may assign a committee for each article, asking its members to deliberate and to evaluate the paper and to send back their final recommendation, in the same way candidates are cho-

[1]In the first round the referees cannot influence each other. In many journals, however, when there is a second round of "revise and resubmit," referees see each other's first round reports, and may therefore be influenced by other referees.

sen.[2] Will these procedures generate different decisions regarding candidates or different profile of published papers? This type of questions is the focus of this paper.

Many decisions are done by committees. For example, the board of directors of commercial firms or public institutes, governments, juries in courts, or even a school's decoration committee. In discussing the effect of committee deliberations the focus of the literature has been its role in information sharing. (For a recent survey see Li and Suen (2009) and the related literature subsection). Given that committee members may have different information and different preferences, the literature considers the incentives committee members have to disclose or distort their private information or to acquire new information.

There is however another important dimension of committees' work which has been largely ignored. When committee members explain and express their opinion other committee members may be persuaded by their arguments or even just by listening to other opinions. In many committee discussions members indeed try to convince and persuade other members regarding the attractiveness of different alternatives.

In a previous paper (Fershtman and Segal (2018), hereafter FS) we modeled social influence by introducing a setup in which each individual is characterized by two sets of preferences: unobservable core preferences and observable behavioral preferences, where actual choice is determined by the latter. Each individual has a social influence function that determines his behavioral preferences as a function of his core preferences and the observed

[2] This is how papers are accepted for presentation in some computer science conferences.

behavioral preferences of others. In the present paper we capture the effect of deliberation by using our social influence procedure, where each person votes according to his behavioral preferences which depend on his core preferences and on the behavioral preferences of those who participate in the deliberation. Note that we do not assume that committee members have some type of social preferences, for example, for conformity. We assume that preferences, and not just actions, may change as a result of social interaction. So even if conformity is part of individuals preferences, it may change as a result of social influence.

We consider a committee of n individuals who need to choose between two candidates (or alternatives), differing with respect to two attributes. The levels of these attributes are perfectly observable by all committee members and there is no disagreement among them on the candidates' types. Committee members may differ in their preferences regarding the relative importance of these attributes. Such situations may occur, for example, when choosing between two candidates for a faculty position who have different research and teaching abilities, choosing between investment projects with different expected returns and different levels of risk, choosing a location for a new facility with a trade-off between convenience and price, etc. We assume that there is no private information regarding the abilities or characteristics of these alternatives. As committee members would prefer one of the alternatives depending on their preferences, there is no "best" alternative in our setting. During the deliberation stage committee members argue, express and explain their opinions, and try to convince each other regarding the " right" criterion for choosing an alternative. Such deliberations create social influence which may alter other members' preferences. In this paper we examine the equilibrium of this process and the type of decisions that emerge under different types of social influence.[3]

We start by considering a committee with an open deliberation procedure in which all members participate in the deliberation and influence each other. We examine some of the properties of the equilibrium of this process. For example, social influence may imply that deliberation with social influence may violate the unanimity property. That is, even when all committee members prefer (given their core preferences) one alternative, they may end up voting for the other alternative.

Committees may have different protocols of deliberation and voting. In some cases members do not have to express their opinion before the voting, i.e., they may choose only to listen without expressing their opinion. In other cases they must explain their decision (e.g., judges siting together on the bench). There are committees in which members do not have to attend meetings as they may choose just to send their written ballots. Deliberation and voting can be done simultaneously or sequentially (and in different orders). The order of a sequential deliberation implies that early speakers influence the preferences of other committee members but they will not be influenced by them. The outcome of the deliberation and voting thus depends on the order in which it is done. We capture these types of deliberation and voting protocols by analyzing a model in which the pattern of social influence

[3]Note that we do not assume a strategic influence motive. That is, we do not assume that individuals change their behavior in order to influence other committee members. We simply model the effect of such social influence on the outcome of the deliberation and decision by committees.

is modeled as a directed social network in which individuals influence others only if they are connected and the direction of the network determines the direction of the social influence.

Finally, we consider situations in which there is one person who is making all the decisions but there is a group of "advisors" that may consult him, for example, a CEO of a firm with a board of directors. We use the star network structure to model this situation and we distinguish between situations in which the advisors only consult the chair and situation in which there is an open deliberation. The pattern of consulting may be decentralized, where each advisor talks only with the chair but not with other advisors, or it can be centralized in which case advisors also talk with each other. Each such a procedure determines a different pattern of social influence and we demonstrate how such procedures may lead to different decisions.

1.1 Related Literature

This paper relates to several strands of literature. Starting from Condorcet (1785) there are numerous studies on decision making by committees.[4] Following his work most of the literature focuses on information aggregation and voting protocols. For a survey of this literature, see Li and Suen (2009). The meaning of deliberation in this literature is information sharing, manipulation, and information aggregation. There is no arguing, convincing, and social influence in the formal deliberation process unless it involves provid-

[4]Condorcet (1785) showed that the quality of decisions made by committees with diverse information is increasing with the group size.

ing additional information.[5] It is these aspects of deliberation which are the focus of our paper.

Our analysis considers also the effect of deliberation protocol on committee decisions and therefore it relates to the literature which considers dynamic committee decision making, see for example Moldovanu and Shi (2013), Dekel and Piccione (2000, 2014), Damiano, Li and Suen (2009) and Chan, Lizzeri, Suen and Yariv (2018).[6]

There is an extensive documentation of the effect of social interaction on individuals' behavior and opinions. For a review of this literature in social psychology, see Isenberg (1986), Myers and Lamm (1976), and Myers (1975, 1982). The effect of deliberation on jury decisions was discussed by Schade, Sunstein, and Kahneman (2000) and Mendelberg (2006). Political scientists too argue that "the composition of the discussion group changes the views expressed by those who participate in it." (See Farrar, Green, Green, Nickerson and Shewfelt (2009, p. 616)). Ariely and Levav (2000) provide an experiment suggesting that social influence affects the choice of dishes in restaurants.[7] Aronson, Wilson, and Akert (2010) claim that group discussions may make people more risk taking than their initial tendencies. In a recent article, Hoff and Stiglitz (2016) claim that preferences and behavior

[5]We assume that committee members have heterogeneous preferences and therefore there is a room for social influence and there is no career concern or reputation effect. Such committees of experts were discussed by Swank and Visser (2007), Levy (2007), and Gersbach and Hahn (2012).

[6]Recently Iaryczower, Shi and Shum (2018) study the effect of deliberation on the probability of incorrect decisions by a jury in the context of criminal cases.

[7]Specifically, they found a larger variance in the dishes ordered by individuals who were part of a group than by individuals sitting by themselves.

are influenced by actions and beliefs of people around the decision maker. An alternative formulation of social influence was introduced by Cumadaroglu (2017). In this paper individuals are assumed to have incomplete preferences and are socially influenced by other individuals only on issues which they cannot resolve by themselves.

Our paper is also related to the literature on social preferences (see, for example, Charness and Kuhn (2011), Fehr and Gächter (2000), Sobel (2005), and Fehr and Schmidt (1999)). Social preferences imply that the utility of an individual depends on other people's outcomes, on the distribution of payoffs, or on the actions taken by other people. The literature focuses, for example, on altruism, fairness concerns, reciprocity, or inequality aversion. There is however a difference between "social preferences" and our concept of "social influence." We assume that when individuals need to make decisions, their preferences may be altered by the interaction with other people. However, these preferences can be purely egoistic or with a social element. So even when there is a social concern like fairness, it may change as a result of social influence.

