Committee composition: The impact of diversity and partisanship on voting behavior*

Anne-Katrin Roesler†

July 7, 2022

Abstract

We propose and analyze a committee model in which players with interdependent values vote on whether to accept an alternative or to stay with the status quo. Players hold two-dimensional private information: They obtain a private signal about the payoff state, and have a private preference type. The latter reflects a player's level of partisanship and determines how they aggregates signals into preferences.

We show that, in equilibrium, committee members adopt cutoff strategies and cutoffs are monotone in preference types. We identify how the composition of a committee, i.e. the distribution of private preference types, affects its decisions. As the population from which committee members are drawn becomes more partisan (a first-order stochastic dominance shift) equilibrium cutoffs move away from the sincere voting threshold. By contrast, more heterogeneity of committee members (a mean-preserving spread) leads to equilibrium cutoffs closer to the sincere voting threshold. In this case, a player who faces more uncertainty about the preferences of others bases his vote more on his own privately observed signal.

*An early version of this paper has been circulated with the title *Preference Uncertainty and Conflict of Interest in Committees.*

†Department of Economics, University of Toronto, 150 St George St, Toronto, Canada. ak.roesler@utoronto.ca.
I thank Benny Moldovanu, Heski Bar-Isaac, Dirk Bergemann, Rahul Deb, Johannes Hörner, Daniel Krähmer, Marcin Peski, and various seminar and conference audiences for helpful comments and discussion. The most recent version of this paper is available at here.

1 Introduction

In most organizations, complex decisions are made by committees, not by individuals. Corporate boards decide how to invest, whom to hire, and whether or not to adopt a new technology. Similarly, the allocation of research grants, the approval of new drugs by the FDA, and academic hiring are typically committee decisions, and these decisions are reached by voting.

Due to the complexity of matters that are voted upon, committee members often cannot assess all information about the proposal. Rather, they pay attention to the details that are most important to them, but are aware that other aspects—and hence the signals (i.e., information) held by other committee members—also contain relevant information. In such situations it seems natural to assume that members put (weakly) more weight on their own signal than on information held by others. That is, members differ in how they aggregate available information into preferences. Even if members have the same information, they may disagree on whether a proposal should be accepted or not. Therefore, committee members typically have interdependent, but not purely common, preferences.[1]

In these contexts, it seems natural to assume that committee members have two-dimensional private information: First, they possess a private signal about the proposal to be voted upon, which is payoff-relevant to all players. Second, players also have private information about their *preference type*, which determines how they aggregate available information about the proposal into preferences. In this paper, we propose a committee voting framework where players have interdependent preferences and private preference types.

In our model, n players vote whether to accept a proposal $x = (x_1, \dots, x_n)$ or to stick to the status quo. The decision is made by generalized majority voting. The private signals $x_i \in [x_i^\ell, x_i^h]$ are determined by independent draws from commonly known distributions F_i, for all $i = 1, \dots, n$. Player i evaluates proposal x at $\theta_i x_i + (1 - \theta_i) \sum_{j \neq i} x_j$, where $\theta_i \in [1/n, 1]$ is the player's (private) preference type, which is drawn from a commonly known distribution G_i. All players value the status quo at zero. We assume that x_i and θ_i are private information of player i. Here, x_i can be interpreted as a private signal about the payoff-relevant state, and θ_i is the player's level of *partisanship*, which is the extent to which he favors his own private signal over the average signal held by other players. One can interpret this model as a committee of partisan experts who can each evaluate the proposal in their field of expertise and each favor their own field. An alternative interpretation is that by assessing the proposal players obtain a private signal, and the private preference type captures their excess confidence in their own assessment abilities relative to the abilities of others.

Note that the distribution of private preference types represents the *population* from which committee members are drawn. The use of private preference types captures the idea that the partisanship level of an individual is intrinsic in nature, and this can be regarded as part of their personality. Consequently, there is conflict of interest among committee members, though there is uncertainty about the extent of the conflict. Since players hold two-dimensional private informa-

[1] This is in contrast to the traditional assumption in the voting literature that players share a common interest.

tion, even if all private signals about the state were made public, players would still hold private information about how they aggregate these signals into preferences; therefore, we say there is *preference uncertainty.*

Our goal in this paper is to understand how private preference types, preference uncertainty, and the composition of the committee affect equilibrium voting behavior and outcomes in committee decisions. We first show that, in equilibrium, players adopt cutoff strategies, where the cutoffs (*acceptance standards*) reflect their level of partisanship. Players take into account the information about the other players' signals that they can derive from the event of being pivotal, which—depending on the majority rule—is either good news or bad news. Hence, players adjust their acceptance thresholds accordingly, thus moving away from the sincere voting threshold of zero. The amount of weight that players place on the information held by other players depends on their level of partisanship. Strongly partisan players base their votes primarily on their own observed signal, such that they adopt an acceptance threshold close to the sincere voting threshold of zero.[2] For example, under unanimity voting, being pivotal is good news. Hence, acceptance thresholds are non-positive where more partisan players adopt higher acceptance standards.

We focus on two novel questions that we can address with this framework: 1) How does the level of partisanship of the population from which committee members are drawn affect acceptance standards? 2) What can we say about committee decisions when the committee diversity is increased by drawing members from a more heterogeneous population?

The analysis is motivated by the observation that committees differ significantly in their composition. Partisanship levels of members naturally vary across committees. The distribution of partisanship levels of committee members depends, for example, on their cultural background or the culture within an organization. Members from individualistic cultures are more likely to show a high level of partisanship compared to their colleagues that have a more collectivist, socially-minded cultural background.[3] We therefore compare voting behavior across committees where the populations from which members are drawn differ by a first-order stochastic dominance shift.

A second dimension of the composition of committees is the heterogeneity of preference types of its members. Two committees whose members display the same average level of partisanship may still have member preference type distributions that differ in their heterogeneity.The partisanship levels of committee members may show a high or low level of variation.[4] If committee members stem from a group with diverse backgrounds, one would expect this population to display a higher level of preference heterogeneity. Understanding how more preference heterogeneity in the population affects voting behavior of committee members is of particular relevance nowadays in light of the

[2]The model is normalized such that the most partisan type—who has private values—will vote affirmatively if he observes a positive signal, and he will reject the proposal otherwise, which corresponds to an acceptance threshold of zero.

[3]Hofstede (1991) identifies individualism vs. collectivism as one dimension along which cultural differences can be analyzed, and Triandis (2001) links this cultural dimension to differences in personality and behavior.