The paper is related to the literature on endogenous preferences. For a survey of the literature on evolutionary sociobiology, see Becker (1970) and Dawkins (1976) and for a survey of applications in economics see Bowles (1998), Samuelson (2001), and more recently Alger and Weibull (2013). This literature assumes that preferences change over time but the assumed dynamics follows a simple evolutionary rule such that people adopts the preferences of "successful" (high fitness) individuals. The second approach for endogenous preferences is the dynamic cultural transmission framework (see Bisin and Verdier (2001), Boyd and Richerson (1985), and Cavalli-Sforza and Feldman (1973)). Our approach does not assume endogenous preferences but that choices made by individuals are affected by the choices made by individuals with whom they interact.

2 The Model

2.1 Preliminaries

We consider a committee consisting of $n > 2$ members that needs to choose one of two possible options $\{A, B\}$. We assume that the decision is based on two attributes of the alternatives, denoted (a_1, a_2) for A and (b_1, b_2) for B. These attributes can be a candidate's ability and willingness to work, research and teaching abilities, the expected return and the risk of a project, etc. We assume that these attributes are perfectly observable and there is no dispute among committee members regarding their levels. If $a_1 \geqslant b_1$ and $a_2 \geqslant b_2$, A dominates B and the choice is trivial. We therefore assume wlg that $a_1 > b_1$ but $a_2 < b_2$.

Members of the committee have their own core preferences $\alpha_i \in [0, 1]$ over the relative importance of the two attributes.[8] With these preferences, individual i prefers B to A iff $b_1 + \alpha_i b_2 \geqslant a_1 + \alpha_i a_2$. Let $\alpha = (\alpha_1, \ldots, \alpha_n)$, and assume wlg that $\alpha_1 \geqslant \ldots \geqslant \alpha_n$. Given our assumptions, for any given pair of candidates $\{A, B\}$ with known and observable attributes there is a critical value $\gamma = (b_1 - a_1)/(a_2 - b_2)$ such that committee members would

[8] More precisely, members of the committee have core preferences $\alpha_i \in [\underline{\alpha}, \overline{\alpha}]$, but to simplify notation we assume wlg that $\underline{\alpha} = 0$ and $\overline{\alpha} = 1$.

prefer A to B iff $\alpha_i \leqslant \gamma$.

2.2 Social Influence

When there is no deliberation and individuals cast their votes without any social interaction they vote according to their core preferences $(\alpha_1, \ldots, \alpha_n)$. But when the committee deliberates we assume that there is some social influence among its members and the deliberation process itself affects their vote. Following FS, we assume that each individual has behavioral preferences that govern his behavior. Without social influence his behavioral preferences are just his core preferences, but when there is social influence his behavioral preferences depend on his core preferences and the behavioral preferences of other individuals with whom he interacts. We assume that voting after deliberation would be according to a behavioral parameter β_i, $\beta_i \in [0,1]$ and that this parameter is a function of the individual core preferences α_i and the behavioral parameters of other committee members. Formally, $\beta_i = g^i(\alpha_i, \beta_{-i})$ where $\beta_{-i} = (\beta_1, \ldots, \beta_{i-1}, \beta_{i+1}, \ldots, \beta_n)$. We refer to this function as the *social influence* function. We further assume that for all $j \neq i$, $\partial g^i/\partial \beta_j < 1$, implying that the change in one's behavioral preferences cannot be larger than the change in someone else's behavioral preferences that induce this change.

Fershtman and Segal (2018, Claim 2) offered an axiomatic framework under which the behavioral parameter β_i depends only on one's core preferences and the average of the observable behavioral parameters of everyone else. That is, $\beta_i = g^i(\alpha_i, \sum_{j \neq i} \beta_j/(n-1))$.[9] We proved the following result.

[9] Our setup assumes that g depends on one's core preferences and the average behavioral

Fact 1 Suppose that all agents have the same social influence function g. Then:

1. If all agents start with the same α, then $\beta := \beta_1 = \ldots = \beta_n \geqslant \alpha \Longleftrightarrow g(\alpha, \alpha) \geqslant \alpha$
2. $\beta_i \geqslant \beta_j \Longleftrightarrow \alpha_i \geqslant \alpha_j$; and
3. If $\alpha_i < \alpha_j$ then it cannot be the case that $\beta_i < \alpha_i$ and $\beta_j > \alpha_j$.

Given this model of social influence we assume that voting by committee members is done according to their behavioral preferences such that individual i votes for A over B iff $\beta_i \leqslant \gamma$.

2.3 Networks of Influence

Deliberation and voting procedures may interact in different ways with a rich set of possible scenarios. Social influence may occur as a direct outcome of any meeting and discussion protocol in which committee members express their opinion and proceed to the next meeting which is going to shape their new opinion. For example, it is possible that agent A meets with agent B, discusses with her his current opinion and proceeds to a meeting with agent C which may again change his opinion and affect his final vote. In this story the behavioral preferences of B are influenced by preferences A has at a certain point, but which are not his final preferences and therefore not the preferences according to which he behaves. While in principal our setting

preferences of the rest without specifying how many other individuals there are in the influence group. One can modify this assumption by indexing the g function according to the number of individuals in the influence group.

allows us to consider different protocols of meeting and social influence, we limit our discussion to situations in which if the opnion of a certain person is going to be considered by others, it is only the *final* opinion that will be considered, and it is the only relevant input with respect to social influence. We believe that such an assumption is the appropriate one for the analysis of committees work. Note that while our structure allows only for direct social influence, indirect influence may play an important role in the model. Agent A may never meet agent C but he may still be indirectly influenced by her whenever agent C meets agent B and there is a social influence between agents A and B. Given this assumption we can model any social influence pattern by a directed network in which there is a directed link between agent A and agent B only when agent B is socially influenced by agent A and the preferences she observes are A's final behavioral preferences. Given this approach we need to look for equilibrium in the behavioral preferences which would depend on the network of social influence.

A deliberation network is a pair (N, Γ), such that N is the set of players and Γ is a directed social network on the nodes N. The network $\Gamma \subseteq \{(i,j) | \, i,j \in N, i \neq j\}$ denotes the pairs of nodes that are socially connected and the direction of social influence, where $(i,j) \in \Gamma$ indicates that agent i is influenced by player j.[10] The set Γ is not necessarily symmetric and it is possible that $(i,j) \in \Gamma$ but $(j,i) \notin \Gamma$. In this case agent j influences agent i but is not influenced by him. Such situations occur for example when de-

[10] As an alternative we can let Γ be an $n \times n$ adjacency matrix, with entry $\Gamma_{ij} \in \{0,1\}$ denoting whether i interacts with player j. In this formulation one can permit $\Gamma_{ij} \in [0,1]$, indicating intensities of influence, so it is possible to consider committees in which some individuals have a greater social influence than others.

liberation and voting are sequential and if agent j's turn precedes i's. The structure discussed in Section 3 is such that Γ is the complete network which includes all possible directed pairs. In sections 5 and 4 we discuss cases of directed influence.