[4]In existing voting models with interdependent values (e.g. Yildirim (2012), Moldovanu and Shi (2013), and Name Correa and Yildirim (2021)), all committee members have the same level of partisanship and hence the effect of changes in the distribution of committee members cannot be studied.

prevalence of diversity initiatives. Such diversity initiatives lead to more preference heterogeneity in organizations and eventually committees within those organizations as well. Similarly, committees or parliaments from small states like Luxembourg, Monte Carlo, or the Netherlands are less likely to display strong preference heterogeneity compared to a congress of a large states like the United States, Canada, or multinational assemblies, such as the European Union or the United Nations general assembly.

Our results provide insights into how the composition of committees, in terms of the distribution and the heterogeneity of preference types of its members, affects the acceptance standards in collective decisions. For the comparative statics analysis of analyzing behavior across committees from different populations, we consider a symmetric environment and the unanimity rule. We establish the existence of a unique symmetric voting equilibrium, which we focus on throughout the analysis.

We show that players who find themselves in a committee formed from a more partisan population (in the sense of a first-order stochastic dominance shift) adopt lower acceptance standards than when in a committee formed from a less partisan population. Intuitively, since under unanimity voting more partisan players adopt higher acceptance thresholds, shifting to a more partisan population results in the event of being pivotal being better news (for a fixed profile of strategies and in equilibrium as well). In other words, a player's expected value of the average signal of others conditional on being pivotal increases. In response, players adjust (lower) their acceptance standards to a greater extent. We will show that this counteracts, but does not completely offset, the initial effect.

How do players react if they find themselves in a committee composed of members from a more diverse population? In this case there is greater preference uncertainty. One might expect that this increased uncertainty leads to a player adopting a more lenient acceptance standard in order to avoid too few alternatives being accepted. However, the opposite occurs where greater preference uncertainty causes a player to increase his acceptance standard, thus voting based more on his own private signal. Greater heterogeneity of preference types leads to more uncertainty regarding why a player votes affirmatively: Is it because the player observed a high signal? Or, did he observe an intermediate signal that is still above his acceptance threshold since he is a less partisan preference type? In other words, the event of being pivotal is less informative about the other players' signals. Consequently, players base their vote more on their own signal and adopt a cutoff closer to the sincere voting threshold.

Related Literature. This paper contributes to the relatively small literature on committee voting models with interdependent values. Similar models where committee members have interdependent preferences and their level of partisanship determines their bias towards their own information are studied in Yildirim (2012), Moldovanu and Shi (2013), and Name Correa and Yildirim (2021). In these models all committee members possess the same preference type, which determines the conflict of interest among committee members. Our model departs from existing models in two ways. First, we assume that players have individual preference types. Second, these individual preference types are private to the players, and thus there is preference uncertainty. This modeling choices capture the idea that partisanship levels differ across individuals and are intrinsic in nature. We introduce a new model in which players hold two-dimensional private information to study new questions, such as: How do individual preference types differ in their equilibrium decisions, and how does the composition of a committee affect collective decisions?[5]

The aforementioned papers and ours therefore focus on different questions. Name Correa and Yildirim (2021) study how majority rules and the level of conflict of interest in a committee (captured by the level of partisanship of all committee members) affect collective decisions. For different majority rules they identify the optimal level of conflict—which they refer to as the composition of the committee—that a biased principal would choose if he had to delegate a decision to a committee.[6] By contrast, we allow for individual and private preference types and consider how the distribution of the population (which we refer to as committee composition) from which committee members are drawn affects committee decisions. Moldovanu and Shi (2013) consider a dynamic search model in which the decision to stop is made by a committee by unanimity voting. They characterize a stationary equilibrium in cutoff strategies. In this equilibrium, acceptance standards increase and welfare decreases in the level of conflict among committee members.[7]

Other interdependent values models that study collective decision making include Grüner and Kiel (2004) and Rosar (2015). They consider a different functional form of utilities (quadratic losses) and continuous collective decisions whereas we focus on a binary decision problem. Grüner and Kiel (2004) show that, with an unrestricted report space and from a utilitarian perspective, the average mechanism performs better in the common values case whereas the median mechanism is preferable for the private values case. By contrast, Rosar (2015) finds that with an optimally designed report space and for uniformly distributed information or large electorates, the average mechanism performs better for any degree of interdependence.

More broadly, this paper ties into the voting literature that goes back to Condorcet (1785). Building on seminal works such as Austen-Smith and Banks (1996) and Feddersen and Pesendorfer (1998), there is now extensive literature on collective decision making, which typically focuses on strategic voters who update their beliefs about the information held by other players conditional on the event of being pivotal. Li and Suen (2009) provide an excellent survey. Most of the traditional theoretical voting models study settings in which individuals share a common interest such that committee members would agree on the best outcome if they knew the state.[8] It is also common that an even stronger assumption is imposed where players have perfectly aligned preferences. This assumption implies that there is an underlying consensus where players would agree on the best

[5]A loosely related paper is Bardhi and Bobkova (2021) who study the selection of the composition of minipublics by policymakers and find that moderate political uncertainty leads to inefficiently low diversity.

[6]Yildirim (2012) identifies time-consistent majority rules, i.e., majority rules that a designer can implement if he cannot commit to a rule prior to observing the votes.

[7]Meyer and Strulovici (2013) extend some of the results of Moldovanu and Shi (2013) to more general preference structures.

[8]There is also a strand of literature that considers private value models and typically studies questions such as costly voting and voter turnout (e.g Börgers, 2004).

action if there was no asymmetric information (i.e. if all private information were publicly available).

Naturally, one may wish to allow for heterogeneity of committee members' preferences and there are different ways to do so. One option is to introduce a private value component in players' preferences. The model in this paper takes this approach as do the aforementioned papers with interdependent preferences. The analyzed interdependent values environment incorporates both the private values case as well as the common values case as special cases. Li, Rosen, and Suen (2001) choose a different approach to introduce heterogeneity among voters. They relax the assumption that players' preferences are perfectly aligned, but they still assume that players share a common objective. If there is uncertainty about the state there may be conflict of interest, but disagreement vanishes if all uncertainty is resolved. The authors discuss how the (known) level of conflict among committee members affects their incentives to strategically misrepresent their information and thus hinder information aggregation.