We are looking for a social influence equilibrium when the pattern of social influence is governed by the directed network Γ. A social influence equilibrium is a vector of behavioral preferences $\beta = (\beta_1, \ldots, \beta_n)$ such that each agent i's behavioral preferences are determined by his core preferences α_i and the equilibrium behavioral preferences of the agents by whom he is influenced. Formally, the social influence function takes the form of $\beta_i = g_i(\alpha_i, \beta_{-i}|\Gamma)$ which means that agent i is influenced only by agents that are defined by the directed network Γ. We assume that $g_i(\alpha_i, \beta_{-i}|\Gamma)$ is continuous in all its arguments.

For any profile of core utilities $\alpha = (\alpha_1, \ldots, \alpha_n)$, social influence functions $g = (g_1, \ldots, g_n)$, and a directed network Γ, we define *equilibrium behavioral preferences* as $\beta^*(\alpha, \Gamma) = (\beta_1^*(\alpha, \Gamma), \ldots, \beta_n^*(\alpha, \Gamma))$ such that for every i, $\beta_i^*(\alpha, \Gamma) = g_i(\alpha_i, \beta_{-i}^*|\Gamma)$.

Claim 1 For every profile of core utilities α, social influence functions g, and a directed social network Γ, there is an equilibrium behavioral preferences vector $\beta^*(\alpha, \Gamma)$.

Proof: Note that $\alpha, \beta \in [0, 1]^n$. Thus the social influence function $\beta(\alpha, \Gamma)$ is a continuous function from $[0, 1]^n$ to itself and therefore has a fixed point. This fixed point defines an equilibrium in behavioral preferences. ■

The proof is a special case of the proof of Claim 1 in FS which considers a case in which both the core and the behavioral preferences are utility function on $[0,1]$ which are assumed to be bounded, continuous and equi-Lipschitz functions on $[0,1]$, but are not necessarily represented by a single parameter β. The social influence there is defined with respect to complete undirected network but can be easily extended to any directed network.[11]

3 The Effect of Deliberation in Complete Networks

In this section we analyze the effect of deliberation on committees' decisions when there is no special deliberation protocol. We assume a complete network of social influence such that all committee members participate in the deliberation, which is then followed by voting. There is no particular order of deliberation, each member hears all other opinions and is therefore influenced by all other committee members. We focus on how deliberation may change the vote of the committee. We define several properties that the deliberation process may satisfy, and show how they affect the outcome of the voting.

Property 1 (Unanimity): If all committee members prefer one candidate (e.g. for all i, $\alpha_i < \gamma$), then social influence during the deliberation process results in an equilibrium behavioral preferences β which implies that the same candidate is chosen.

[11] We can extend the existence claim to the case of a general (bounded and equi-Lipschitz) preferences over $[0,1]$ following the same step of the proof in FS.

Note that this is a weak notion of unanimity. A stronger version would imply that if prior to the deliberation all committee members prefer candidate A then after the deliberation they still unanimously vote for A. The justification for such a strong version of unanimity is that if no committee member supports alternative B, then no one can convince others to vote for B. Note however that the social influence is with respect to preferences, represented by β, and not directly with respect to the candidates. Our weaker concept only requires that if there is a unanimous support for candidate A prior to the deliberation, then A will be chosen by the committee after the deliberation.

Next, we analyze the effects of changes in the composition and size of the committee.

Property 2 (Consistency): If B is selected after deliberation then (i) if a member is replaced with another member that in his core preferences prefers B, then the new committee will also vote for B. (ii) if a new member supporting B is added to the committee, then the new committee will still vote for B.

Property 3 (Monotonicity): If a committee votes for alternative B and one of its members is replaced with a new member with the same social influence function who, in his core preferences, is more inclined to vote for B, then the new committee will also vote for alternative B.

Consistent preferences are in particular monotonic, as they require consistency with respect to all replacements of a person with another member with the same core preferences over the candidates. But monotonic preferences need not be consistent. It requires not only the same ordinal preferences over the two candidates, but also higher value of the core preferences index.

Claim 2 The deliberation process satisfies the monotonicity property, but it does not satisfy unanimity and consistency.

Our social influence setting implies that what matters for understanding the committee voting is not just whether its members prefer A or B but also the intensity of these preferences. This intensity also determines the way committee members affect other members. It is therefore important to have a deliberation stage which reveals intensity of preference and not just a voting stage which reveals members' ordinal preferences. It is this characteristic of our social influence setting which generates the possibility of inconsistencies in the committees' decisions. Consider for example a committee of three individuals such that two of them mildly prefer A to B while the third strongly prefers B to A. We can imagine a social interaction in which the first two members switch and vote for B. In this case they are influenced by the strong preferences of the third member. Now replace this third member with a new member who has mild preferences for B over A (lower α in our setting). In this case his weak preferences are not sufficient to influence the first two members to vote for B.

Alternatively, consider a committee of three members of which two strongly prefer B while the third mildly prefers A. Given the strong preferences of the first two members the third may be driven to vote for B. Add to this committee a fourth member with mild preferences for B over A, and the third member whose core preferences are for A may, after observing the preferences of the new committee member, decides to stay and support candidate A. And if a unanimous voting is required candidate B will not be elected.

Proof: **Monotonicity**: Consider the system $\beta_i = g^i(\alpha_i, \sum_{j\neq i} \beta_j/(n-1))$, $i = 1, \ldots, n$. Take the total differential to obtain for $i = 1, \ldots, n$

$$g_1^i\left(\alpha_i, \sum_{j\neq i} \frac{\beta_j}{n-1}\right) = \frac{\mathrm{d}\beta_i}{\mathrm{d}\alpha_i} - \frac{1}{n-1}\sum_{j\neq i} g_2^i\left(\alpha_i, \sum_{j\neq i}\frac{\beta_j}{n-1}\right)\frac{\mathrm{d}\beta_j}{\mathrm{d}\alpha_i} \tag{1}$$

Let the matrix B be given by $b_{i,i} = 1$, and $b_{i,j} = -\frac{1}{n-1}g_2^i\left(\alpha_i, \sum_{j\neq i}\frac{\beta_j}{n-1}\right)$ whenever $i \neq j$. Observe that B has 1 on the main diagonal, and all entries on a row (except for b_{ii}) are the same and between zero and 1. To prove that $\det(B) > 0$, diagonalize $B^1 = B$ in $n-1$ steps to create $B^2, \ldots, B^n$, where

1. For $i \leqslant k$, $b^k_{i,i} > b^k_{i,i+1} = \ldots = b^k_{i,n} > 0 = b^k_{i,1} = \ldots = b^k_{i,i-1}$
2. For $i > k$, $b^k_{i,i} > b^k_{i,k} = \ldots = b^k_{i,i-1} = b^k_{i,i+1} = \ldots = b^k_{i,n} > 0 = b^k_{i,1} = \ldots = b^k_{i,k-1}$

The conditions are obviously satisfied for $B^1 = B$. Suppose we created $B^1, \ldots, B^k$, and create B^{k+1}. Multiply row k by $-b^k_{i,k}/b^k_{k,k}$ and add to raw i, $i = k+1, \ldots, n$. We obtain that for $i > k$,

1. $b^{k+1}_{i,1} = \ldots = b^{k+1}_{i,k-1} = 0 + 0 = 0$ and $b^{k+1}_{i,k} = b^k_{i,k} - b^k_{k,k} \times (b^k_{i,k}/b^k_{k,k}) = 0$.
2. Since for $i = k+1, \ldots, n$ and for $j \neq i$, $j \geqslant k+1$, $b^k_{i,i} > b^k_{i,j}$, and since $b^k_{k,k+1} = \ldots = b^k_{k,n}$, it follows that for each $i > k$, the same number is added to $b^k_{i,k+1}, \ldots, b^k_{i,n}$, hence $b^{k+1}_{i,i} > b^{k+1}_{i,j}$ for all $j \neq i$, $j \geqslant k+1$.
3. For $i, j > k$, $j \neq i$, $b^{k+1}_{i,j} > 0$ iff $b^k_{i,j}(1 - b^k_{k,j}/b^k_{k,k}) > 0$ iff $b^k_{k,k} > b^k_{k,j}$, which hold for B^k. In particular, $b^{k+1}_{i,i} > b^{k+1}_{i,j} > 0$.

By construction, $\det(B) = \det(B^1) = \ldots = \det(B^n) = \prod_i b^n_{i,i} > 0$. Similarly, $\det(C_j) > 0$, where C_j is obtained from B by replacing column j of B with $\left(0, \ldots, 0, g^i_1\left(\alpha_i, \sum_{j \neq i} \frac{\beta_j}{n-1}\right), 0, \ldots, 0\right)^T$. It thus follows from the system of linear equations (1) that for all i, j, $\frac{\mathrm{d}\beta_j}{\mathrm{d}\alpha_i} > 0$. All committee members are now more inclined to choose candidate B, and as he was preferred to A before the shift, he is certainly preferred after.

Unanimity: Suppose that all agents have the same social influence function $g(\alpha, \beta)$ such that β is the average preferences of everyone else. If $g(\alpha, \alpha) > \alpha$ and all agents have the core preferences α, then the equilibrium occurs at $\beta > \alpha$ (see Claim 6 in FS). Let α' and β' be such a pair where $\beta' = g(\alpha', \beta')$. If $\alpha' < \gamma < \beta'$ then by their core preferences all agents prefer A to B (since $\alpha' < \gamma$), but by the behavioral preferences they would vote for B, that is $B \succ A$ since $\gamma < \beta'$.[12]

Consistency: Consider a committee with four members. Three of them are identical with core preferences just below the critical value γ, while the core preferences of the fourth are at α_4 which is much larger than γ. It is easy to construct social influence functions that will imply $\beta' = \beta_1 = \beta_2 = \beta_3 > \alpha' = \alpha_1 = \alpha_2 = \alpha_3$, and therefore, if $\gamma \in (\alpha', \beta')$, the committee will vote for B. Add now a new member with $\alpha_5 > \gamma$ but sufficiently close to γ. If the new β value of the first three members of the original committee is less than before, then it is possible to have γ between their new and old values of β. The majority will now vote for A, and the committee's preferences are

[12] This proof is stronger than the claim itself, as it shows that it is possible that prior to the deliberation all members favor one candidate but as a result of the deliberation all of them favor the other candidate.

reversed. ■

So far we've considered some possible changes in committee's vote when the distribution of core preferences of committee members is changed by replacing or by adding a committee member. We now consider situations where the distribution of core preferences does not change and examine whether such changes may still affect committees' vote. An m-replica of a committee is a committee which is m times larger but with the same distribution of core preferences as the original one. That is, instead of having a committee with n individuals we have mn members such that for each i there are m members with the same core preferences α_i and the same social influence function.

Property 4 (Stability under Replication): The deliberation process would be *stable under replica* if when we replicate the committee its decision will not change.

Claim 3 The deliberation process is *not* stable under replication.

Proof: The claim is proved by means of an example, using the following lemma.

Lemma 1 Consider a committee with two types of n members each. If $\alpha_1 < \alpha_2$ (and hence $\beta_1 < \beta_2$), then β_1 is decreasing and β_2 is increasing with n.

For the proof of this lemma, see the appendix. It follows that doubling the size of a committee with two types of equal size will push the two behavioral preferences away from each other. Consider two committees where $\beta_1^n < \alpha_1 < \alpha_2 < \beta_2^n < \gamma$ and $\gamma < \bar{\beta}_1^n < \bar{\alpha}_1 < \bar{\alpha}_2 < \bar{\beta}_2^n$ but such that $\beta_1^{2n} < \alpha_1 <$

$\alpha_2 < \gamma < \beta_2^{2n}$ and $\bar{\beta}_1^{2n} < \gamma < \bar{\alpha}_1 < \bar{\alpha}_2 < \bar{\beta}_2^{2n}$. By unanimity, the first original committee will choose the first and the second committee will choose the second candidate. But when both committees are doubled in size, both are evenly split on both sides of γ. Whatever the tie-breaking rule, one of the new committees will decide the opposite of the original one. ■

The intuition of the above lemma is straightforward. While the distribution of preferences of committee members is not changed under replication, the distribution of preferences that each committee observes during the deliberation process is now different. Each person sees the same profile as before twice, with one important addition: an extra agent with the same preferences as his. The presence of this extra agent may affect his behavioral preferences.

4 Star Network: Committee with a Chair

There are situations in which there is one individual, the "chair," who is making the decision but there is a group of "advisors" or "directors" with whom he may consult and deliberate. This person can be a CEO of a company consulting with his board of directors or a president of a country deliberating or consulting with his cabinet members before making a decision. This kind of a committee can be modeled as a star network such that the chair is the agent in the center who is directly connected to all the other agents who may or may not be connected among themselves.

This type of advisory network can function in different ways. First we distinguish between a "deliberation process," in which the chair and the advisors deliberate the decision problem among themselves, and a "consultation process," in which the chair asks his advisors for their opinion but does not express his own. The main difference between the two processes is that in the former the chair participates in the deliberation and affects the preferences of his advisors while in the latter his role is more passive as he only listens to his advisors without expressing his own views and therefore without affecting the advisors' opinions.

We also distinguish between a "decentralized procedure" in which the chair discusses (or consults) the issue separately with each of his advisors and a "centralized procedure" in which there is an open discussion among all agents. The difference between the centralized procedure and the procedures of the previous sections is only the identity of the decision maker — the chair or the majority of the committee. But in a decentralized consulting procedure the chair is making the decision after listening to the advice of his advisors, while these advisors do not communicate with one another. We are interested in the effect of such procedures on the decisions made by the chair.

Formally, we consider the following network. There is a chair (agent 0) and a group of n committee members labeled $N = \{1, \ldots, n\}$. We assume for simplicity that all $n+1$ agents (chair and members) have the same social influence function g. We also assume that the n committee members have the same core preferences. The core preference parameter of the chair is given by α_0, and the core preferences parameters of the other n agents are all $\alpha_i = \alpha < \alpha_0$. There is a link between agent 0 and each of the n committee members. When there is a deliberation the link is not directed but consultation is modeled as a directed link (from the agent to the chair). When there is a centralized procedure all the agents are also linked while in the decentralized procedure there are no links between any two of the n committee members.

For the interpretations of our results we will continue to use our benchmark example of choosing between two candidates with two attributes such that candidate A is stronger in the first attribute and candidate B is stronger in the second. Therefore, when the chair ends up with a higher β, it makes candidate B more attractive.

We start by considering the consultation process, in which the chair listens to his team but does not express his own view, and the effect of decentralization on the outcome of such a process. That is, we compare the behavioral preferences of the chair when there is a decentralized consultation process, denoted β_0^{CD}, with his behavioral preferences when there is a centralized consultation process, denoted β_0^{CC}.