Given our focus on how the source population of committee members affects voting behavior and outcomes, this paper may also speak and contribute to the nascent literature on how board composition affects corporate board decisions (e.g Chemmanur and Fedaseyeu, 2018; Kim and Starks, 2016). This literature aims to understand how increased diversity in corporate boards affects a firm's value. An increase in diversity may stem, for example, from increasing the ratio of independent board members to insider directors, or from increasing the gender/cultural diversity of board members. As Kim and Starks (2016) points out, an important yet little understood aspect is understanding through which mechanisms increased diversity influences a firm's value. The results presented in this paper study one specific pathway and explain how increased diversity directly affects the voting behavior of members in corporate boards.

The rest of this paper is structured as follows. The model is introduced in Section 2, and in Section 3 we establish equilibrium existence and characterize fundamental properties of equilibrium strategies. The comparative static results regarding the partisanship level and the heterogeneity of preference types in the population of committee members are presented in Section 4. Section 5 discusses some generalizations and concludes. All proofs are relegated to the appendix.

2 The Model

Consider a committee of n players, $\mathcal{I} = \{1, \ldots, n\}$, who take a binary decision of either accepting a proposal or staying with the status quo. A proposal is characterized by an n-dimensional vector $x = (x_1, \ldots, x_n)$. Values x_i are determined by independent random draws from the interval $\mathcal{X}_i = \left[x_i^\ell, x_i^h\right] \subset \mathbb{R}$ with $x_i^\ell < 0 < x_i^h$ and commonly known (cumulative) distributions F_i. The CDFs F_i are twice continuously differentiable with positive density $f_i > 0$ for all $x_i \in \mathcal{X}_i,\ i \in \mathcal{I}$. The realization x_i is private information to player i. The set of proposals, $\mathcal{X} = \times_{i=1}^n \mathcal{X}_i$ and the joint CDF of proposals, $F = \prod_{i=1}^n F_i$, are common knowledge.

Each player has an individual *private preference type*, $\theta_i \in \Theta_i \subseteq [1/n, 1]$. Preference types θ_i are independently distributed on $\Theta_i = [\underline{\theta}_i, 1]$ with $\underline{\theta}_i \geq 1/n$, commonly known CDFs G_i, and densities $g_i > 0$ for all $\theta_i \in \Theta_i$. Preference type θ_i is private information to player i. As such, players hold two-dimensional private information where (x_i, θ_i) is private information to player i.

Payoffs. A player's preference type determines how he aggregates payoff-relevant information into preferences. For player i with preference type θ_i, the payoff of proposal $x = (x_1, \ldots, x_n)$ is

$$v_i(\theta_i, x) = \theta_i x_i + (1 - \theta_i) \frac{1}{n-1} \sum_{j \neq i} x_j. \tag{1}$$

The payoff of the status quo is 0 for all members. We assume $\mathbb{E}(x_i) = 0$ for every $i \in \mathcal{I}$. That is, ex-ante, players favor neither the status quo nor the proposal.

Decision Rule. The committee decision is made by generalized majority voting. The majority rule, which is characterized by an integer $k \in \{1, \ldots, n\}$, is publicly announced. Players indicate whether they want to accept or reject the proposal. The proposal is adopted if and only if there are at least k affirmative votes. Here, $k = \lceil \frac{n+1}{2} \rceil$ corresponds to simple majority and $k = n$ to unanimity.

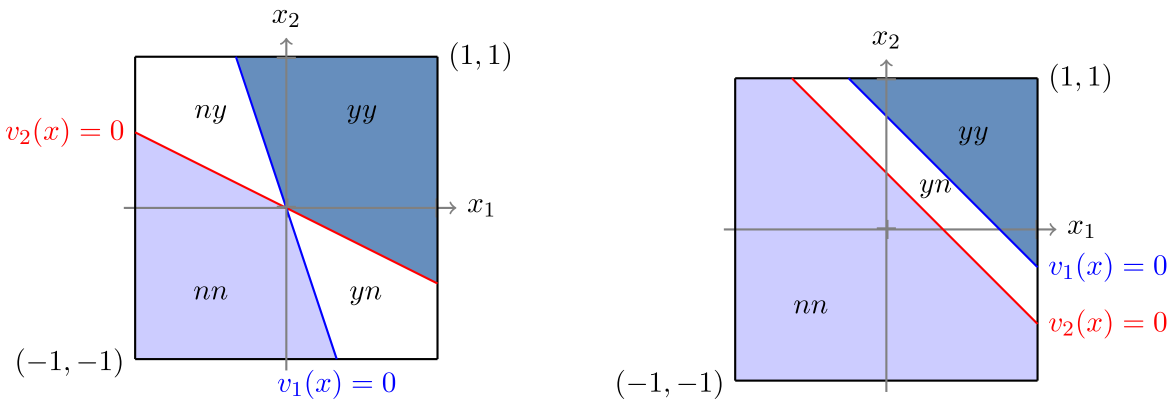
Discussion of the Model. The individual components $x_1, \ldots, x_n$ of a proposal can be interpreted as values of different aspects of the proposal, for example, technical specifications, marketing potential, etc. of a new product. The model then represents a committee of experts where each expert can assess the quality of the proposal with respect to his or her own area of expertise. The payoff function (1) captures that players have interdependent preferences where they place a (weakly) higher weight on the value of the proposal in their own field. A player's type captures the level of interdependency, i.e. the level of partisanship of an expert where a higher θ_i represents a higher level of partisanship. A player with type $\theta_i = 1$ has *private values* and is the most partisan; the pure common values case is captured by $\theta_i = 1/n$ for all $i = 1, \ldots, n$.

Alternatively, the values x_i can be interpreted as the signals that each committee member obtains from paying attention to the evidence presented about the proposal.[9] The payoff function (1) then captures that committee members are aware that their signal is noisy and hence they take other members' signals into account. Preference types θ_i represent the level of overconfidence of each committee member in their own signal, where higher private types reflect a higher level of overconfidence.

To clarify, let us briefly discuss the differences in introducing preference heterogeneity in the present model relative to that used by Li, Rosen, and Suen (2001) and related papers (e.g. Austen-Smith and Feddersen (2006) and Li and Suen (2009)). In the model in Li, Rosen, and Suen (2001), players have different preferences for type-I and type-II errors, and hence require different levels of evidence to prefer the alternative over the status quo. This specification of heterogeneity implies that between any pair of players there is only one direction of disagreement; if a pair of players disagrees, it is always the same player who supports the proposal whilst the other favors staying with the status quo.

By contrast, in the present model, the conflict of interest arises from different preferences of

[9]This interpretation captures the idea that when listening to information we are unable to process all of it. Hence, when listening to the same evidence, committee members obtain different (conditionally independent) signals.