Claim 4 (Consultation): If $\alpha < \alpha_0$, then $\beta_0^{CC} > \beta_0^{CD}$ iff $g(\alpha, \alpha) > \alpha$. That is, under a centralized consultation procedure candidate B looks more attractive than under the decentralized consultation procedure iff $g(\alpha, \alpha) > \alpha$.

Proof: If agents do not deliberate among themselves, then there is no change in their preferences and therefore $\beta^{CD} = \alpha$ and $\beta_0^{CD} = g(\alpha_0, \alpha)$. When the n agents deliberate among themselves their equilibrium behavioral preference is given by $\beta^{CC} = g(\alpha, \beta^{CC})$. By Claim 6 in FS, $\beta^{CC} = g(\alpha, \beta^{CC}) > \alpha$ iff $g(\alpha, \alpha) > \alpha$. And since $g_2 > 0$, $\beta_0^{CC} = g(\alpha_0, \beta^{CC}) > g(\alpha_0, \alpha) = \beta_0^{CD}$. ∎

Turning back to our leading example of choosing between two candidates A and B, claim 4 implies that when $g(\alpha, \alpha) > \alpha$, letting members of the board to deliberate with one another prior to consulting the chair will make candidate B look stronger as $\beta_0^{CC} > \beta_0^{CD}$ and when $g(\alpha, \alpha) < \alpha$, deliberation among the agents makes candidate A stronger.

To understand this effect, consider a situation in which the two relevant attributes are teaching and research. An agent has a core preferences α, but he also believes that relative to other committee members he is putting more emphasis on research relative to teaching. When the committee deliberates he finds out that this is not true and that his preferences are not different from those of other committee members. His reaction would be to adopt a behavioral preferences $\beta > \alpha$. This is the type of scenarios that are captured by the condition $g(\alpha, \alpha) > \alpha$. Claim 4 now captures the intuition that in cases like this when there is a deliberation among committee members before they consult the chair, the deliberation leads to a higher β which affects the chair's behavioral preferences, inducing $\beta_0^{CC} > \beta_0^{CD}$.

Consider now the case in which there is a deliberation between the chair and his advisors during which the chair does not only listen to his team, but also reveals his views to them. In the decentralized procedure the chair deliberates with each of the committee members separately but they do not deliberate among themselves. Denote by β^{DD} and β_0^{DD} the equilibrium behavioral preferences of this procedure. The equilibrium conditions are $\beta^{DD} = g(\alpha, \beta_0^{DD})$ and $\beta_0^{DD} = g(\alpha_0, \beta^{DD})$. In the centralized deliberation procedure on the other hand, the chair and his advisors openly deliberate the problem among themselves. Let β^{DC} and β_0^{DC} be the equilibrium behavioral preferences of this centralized deliberation procedure, where $\beta_0^{DC} = g(\alpha_0, \beta^{DC})$ and $\beta^{DC} = g(\alpha, \frac{\beta_0^{DC}+(n-1)\beta^{DC}}{n})$.

Claim 5 If $\alpha < \alpha_0$, then $\beta_0^{DC} > \beta_0^{DD}$. That is, centralized deliberation of the chair and the committee results in lower emphasis on the second attribute than in a procedure in which the deliberation is with each advisor separately.

Proof: We start with the case DD in which the chair debates with each advisor separately. Consider the behavioral preferences of each advisor which is a function of his core preferences and the behavioral preferences of the chair. I.e., $\beta(\alpha, \beta_0) \equiv g(\alpha, \beta_0)$. Given that $g_2 > 0$, this function is increasing in β_0. Also, $\beta_0(\alpha_0, \beta) \equiv g(\alpha_0, \beta)$ are the behavioral preferences of the chair given his core preferences and the behavioral preferences of the agents. Figure 1 depicts both functions in a $(\beta \times \beta_0)$ space letting (α, α_0) be fixed parameters. The intersection (β^{DD},β_0^{DD}) (point s in figure 1) is an equilibrium of the decentralized deliberation process as $\beta^{DD} = g(\alpha, \beta_0^{DD})$ and $\beta_0^{DD} = g(\alpha_0, \beta^{DD})$. Note also that the equilibrium point is above the 45° line as given that $\alpha < \alpha_0$ at equilibrium $\beta^{DD} < \beta_0^{DD}$.

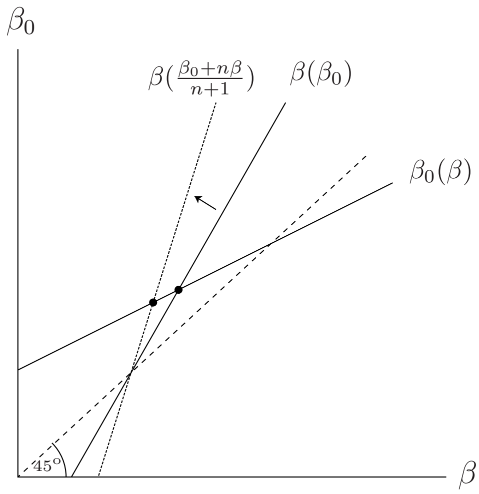

Figure 1: Proof of Claim 5

Examine now the equilibrium of the centralized deliberation process. The function $\beta_0(\alpha_0, \beta)$ is the same as before. The function that determines the behavioral preferences of the advisors given the behavioral preferences of the chair is given now by $\beta = g(\alpha, \frac{\beta_0+(n-1)\beta}{n})$.[13] This curve is a left rotation of the curve $\beta(\alpha, \beta_0)$ around the symmetric point (which is the intersection of the 45° line and the $\beta(\alpha, \beta_0)$ function). The reason is that when $\beta = \beta_0$, the two functions imply the same behavioral preferences. It is a left rotation because for all the points above the 45° line $\beta < \beta_0$ and therefore the function for the centralized procedure yields a higher value. The intersection q between the two curves, $\beta_0(\alpha_0, \beta)$ and $\beta = g(\alpha, \frac{\beta_0+(n-1)\beta}{n})$ yields the equilibrium for the centralized deliberation case. As depicted in Figure 1, comparing the two equilibria points yields that $\beta_0^{DC} > \beta_0^{DD}$. ■

Note that the effect of decentralization on the deliberation process differs from its effect when there is a consultation procedure. When there is deliberation the centralized procedure, in which all the agents interact with each other, leads to a higher β. In the consultation case the effect depends on $g(\alpha, \alpha)$.

Next, we compare the consultation and the deliberation procedure assuming they both adopt the decentralized protocol.

Claim 6 Assume $g(\alpha, \alpha) > \alpha$. Then when $\alpha < \alpha_0$, $\beta_0^{DD} > \beta_0^{CD}$. That is, when there is a decentralized protocol the deliberation procedure yields a higher β, which implies that candidate B looks relatively stronger to the chair under the deliberation procedure.

[13] We can put a higher weight on β_0 if the opinion of the chair is more influential.

Proof: Under the consultation procedure, $\beta^{CD} = \alpha$ and $\beta_0^{CD} = g(\alpha_0, \alpha)$. Under the deliberation procedure $\beta^{DD} = g(\alpha, \beta_0^{DD})$ and $\beta_0^{DD} = g(\alpha_0, \beta^{DD})$. We show first that $\beta^{DD} > \alpha$. If the core preference of the chair is α, then the β values of all members are the same as those of the chair, and they must be larger than the common α. Otherwise, if the common β is (weakly) less than α, then we get the equilibrium equation $\beta = g(\alpha, \beta) \geqslant g(\beta, \beta) > \beta$, a contradiction. As $\alpha_0 > \alpha$, the β value of the chair is higher, and consequently, so is the β values of the rest of the committee.

Since $\beta_0^{DD} = g(\alpha_0, \beta^{DD})$ and $\beta^{DD} > \alpha$, it follows that $\beta_0^{DD} > g(\alpha_0, \alpha) = \beta_0^{CD}$, hence the claim. ■

5 Procedure of Deliberation and Voting

Committees may have different voting and deliberation procedures. In some cases members may choose not to express their opinion or explain their vote. In other cases they must explain their decision (e.g., judges that sit together on the bench). There are committees in which members do not have to attend meetings, they may just send their written vote. Voting can be done simultaneously or sequentially (and in a different order). In this section we demonstrate that procedures may affect the formation of the behavioral preferences and the outcomes of committees' voting. We focus on two aspects of the voting procedure: (i) the requirement to participate in the deliberation and (ii) the effect of the order of deliberation and voting in a sequential procedure.

In order to demonstrate these effects we consider an investment committee consisting of three members who need to vote on whether to accept or reject risky projects. We consider two possible decision rules. The first is a majority rule in which a project is accepted only when at least two members vote to accept it. The second is a unanimity rule in which acceptance requires the support of all three members of the committee. Risk aversion is captured by a single parameter: α (for the core preferences) and β (for the behavioral preferences).[14] Higher values of α and β imply higher levels of risk aversion. Each new project is characterized by a risk index γ such that individuals with $\beta \leqslant \gamma$ vote to accept the project and those with $\beta > \gamma$ reject it. A higher γ implies that the project is less risky as even individuals with a higher level of risk aversion will vote to accept it.

Suppose that the three members have the same social influence function g, but they differ in their core preferences which are given by $\alpha_1 < \alpha_2 < \alpha_3$ with the behavioral preferences $\beta_1, \beta_2, \beta_3$. Denote by $\gamma_m(\beta_1, \beta_2, \beta_3)$ and $\gamma_u(\beta_1, \beta_2, \beta_3)$ the critical risk indices under the majority and the unanimity rules, respectively, such that all projects characterized by values of γ higher than these values will be accepted. Clearly, $\gamma_m \leqslant \gamma_u$, as any project that is accepted by all members is also accepted by at least two members.

When there is no deliberation $\beta_i = \alpha_i$. When there is a deliberation with the participation of all committee members then by Claim 7 in FS, $\beta_1 < \beta_2 < \beta_3$, therefore $\gamma_m(\beta_1, \beta_2, \beta_3) = \beta_2$ and $\gamma_u(\beta_1, \beta_2, \beta_3) = \beta_3$. We simplify our analysis and assume that the social influence function used by all members is such that $g(\alpha, \alpha) = \alpha$ which means that when the core pref-

[14] For example, all members are expected utility maximizers with the vNM utility $\alpha u + (1 - \alpha)\tilde{u}$, where u is a concave transformation of $\tilde{u}$.

erences of a certain member and the average behavioral preferences of other members are the same, then so are the resulting behavioral preferences of that person. Under this assumption (see Claim 8 in FS), equilibrium behavioral preferences move towards the average such that $\beta_1 > \alpha_1$, $\beta_3 < \alpha_3$, but the relationship between β_2 and α_2 is unclear. Therefore, under the unanimity rule $\gamma_u(\beta_1, \beta_2, \beta_3) < \gamma_u(\alpha_1, \alpha_2, \alpha_3)$, which implies that as a result of deliberation and social influence there is a larger set of projects that will be acceptable by the committee. However, if a committee uses the majority rule then the effect of deliberation is unclear as both $\beta_2 > \alpha_2$ and $\beta_2 < \alpha_2$ are possible.

5.1 The effect of no participation in the deliberation

There are committees in which members are allowed to vote without participating in the debate or without explaining their opinion. In other cases, members of the committee must explain their vote and participate in the debate. These rules affect the formation of behavioral preferences. Members who do not express their opinions do not influence other committee members and those who do not participate in the debate at all are not influenced by others. To demonstrate this effect we consider in this subsection once again a 3-person committee in which one of its members, person i, does not take part in the deliberation process, and therefore $\beta_i = \alpha_i$. We continue to assume that all members have the same social influence function g and that $g(\alpha, \alpha) \equiv \alpha$. Denote the behavioral preferences of person j by β^i_j. The analysis of this situation depends on the identity of the non-participating individual.

Claim 7 Suppose that $g(\alpha, \alpha) \equiv \alpha$. If person 1 does not participate in the deliberation, then both unanimity and majority rules accept less projects than the case in which all members participate in the deliberation. But if player 3 does not participate, then the unanimity rule accepts less while the majority rule accepts more projects than the case of full deliberation.[15]

Proof: If person 1 does not participate in the deliberation, then $\beta_1^1 = \alpha_1$. We show first that $\beta_2^1 > \beta_2$ and $\beta_3^1 > \beta_3$. Observe that by Claim 8 in FS, $\beta_2^1 > \alpha_2$. If $\beta_2 \leqslant \alpha_2$, then clearly $\beta_2^1 > \beta_2$, and since $\beta_2 > \beta_1$,

$$\beta_3^1 = g(\alpha_3, \beta_2^1) > g(\alpha_3, \tfrac{1}{2}[\beta_1 + \beta_2]) = \beta_3$$

Suppose that $\beta_2 > \alpha_2$ but $\beta_2^1 \leqslant \beta_2$. Since by Fact 1 part 2 $\beta_1 < \beta_3$,

$$\begin{aligned}
&\beta_2 = g(\alpha_2, \tfrac{1}{2}[\beta_1 + \beta_3]) \geqslant \beta_2^1 = g(\alpha_2, \beta_3^1) \Longrightarrow \\
&\tfrac{1}{2}[\beta_1 + \beta_3] \geqslant \beta_3^1 \Longrightarrow \\
&\beta_3 > \beta_3^1
\end{aligned} \tag{2}$$

Also, since $g_2 < 1$,

$$\begin{aligned}
&\left.\begin{aligned}
&\beta_2 = g(\alpha_2, \tfrac{1}{2}[\beta_1 + \beta_3]) > \\
&\beta_2^1 = g(\alpha_2, \beta_3^1)
\end{aligned}\right\} \Longrightarrow \\
&\beta_2 - \beta_2^1 < \tfrac{1}{2}[\beta_1 + \beta_3] - \beta_3^1
\end{aligned} \tag{3}$$

[15] The case where person 2 does not participate is more involved and the analysis depends on whether β_2 is above or below the average of β_1 and β_3.