(a) Our model with $(\theta_1, \theta_2) = (3/4, 2/3)$. (b) Model in Li, Rosen, and Suen (2001).

Figure 1: Agreement and disagreement sets in our model and in Li, Rosen, and Suen (2001) if $x = (x_1, x_2)$ is common knowledge. Here "yn" denotes the set of x for which player 1 votes *y(es)* and player 2 votes *n(o)*.

committee members. Even if the payoff state $x = (x_1, \ldots, x_n)$ was known, players may not agree on the best outcome. Moreover, the heterogeneity among players is such that the direction of conflict depends on the realization of x; if players disagree, it is not always the same player who favors the proposal. For any two players i and j, with different preference types $\theta_i \neq \theta_j$, there are proposals x that player i wants to accept while player j prefers the status quo, and other proposals x' that only player j wants to accept but player i prefers the status quo. The differences in modeling conflict of interest and heterogeneity among players are illustrated in Figure 1.

Strategies. A pure[10] strategy for player i is a measurable function:

$$\sigma_i : \Theta_i \times \mathcal{X}_i \to \{0, 1\},$$

where $\sigma_i(\theta_i, x_i) = 1$ if player i votes affirmatively when his type is θ_i and his private signal is x_i. The strategy of a given type θ_i of player i is denoted by σ_{θ_i} where $\sigma_{\theta_i}(x_i) := \sigma_i(\theta_i, x_i)$.

A pure strategy for a player characterizes, for each of his preference types θ_i, a corresponding *acceptance set*:

$$A_{\sigma_i}(\theta_i) := \sigma_{\theta_i}^{-1}(1) \subseteq \mathcal{X}_i. \tag{2}$$

This is the set of private signals $x_i \in \mathcal{X}_i$ that will induce the player to vote affirmatively. A strategy of player i thus corresponds to a collection of acceptance sets $\{A_{\sigma_i}(\theta_i)\}_{\theta_i \in \Theta_i}$.

A *cutoff strategy* of player i is a strategy σ_i in which, for every $\theta_i \in \Theta_i$, the acceptance set is of the form $A_{\sigma_i}(\theta_i) = [c_i(\theta_i), x_i^h]$ for some cutoff value $c_i(\theta_i) \in [x_i^\ell, x_i^h]$.[11] A cutoff strategy σ_i of player i thus corresponds to a cutoff function $c_i : \Theta_i \to \mathcal{X}_i$ such that type θ_i votes affirmatively if and

[10]Restricting attention to pure strategies is without loss. It is straightforward to show that for any preference type of any player, it is a best-response to adopt a cutoff strategy. Since we consider a continuum of types and no atoms, the decision of an indifferent type is inconsequential since this is a zero probability event.

[11]To be precise, we would also have to consider acceptance sets $A_{\sigma_i}(\theta_i) = \emptyset$. However, note that since $\{x_i \in \mathcal{X}_i : x_i = x_i^h\}$ is a zero probability event, whenever $A_{\sigma_i}(\theta_i) = [x_i^h, x_i^h]$ or $A_{\sigma_i}(\theta_i) = \emptyset$, player type θ_i accepts the proposal with probability zero. Hence, we identify acceptance set $A_{\sigma_i}(\theta_i) = \emptyset$ with the cutoff $c_i(\theta_i) = x_i^h$. Doing so is without loss since it does not change the expected values or payoffs of players.

only if he observes a signal $x_i \geq c_i(\theta_i)$. Here, $c_i(\theta_i) = x_i^h$ represents the case that type θ_i rejects the proposal with probability one.[12]

Equilibrium Concept. We employ the concept of undominated Bayes Nash equilibrium. That is, we restrict attention to equilibria in which no player plays a weakly dominated strategy.[13] As is standard in the voting literature, we refer to this as a *voting equilibrium*[14].

3 Equilibrium Characterization

In a voting game, a rational player conditions his decision on the event of being pivotal: the event in which the player's own vote determines the outcome. For a given majority rule $k \in \{1, \dots, n\}$, this is the event in which exactly $k-1$ of the other players vote affirmatively.

Now, consider some majority rule $k \in \{1, \dots, n\}$. Recall that every strategy profile σ corresponds to a collection of acceptance sets (2), $\{A_{\sigma_i}(\theta_i)\}_{\theta_i \in \Theta_i, i \in \mathcal{I}}$. Now define[15]:

$$A_{\sigma_{-i}}^{k-1}(\theta_{-i}) := \{x_{-i} : \ |\{j \in \mathcal{I} \backslash \{i\} : \ x_j \in A_{\sigma_j}(\theta_j)\}| = k-1\} \subseteq \mathcal{X}_{-i}. \tag{3}$$

For player i, this is the set of signal profile realizations x_{-i} for which exactly $k-1$ of the other players vote affirmatively given strategy profile σ_{-i} and type-profile realization θ_{-i}. For a three-member committee, Figure 3(a) illustrates the sets $A_{\sigma_{-i}}^{k-1}(\theta_{-i})$ from (3) for player 3, for cutoff strategies of some type-profile realization $\theta_{-3} = (\theta_1, \theta_2)$, and for each of the majority rules $k = 1, 2, 3$.

Since preference types are private information, player i does not know the type realization of other players when casting his vote. Hence, conditional on being pivotal, player i's expectation of the average signal of the other players, $\overline{x}_{-i} := \frac{1}{n-1} \sum_{j \neq i} x_j$, given strategy profile σ_{-i}, is:

$$\mathbb{E}\left[\overline{x}_{-i} \mid piv_k(\sigma_{-i})\right] := \mathbb{E}_{\Theta_{-i}}\left[\mathbb{E}_{\mathcal{X}_{-i}}\left[\overline{x}_{-i} \mid A_{\sigma_{-i}}^{k-1}(\theta_{-i})\right]\right]; \tag{4}$$

and for player i with private information (θ_i, x_i), the expected payoff from implementing the alternative, conditional on being pivotal, is:

$$V_i\left((\theta_i, x_i); \sigma_{-i}\right) = \theta_i x_i + (1-\theta_i) \cdot \mathbb{E}\left[\overline{x}_{-i} \mid piv_k(\sigma_{-i})\right]. \tag{5}$$

We now establish equilibrium existence:

Theorem 1 (Equilibrium Existence)**.**
In a committee of n members, for any generalized majority rule $k \in \{1, \dots, n\}$, there exists a voting equilibrium σ^*. In every voting equilibrium, players adopt cutoff strategies given by:

$$c_i^*(\theta_i) = \max\left\{x_i^\ell, \ \min\left\{-\frac{1-\theta_i}{\theta_i}\mathbb{E}\left[\overline{x}_{-i} \mid piv_k(\sigma_{-i}^*)\right], \ x_i^h\right\}\right\} \quad \forall\, i \in \mathcal{I}, \theta_i \in \Theta_i. \tag{6}$$

In equilibrium, players form beliefs about the expected average signal of other players conditional on being pivotal. Since player's expected payoffs conditional on being pivotal (5) are linear in their

[12]Hence, we define $\mathbb{E}[x_i | x_i = x_i^h] := 0$.