Similarly, using inequality (2)

$$\left.\begin{aligned}&\beta_3 = g(\alpha_3, \tfrac{1}{2}[\beta_1+\beta_2]) > \\ &\beta_3^1 = g(\alpha_3, \beta_2^1)\end{aligned}\right\} \Longrightarrow$$

$$\beta_3 - \beta_3^1 < \tfrac{1}{2}[\beta_1+\beta_2] - \beta_2^1 \tag{4}$$

Combining inequalities (3) and (4) together and recalling that $\beta_1 < \beta_2$, we get

$$2\beta_3 - 2\beta_3^1 < \beta_1 + \beta_2 - 2\beta_2^1 < 2\beta_2 - 2\beta_2^1 < \beta_1 + \beta_3 - 2\beta_3^1 \Longrightarrow$$

$$\beta_3 < \beta_1$$

A contradiction, hence $\beta_2^1 > \beta_2$. And since $\beta_1 < \beta_2$, it follows that $\beta_2^1 > \frac{1}{2}[\beta_1+\beta_2]$, hence $\beta_3^1 > \beta_3$. It thus follows that both unanimity (determined by person 3) and majority (determined by person 2) rules accept less projects than the case in which all members participate in the deliberation

Suppose now that person 3 does not participate. Then by Claim 8 in FS, $\beta_3^3 = \alpha_3 > \beta_3$ and the unanimity rule will accept less projects. Since $\beta_2^3 > \beta_1^3$ (Claim 7 in FS), in order to show that the majority rule will accept more project it is enough to show that $\beta_2 > \beta_2^3$. Since by the aforementioned claim, $\alpha_2 > \beta_2^3$, this is clearly the case when $\beta_2 \geqslant \alpha_2$. We therefore prove the impossibility of $\alpha_2 > \beta_2^3 > \beta_2$. Otherwise,

$$\beta_2^3 = g(\alpha_2, \beta_1^3) \geqslant \beta_2 = g(\alpha_2, \tfrac{1}{2}[\beta_1+\beta_3]) \Longrightarrow \beta_1^3 > \beta_1$$

Since $g_2 < 1$, we get

$$\left.\begin{aligned}&\beta_2^3 - \beta_2 < \beta_1^3 - \tfrac{1}{2}[\beta_1+\beta_3] \\ &\beta_1^3 - \beta_1 < \beta_2^3 - \tfrac{1}{2}[\beta_2+\beta_3]\end{aligned}\right\} \Longrightarrow$$

$$2\beta_3 < \beta_1 + \beta_2$$

A contradiction to the fact that $\beta_3 > \beta_2 > \beta_1$. ■

Claim 7 demonstrates that not participating in the debate may affect the decision of the committee but this effect depends on the identity of the non-participating agents. While we do not consider in this paper a strategic manipulation of the deliberation procedure, clearly a choice not to participate or to exclude some committee members from the deliberation may have a strategic element, affecting the voting outcome.

5.2 The effect of the order of deliberation.

There are many situations in which deliberation and voting is done sequentially. The order may be according to seniority, rank, or even by a lottery. In this subsection we analyze the effect of the order of deliberation on the outcome of the debate. Note that if there is no social influence, then the order has no effect as members express their core preferences which are unaffected by the opinion of others. But if behavioral preferences are formed during the deliberation then the order of the the deliberation may play an important role in shaping those preferences as committee members are influenced only by individuals who have already expressed their opinions.

We consider a committee consisting of three members expressing their views sequentially. The first person hears no other views, so his critical value equals his core value. The second person is influenced only by the first, while the third person is influenced by the other two. Denote the order i-j-k. We get $\beta_i = \alpha_i$, $\beta_j = g(\alpha_j, \beta_i) = g(\alpha_j, \alpha_i)$, and

$$\beta_k = g(\alpha_k, \tfrac{1}{2}[\beta_i + \beta_j]) = g(\alpha_k, \tfrac{1}{2}[\alpha_i + g(\alpha_j, \alpha_i)])$$

Denote the six procedures (a) 1-2-3, (b) 1-3-2, (c) 2-1-3, (d) 2-3-1, (e) 3-1-2, and (f) 3-2-1. We say that two members are consistent if the order of their behavioral parameters β is the same as the order of their core preferences α.

Claim 8 Suppose that $g(\alpha, \alpha) \equiv \alpha$ and that $\alpha_1 < \alpha_2 < \alpha_3$. Under procedures (a) and (f), $\beta_1 < \beta_2 < \beta_3$. Under procedures (b) and (e), the order between the behavioral parameters of the last two speakers may disagree with their core preferences, but they are consistent with that of the first speaker. Finally, under procedures (c) and (d) the behavioral parameters of the middle speaker is consistent with that of each of the other speakers, but both orders of the first and last speaker are possible.

Proof: Since $g_1, g_2 \in (0, 1)$, it follows that

$$\left.\begin{array}{l} \beta_2^{\mathrm{a}} = g(\alpha_2, \alpha_1) > g(\alpha_1, \alpha_1) = \alpha_1 = \beta_1^{\mathrm{a}} \\ \beta_3^{\mathrm{a}} = g(\alpha_3, \frac{1}{2}[\alpha_1 + g(\alpha_2, \alpha_1)]) > g(\alpha_2, \alpha_1) = \beta_2^{\mathrm{a}} \end{array}\right\} \Longrightarrow \beta_1^{\mathrm{a}} < \beta_2^{\mathrm{a}} < \beta_3^{\mathrm{a}}$$

A similar argument holds for procedure (f).

Next we show that under procedure (b) it may happen that $\beta_2^{\mathrm{b}} > \beta_3^{\mathrm{b}}$, but both must be greater than β_1^{b}. The proof that under procedure (e) it may happen that $\beta_2^{\mathrm{b}} < \beta_1^{\mathrm{b}}$, but both must be less than β_3^{b}, is similar.

We have $\beta_3^{\mathrm{b}} = g(\alpha_3, \alpha_1) > \alpha_1 = \beta_1^{\mathrm{b}}$ and $\beta_2^{\mathrm{b}} = g(\alpha_2, \frac{1}{2}[\alpha_1 + g(\alpha_3, \alpha_1)]) > g(\alpha_2, \alpha_1) > \alpha_1 = \beta_1^{\mathrm{b}}$. Observe however that when $\alpha_3 = \alpha_2$, $\beta_3^{\mathrm{b}} = g(\alpha_2, \alpha_1) < g(\alpha_2, \frac{1}{2}[\alpha_1 + g(\alpha_2, \alpha_1)]) = \beta_2^{\mathrm{b}}$. On the other hand, for symmetric g, if $\alpha_2 = \alpha_1$, then $\beta_2^{\mathrm{b}} = g(\alpha_1, \frac{1}{2}[\alpha_1 + g(\alpha_3, \alpha_1)]) < g(\alpha_1, \alpha_3) = g(\alpha_3, \alpha_1) = \beta_3^{\mathrm{b}}$.

Finally, consider procedure (c). Since $g(a, a) \equiv a$ and $g_1, g_2 \in (0, 1)$, it follows that $\beta_2^{\mathrm{c}} = \alpha_2 > g(\alpha_1, \alpha_2) = \beta_1^{\mathrm{c}}$. But as $\beta_3^{\mathrm{c}} = g(\alpha_3, \frac{1}{2}[\alpha_2 + g(\alpha_1, \alpha_2)])$, it follows that for $\alpha_2 = \alpha_1$, $\beta_3^{\mathrm{c}} = g(\alpha_3, \alpha_2) > \alpha_2 = \beta_2^{\mathrm{c}} > \beta_1^{\mathrm{c}}$. On the other hand, if $\alpha_3 = \alpha_2$, $\beta_3^{\mathrm{c}} = g(\alpha_3, \frac{1}{2}[\alpha_3 + g(\alpha_1, \alpha_3)]) < g(\alpha_3, \alpha_3) = \alpha_3 = \beta_2^{\mathrm{b}}$ while for symmetric g, $\beta_3^{\mathrm{c}} = g(\alpha_2, \frac{1}{2}[\alpha_2 + g(\alpha_1, \alpha_2)]) > g(\alpha_2, \alpha_1) = g(\alpha_1, \alpha_2) = \beta_1^{\mathrm{c}}$. The analysis of case (d) is similar. ■

6 Concluding Remarks

There are many decisions that are done by committees. But before making decisions committee members typically discuss the problems, exchange relevant information, and try to convince each other regarding the right choice. Our paper focuses on social influence and not on information exchange. We present a model of social influence in which the deliberation and voting protocols as well as the core preferences of committee members affect the pattern of social influence and consequently the committee's decision. Our model of social influence is of an automatic process that occurs between individuals who influence each other without necessarily being aware of it. Under this approach there is no role for strategic manipulation of preferences. However, one can still consider strategic manipulation of deliberation and voting protocols. Such manipulations may include the order of speaking and voting in the committee, the protocol of meetings, etc. In particular when there is a chair or another person in control of these protocols and if this person is aware of the social influence aspect of the committee deliberation, this person may manipulate the protocol in order to change the committee's decisions.