[13]This eliminates trivial equilibria where all players play extreme strategies, i.e., always accept the proposal or always reject the project.

[14]cf. e.g. Feddersen and Pesendorfer (1997) and related literature.

[15]Here, $|S|$ denotes the cardinality of the set S.

own signals, it follows immediately that, in equilibrium, players adopt cutoff strategies.

As can easily be seen from (6), the most partisan (or private values) type $\theta_i = 1$ adopts a cutoff of 0. For this type, the signals of the other players do not influence his preferences, and thus the information that he derives from the event of being pivotal does not affect his decision. In other words, he votes *sincerely*, i.e. solely based on his own private signal x_i.

Every other type (with interdependent values) takes into account the information that can be gained from the event of being pivotal about the average signal of other players. In particular, being pivotal is either good news (if $\mathbb{E}\left[\overline{x}_{-i} \mid piv_k(\sigma^*_{-i})\right] > 0$) or bad news (if $\mathbb{E}\left[\overline{x}_{-i} \mid piv_k(\sigma^*_{-i})\right] < 0$). If being pivotal is good (bad) news, a player will require weaker (stronger) evidence to accept an alternative, and hence adopt a negative (positive) cutoff. The expected information derived from the event of being pivotal is the same for all types of player i, the sign depends on the majority rule.[16] Consequently, the sign of equilibrium cutoffs does not change across preference types, such that all types $\theta_i \neq 1$ adopt a positive, or all adopt a negative, cutoff. Moreover, since moderate types put more weight on the information held by other players, the information they derive about other players' signals from the event of being pivotal is reflected to a greater extent in their cutoffs (6). In other words, their cutoffs are further from the sincere voting cutoff of zero than the cutoff of the more partisan committee members.

The following proposition summarizes these equilibrium properties:

Proposition 1. *In any voting equilibrium, for all $i \in \mathcal{I}$, the cutoff functions $c_i^*(\cdot)$ are continuous in the player's preference type θ_i, and are twice continuously differentiable almost everywhere. Moreover, either $c_i^*(\theta_i) \geq 0$ for all $\theta_i \in \Theta_i$ or $c_i^*(\theta_i) \leq 0$ for all $\theta_i \in \Theta_i$; $|c_i^*(\theta_i)|$ is non-increasing in θ_i, and $c_i^*(1) = 0$.*

An immediate corollary of this result is that, in equilibrium, there are always some *responsive* types, i.e. types whose vote depends on the realization of their private signal. Formally, we say that type θ_i of player i is *responsive* given cutoff strategy $c_i(\cdot)$ if he adopts an interior cutoff $c_i(\theta_i) \in (x_i^\ell, x_i^h)$. A strategy of player i is *responsive* if there is a positive measure of preference types that are responsive given cutoff strategy $c_i(\cdot)$.

Corollary 1. *In any voting equilibrium, players' cutoff strategies are responsive. Moreover, there exists some type $\hat{\theta}_i \in [\underline{\theta}_i, 1)$ such that all types $\theta_i \geq \hat{\theta}_i$ are responsive, and all types $\theta_i < \hat{\theta}_i$ adopt the same extreme cutoff, which is either x_i^ℓ or x_i^h.*

In equilibrium, for each player, there is a positive measure of responsive preference types whose decision to vote affirmatively or not depends on their private signal. Responsiveness of players' equilibrium strategies is a necessary condition for information aggregation. While we do not focus on information aggregation in this paper, the corollary shows that in equilibrium some information aggregation occurs.

[16] Roughly put, for more stringent majority rules (when more affirmative votes are required for approval), in equilibrium, a player's conditional expectation of the other players' average signal is larger, which results in the best-response of the player being to choose a lower cutoff.

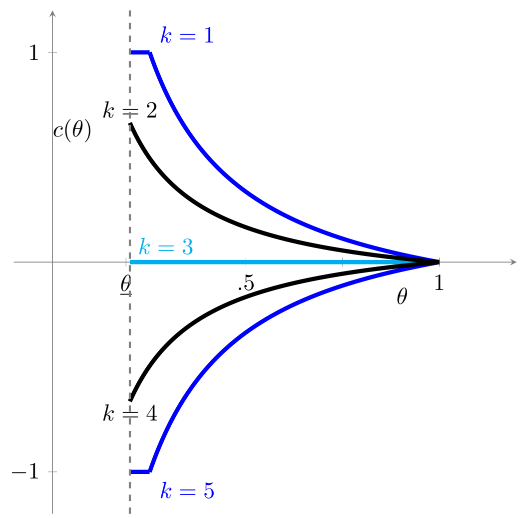


Figure 2: Equilibrium cutoff functions for $n = 5$, for different majority rules, for $x_i \overset{iid}{\sim} U[-1, 1]$, $\theta_i \overset{iid}{\sim} U[1/5, 1]$.

As previously mentioned, whether all types of a player adopt cutoffs that are non-negative or non-positive depends on the quorum rule and the distribution of types and signals. As the next result shows, if equilibrium cutoffs are non-positive (non-negative), then the corresponding cutoff function is concave (convex) on the set of responsive types. Possible shapes of the equilibrium cutoff functions are illustrated in Figure 2.