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Appendix

Proof of Lemma 1: We have

$$\beta_1 = g^1\left(\alpha_1, \frac{(n-1)\beta_1 + n\beta_2}{2n-1}\right)$$
$$\beta_2 = g^2\left(\alpha_2, \frac{n\beta_1 + (n-1)\beta_2}{2n-1}\right)$$

Consider n as a continuoius variable, and ake the total differantial of the above system wrt β_1, β_2, and n to obtain

$$\begin{aligned}
&\left[g_2^1\left(\alpha_1, \frac{(n-1)\beta_1 + n\beta_2}{2n-1}\right)\left(\frac{n-1}{2n-1}\right) - 1\right]\mathrm{d}\beta_1 + \\
&\qquad\left[g_2^1\left(\alpha_1, \frac{(n-1)\beta_1 + n\beta_2}{2n-1}\right)\left(\frac{n}{2n-1}\right)\right]\mathrm{d}\beta_2 = \\
&\qquad\qquad -\left[g_2^1\left(\alpha_1, \frac{(n-1)\beta_1 + n\beta_2}{2n-1}\right)\left(\frac{\beta_1-\beta_2}{(2n-1)^2}\right)\right]\mathrm{d}n
\end{aligned}$$

$$\begin{aligned}
&\left[g_2^2\left(\alpha_1, \frac{n\beta_1 + (n-1)\beta_2}{2n-1}\right)\left(\frac{n}{2n-1}\right)\right]\mathrm{d}\beta_1 + \\
&\qquad\left[g_2^2\left(\alpha_1, \frac{n\beta_1 + (n-1)\beta_2}{2n-1}\right)\left(\frac{n-1}{2n-1}\right) - 1\right]\mathrm{d}\beta_2 = \\
&\qquad\qquad -\left[g_2^2\left(\alpha_1, \frac{n\beta_1 + (n-1)\beta_2}{2n-1}\right)\left(\frac{\beta_2-\beta_1}{(2n-1)^2}\right)\right]\mathrm{d}n
\end{aligned}$$

Rewrite these equations as

$$\left.\begin{aligned}
A\frac{\mathrm{d}\beta_1}{\mathrm{d}n} + B\frac{\mathrm{d}\beta_2}{\mathrm{d}n} &= -C \\
D\frac{\mathrm{d}\beta_1}{\mathrm{d}n} + E\frac{\mathrm{d}\beta_2}{\mathrm{d}n} &= -F
\end{aligned}\right\} \Longrightarrow \begin{aligned}
\frac{\mathrm{d}\beta_1}{\mathrm{d}n} &= \frac{BF - CE}{AE - BD} \\
\frac{\mathrm{d}\beta_2}{\mathrm{d}n} &= \frac{CD - AF}{AE - BD}
\end{aligned}$$

Hence

$$\left.\begin{aligned}\frac{\mathrm{d}\beta_1}{\mathrm{d}n} &= \frac{g_2^1 g_2^2[n(\beta_2-\beta_1)-(n-1)(\beta_1-\beta_2)]+g_2^1(2n-1)(\beta_1-\beta_2)}{g_2^1g_2^2[(n-1)^2-n^2](2n-1)-[g_2^1+g_2^2](n-1)(2n-1)^2+(2n-1)^3}\\ \frac{\mathrm{d}\beta_2}{\mathrm{d}n} &= \frac{g_2^1 g_2^2[n(\beta_1-\beta_2)-(n-1)(\beta_2-\beta_1)]+g_2^2(\beta_2-\beta_1)(2n-1)}{g_2^1g_2^2[(n-1)^2-n^2](2n-1)-[g_2^1+g_2^2](n-1)(2n-1)^2+(2n-1)^3}\end{aligned}\right\}\Longrightarrow$$

$$\begin{aligned}\frac{\mathrm{d}\beta_1}{\mathrm{d}n} &= \frac{g_2^1(1-g_2^2)(\beta_1-\beta_2)}{-g_2^1g_2^2(2n-1)-[g_2^1+g_2^2](n-1)(2n-1)+(2n-1)^2}\\ \frac{\mathrm{d}\beta_2}{\mathrm{d}n} &= \frac{g_2^2(1-g_2^1)(\beta_2-\beta_1)}{-g_2^1g_2^2(2n-1)-[g_2^1+g_2^2](n-1)(2n-1)+(2n-1)^2}\end{aligned}$$

The denominators are the same, and since $g_2^1 < 1$ and $g_2^2 < 1$, it follows that β_1 and β_2 move in opposite directions. Suppose that $\beta_1^{n+1} > \beta_1^n$ while $\beta_2^{n+1} < \beta_2^n$, hence

$$\beta_2^{n+1} - \beta_1^{n+1} < \beta_2^n - \beta_1^n \tag{5}$$

By the definition of β and the monotonicity of the function g with respect to its second argument, we get

$$\begin{aligned}&\beta_1^{n+1} > \beta_1^n \Longleftrightarrow \frac{n\beta_1^{n+1}+(n+1)\beta_2^{n+1}}{2n+1} > \frac{(n-1)\beta_1^n+n\beta_2^n}{2n-1} \Longleftrightarrow\\ &n(2n-1)\beta_1^{n+1}+(n+1)(2n-1)\beta_2^{n+1} > (n-1)(2n+1)\beta_1^n+n(2n+1)\beta_2^n\end{aligned}$$

While

$$\begin{aligned}&\beta_2^{n+1} > \beta_2^n \Longleftrightarrow \frac{(n+1)\beta_1^{n+1}+n\beta_2^{n+1}}{2n+1} < \frac{n\beta_1^n+(n-1)\beta_2^n}{2n-1} \Longleftrightarrow\\ &(n+1)(2n-1)\beta_1^{n+1}+n(2n-1)\beta_2^{n+1} < n(2n+1)\beta_1^n+(n-1)(2n+1)\beta_2^n\end{aligned}$$

Adding these inequalities to each other we get

$$\begin{aligned}&(2n-1)\beta_2^{n+1}+(2n+1)\beta_1^n > (2n-1)\beta_1^{n+1}+(2n+1)\beta_2^n \Longleftrightarrow\\ &\frac{\beta_2^{n+1}-\beta_1^{n+1}}{2n+1} > \frac{\beta_2^n-\beta_1^n}{2n-1}\end{aligned}$$

A contradiction to eq. (5). $\blacksquare$