Proposition 2. *In any voting equilibrium, every cutoff function with non-positive cutoffs $c_i^*(\theta_i) \leq 0$ (non-negative cutoffs $c_i^*(\theta_i) \geq 0$) is concave (convex) on the set of responsive types $\left[\hat{\theta}_i, 1\right]$. Equilibrium cutoff functions satisfy:*

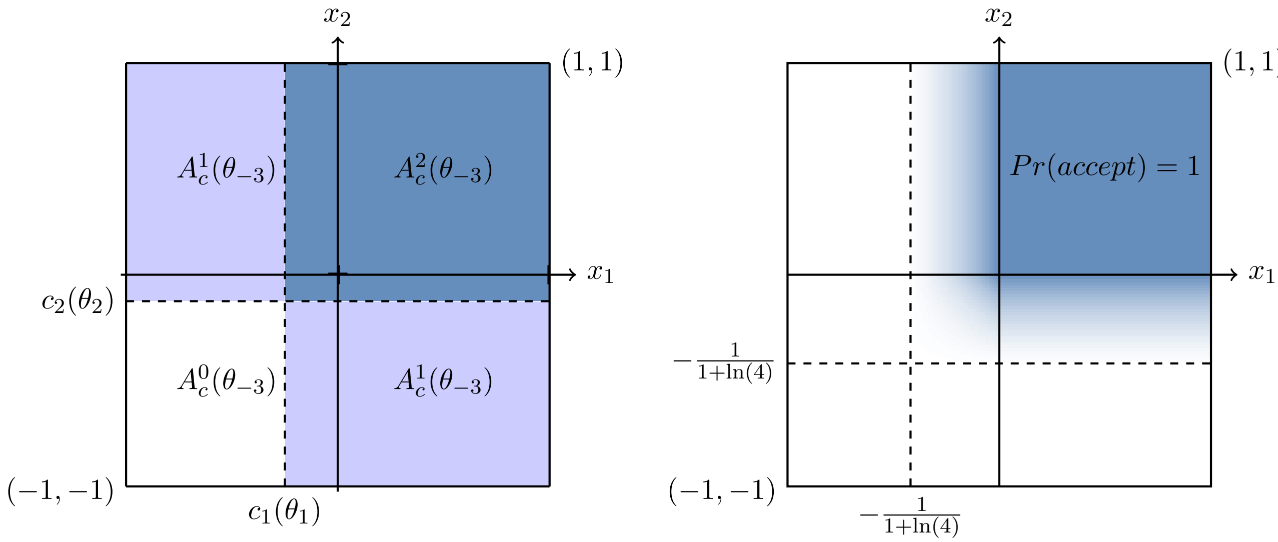
$$(c_i^*)' \cdot (c_i^*)'' \leq 0 \quad \forall i \in \mathcal{I}. \tag{7}$$

We conclude this section by discussing an example to illustrate equilibrium properties. We will build on this example in Section 4 and use it to illustrate our results about committee composition.

Example. Consider a two-member committee that must decide whether to accept or reject a proposal. For example, a technology and a media expert may decide on whether to bring a product update to market or to stick with the current product version. Acceptance of the proposal requires unanimity ($k = 2$). Attribute values and preferences types are independently and uniformly distributed with $x_i \overset{iid}{\sim} U[-1, 1]$ and $\theta_i \overset{iid}{\sim} U[1/2, 1]$ for $i = 1, 2$. For example, x_1 could represent the quality of the product and x_2 its marketability.

Theorem 1 establishes that, in equilibrium, both experts will use cutoff strategies. Under the unanimity rule, an expert's vote only matters if the other expert votes affirmatively. Thus, conditional on being pivotal, the expected payoff of the proposal for expert i with private information (θ_i, x_i) is:

$$V_i(x_i, \theta_i) = \theta_i x_i + (1 - \theta_i)\mathbb{E}_{\Theta_j}\left[\mathbb{E}_{\mathcal{X}_j}\left[x_j | x_j \geq c_j(\theta_j)\right]\right].$$



(a) Illustration of acceptance sets: sets of signals for which exactly 0 (white), 1 (light blue), or 2 (dark blue) of players 1 and 2 vote affirmatively for some cutoff strategy profile $c = (c_1, c_2)$ and type realization $\theta_{-3} = (\theta_1, \theta_2)$.

(b) Equilibrium acceptance probabilities for $n = k = 2$ and uniformly distributed signals and types. Darker shading represents a higher acceptance probability.

Figure 3: Illustrations of acceptance sets for given type realizations and different majority rules (a), and equilibrium acceptance sets/probabilities (b).

Solving for the equilibrium cutoff functions (6) yields:

$$c_i^*(\theta_i) = -\frac{1-\theta_i}{\theta_i} \cdot \frac{1}{1+\ln 4} \quad \text{for } i \in \{1,\, 2\}.$$

Equilibrium cutoffs range from $c_i^*(1/2) = -\frac{1}{1+\ln 4} \approx -0.42$ for the most moderate type to $c_i^*(1) = 0$ for the most partisan type. Calculating the probability $p(x)$ that, in equilibrium, an alternative $x = (x_1, x_2) \in [-1, 1]^2$ is accepted by the committee yields:

$$p(x_1, x_2) = \begin{cases} \min\{1, \left|\frac{(1+x_1+x_1\ln(4))}{(1-x_1-x_1\ln(4))}\right|\} \cdot \min\{1, \left|\frac{(1+x_2+x_2\ln(4))}{(1-x_2-x_2\ln(4))}\right|\} & \text{if } (x_1, x_2) \in \left[-\frac{1}{1+\ln(4)}, 1\right]^2, \\ 0 & \textit{otherwise.} \end{cases}$$

These acceptance probabilities are illustrated in Figure 3(b) where lighter shading represents a lower acceptance probability. For $(x_1, x_2) \in (-\frac{1}{1+\ln 4}, 1]^2$, the acceptance probabilities are strictly positive (equal to one in the upper quadrant) and they are zero otherwise.

4 Comparative Static Effects of Preference Uncertainty

We now turn to the question of how the committee composition affects voting behavior. That is, how do individual committee member's acceptance standards differ if we compare them across committees from a more partisan versus more moderate population, or if we compare committees constituted from more or less diverse populations? Additionally, how does this affect the set of alternatives that are accepted by such committees? The model introduced in this paper establishes a framework that allows us to study these questions. In our analysis, a more partisan population will be captured by a first-order stochastic dominance shift of the distribution of private preference types. A mean-preserving spread of the distribution of private preference types introduces more heterogeneity, which can be interpreted as a more diverse population.

For simplicity, we present the results in this section for a symmetric setting in which decisions require unanimity. A brief discussion of the case of generalized majority rules is provided in Section 5.

4.1 Symmetric Environment, Unanimity Voting

For our comparative statics analysis, we consider the symmetric case with iid attribute values and preference types. We focus on symmetric equilibria, which, as the next result shows, are unique in this case:

Proposition 3 (Symmetric Equilibrium – Uniqueness).
If attribute values and preference types are iid, $F_i = F_j$, and $G_i = G_j$ for all $i, j \in \mathcal{I}$, and accepting the proposal requires unanimity ($k = n$), then there exists a unique symmetric voting equilibrium.

In a symmetric equilibrium, all players adopt the same cutoff function. We thus drop the subscript and simply refer to the equilibrium cutoff functions by $c^* : \Theta_i \to \mathcal{X}_i$ for all $i \in \mathcal{I}$. Notice that in a symmetric equilibrium, even though all players adopt the same cutoff function $c^*(\cdot)$, for a given realization of private types $(\theta_1, \ldots, \theta_n)$, the realized cutoffs $(c^*(\theta_1), \ldots, c^*(\theta_n))$ are typically not identical.

By combining Proposition 3 with the equilibrium properties established in Section 3, it is straightforward to show that under unanimity voting and in a symmetric equilibrium, all cutoffs are non-positive[17].

Corollary 2 (Unanimity Voting)**.** *For the unanimity rule $k = n$, equilibrium cutoffs are non-positive, $c^*(\theta_i) \leq 0 \ \forall \theta_i \in \Theta_i,\ i \in \mathcal{I}$, and $c^*(\theta_i)$ is increasing in θ_i.*

To see this, observe that under the unanimity rule, a player is pivotal if all other players vote affirmatively. Hence, being pivotal is good news for this player—his expected average signal of other players conditional on being pivotal is:

$$\mathbb{E}_{\Theta_{-i}}\left[\mathbb{E}_{\mathcal{X}_{-i}}\left[\bar{x}_{-i} | x_j \geq c(\theta_j) \forall j \in \mathcal{I}\backslash\{i\}\right]\right] \geq 0,$$

for any given cutoff function $c(\cdot)$ of other players. Moreover, since equilibrium strategies are continuous and partisan players (with type $\theta_j = 1$) vote sincerely, the above inequality is strict in equilibrium.

4.2 Extent of Partisanship in the Population

We now turn to the analysis of how acceptance standards depend on the distribution of preference types of the population from which committee members are drawn. If committee members' preference types are drawn from distribution G, we denote the equilibrium cutoff functions by

[17]We formally establish this for symmetric equilibria, however the result applies more generally for every voting equilibrium for the unanimity rule.

$c^*_G : \Theta_i \to \mathcal{X}_i$ for all $i \in \mathcal{I}$.

As our first result, we now show that players adopt lower acceptance standards if they find themselves among fellow committee members from a more partisan population. This is true for any preference type θ_i. Formally, when comparing two populations G and H from which committee members' preference types are drawn, we say that H is a *more partisan population* if the distribution H first-order stochastically dominates G, denoted by $H \succsim_1 G$. That is, distribution H puts more mass on higher (i.e. more partisan) types than G.

Proposition 4 (More Partisan Populations)**.**
For the unanimity rule, when comparing symmetric voting equilibria, for a committee whose members stem from a more partisan population, each preference type will adopt a lower cutoff compared to a committee with more moderate members:

$$\textit{If } H \succsim_1 G, \quad \textit{then} \;\; c^*_H(\theta_i) \leq c^*_G(\theta_i) \quad \forall\, \theta_i \in \Theta_i,\; \forall\, i \in \mathcal{I}.$$

The result shows that every preference type adopts less stringent acceptance standards when in a committee constituted of members from a more partisan population than when in a committee with more moderate members. In particular, one can interpret this result as partisan players acting more leniently among their peers than if they were in a committee with members from a more moderate population. For example, in a committee formed from a moderate population, a partisan member (with type θ_i close to one) will adopt a stringent acceptance standard for a proposal's quality in his own area of expertise. Consequently, only proposals that are strong in this expert's area may pass. Putting the same expert in a committee formed from a more partisan population, would result in him acting more leniently, allowing for a broader range of proposals to pass. This result captures the effect that, believing to face more partisan committee, members will make every preference type act more lenient to reduce the risk of the committee not accepting any proposals. When comparing types within the same committee, it remains that more partisan types adopt a higher acceptance standard (cutoff) than more moderate types.

To gain intuition for the result, consider a first-order shift in the distribution of preference types of the committee members. From Proposition 1, we know that more partisan types adopt more stringent acceptance standards than more moderate committee members. These more partisan types primarily base their vote on their own signal. Hence, if cutoff strategies remain the same, for an individual who faces fellow committee members from a more partisan population, being pivotal is more informative about other members' signals than if his fellow committee members were from a more moderate population. Under unanimity voting, being pivotal is good news about the average signal of other players. When the cutoff function remains fixed, this conditional expected value increases when moving to a more partisan population. Consequently, each preference type would lower his acceptance standard, counteracting the initial effect. As it turns out, in equilibrium the lower cutoffs do not completely offset that being pivotal is better news when facing a more partisan population and hence equilibrium cutoff functions shift downwards.

The central idea in the proof of Proposition 4 is to simplify the problem by showing that every symmetric equilibrium corresponds to a real number $\gamma_G^* \in \mathbb{R}$ that captures the expected average signal of others conditional on being pivotal in equilibrium, and that any such γ_G^* is a fixed point of a one-dimensional mapping. Moreover, it is established that there is a one-to-one relation (bijection) between fixed points of this one-dimensional mapping and symmetric equilibria of the original problem. One can then identify the effect of changes in the distribution of preference types on the fixed point of the one-dimensional mapping in order to then determine the induced effect on equilibrium cutoff strategies. Details of the proof are in the appendix.

4.3 Level of Preference Heterogeneity of the Populations

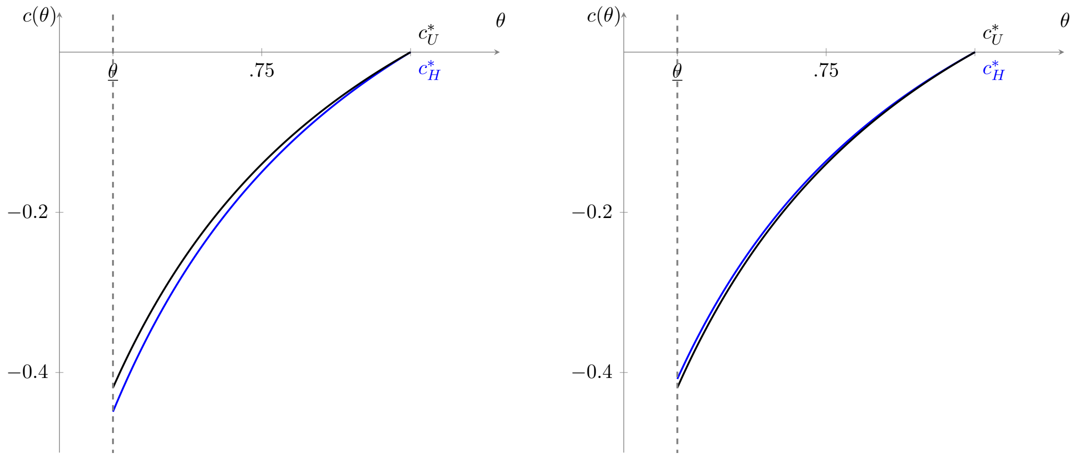
Another question that arises naturally is how the heterogeneity of the population from which committee members are drawn influences voting behavior and outcomes. With diversity initiatives aimed at increasing diversity – and hence heterogeneity of preferences – in organizations, one may wonder what effects could be expected in terms of voting behavior and outcomes of committee decisions. We model this by comparing two committees from populations with the same expected partisanship level but with either greater or less preference heterogeneity. Formally, when comparing two committees whose members' preference types are drawn from distributions H and G, we say that population H is more heterogeneous if H is a mean-preserving spread of G, $H \succsim_{MPS} G$. As the following result shows, players who find themselves in a committee with members from a more heterogeneous population adopt more stringent acceptance standards than they would in a committee constituted of members from a more homogeneous population.

Proposition 5 (More Heterogeneous Populations)**.**
For the unanimity rule and symmetric voting equilibria, when in a committee that is constituted of members from a more heterogeneous population, each preference type will adopt more stringent acceptance standards than when in a committee with members from a more homogeneous population:

$$\text{If } H \succsim_{MPS} G \text{ then } c_H^*(\theta_i) \geq c_G^*(\theta_i) \quad \forall\, \theta_i \in \Theta_i,\ \forall\, i \in \mathcal{I}.$$

The proof of the result uses the same key simplification as Proposition 4 and is relegated to the appendix.

Let us provide some intuition for the result. The more heterogeneous the population from which committee members are drawn, the more uncertainty there is for each player about other members' preferences. In other words, the event of being pivotal is less informative for a player such that it is hard for a player to infer whether fellow committee members vote affirmatively because of a high signal or because they have a low preference type resulting in a low acceptance threshold. In the latter case, a player may vote affirmatively even though he observes a relatively low signal (cf. Proposition 1). Hence, a player in a diverse committee bases his vote more on his own private signal than a player who finds himself in a committee of members from a less heterogeneous population. For the unanimity rule, this implies that players adopt higher acceptance standards when in a committee composed from a more diverse population than if they find themselves in a more homogeneous committee.



(a) Increased partisanship: $H \succsim_1 U$.

(b) Increased diversity: $H \succsim_{MPS} U$.

Figure 4: Effect of increase in partisanship (a) and diversity (b) on equilibrium cutoff functions. Here, U is the uniform distribution on $[1/2, 1]$.

The results suggest that for decisions that require unanimity, individual members will raise their acceptance standards when committee diversity increases. Hence, the committee only accepts alternatives that are of sufficiently high quality in each dimension. This is in line with the finding that having women on a board results in less aggressive risk-taking (e.g. Chen, Leung, Song, and Goergen, 2019). For decisions that require unanimous support, as diversity in a committee increases the set of proposals that are accepted in equilibrium with positive probability is reduced.

Example: (*continued*) Here, we revisit our example of a two-member committee and unanimity voting ($n = k = 2$) with uniformly distributed signals $x_i \overset{iid}{\sim} U[-1, 1]$. Suppose we compare our initial committee in which the members are drawn from a population with uniformly distributed preference types $\theta_i \overset{iid}{\sim} U[1/2, 1]$ for $i = T, M$ to a committee whose members stem from a more partisan population $\theta_i \overset{iid}{\sim} H$ on $[1/2, 1]$ with increasing density $h(\theta_i) = \frac{5}{8}(\theta_i - \frac{1}{2})$. This implies $H(\theta_i) = 1 - 4\theta_i + 4\theta_i^2$ and that H first-order stochastically dominates the uniform distribution $U[1/2, 1]$. Solving for a symmetric equilibrium, we obtain the equilibrium cutoff function $c_H^*(\theta_i) = -\frac{1-\theta_i}{\theta_i} \cdot \frac{1}{5-2\ln(4)}$. As illustrated in Figure 4(a), for any type $\theta_i < 1$ this cutoff is lower than that which would be adopted in a committee with uniformly distributed preference types (a less partisan population).

Similarly, we can compare the behavior across committees whose members stem from populations with either more or less preference heterogeneity. Here, we compare our initial example with $\theta_i \overset{iid}{\sim} U[1/2, 1]$ to a committee with $\theta_i \overset{iid}{\sim} H$ where H is constructed from the $Beta(1/5, 1/5)$ distribution adjusted to have support $[1/2, 1]$.[18] It is straightforward to verify that, for these distributions, H is a mean-preserving spread of the uniform distribution on $[1/2, 1]$. That is, we compare our committee from the initial example in Section 3 to a committee whose members are drawn drawn from a more diverse population H. Solving for a symmetric equilibrium, we obtain cutoff function

[18] Specifically, the density function is $h(\theta_i) = \frac{2\Gamma\left(\frac{2}{5}\right)}{\left(-4\theta_i^2+6\theta_i-2\right)^{4/5}\Gamma\left(\frac{1}{5}\right)^2}$.

$c_H^*(\theta_i) \approx -0.41 \cdot \frac{1-\theta_i}{\theta_i}$, which is illustrated in Figure 4(b). Here we can see that every preference type adopts a higher cutoff when they are part of a more diverse committee compared to when they are part of a committee constituted of members from a more homogeneous population.

5 Discussion and Concluding Remarks

We have proposed a model of committee voting in which each player obtains a private payoff-relevant signal about the proposal that is up for vote. The model features two novelties: 1) how a player aggregates this information into preferences depends on his individual preference type, and 2) this preference type is private information to the player.

First, we establish equilibrium existence and show that, in equilibrium, players adopt cutoff strategies that are monotone in their preference type where a player's preference type is reflected in his individual acceptance standard (cutoff). Partisan players base their vote largely on their own private signal, whereas more moderate types place more weight on the information that they obtain from being pivotal such that their acceptance standard shifts away from the sincere voting cutoff (zero).

Next, we identified how acceptance standards react to changes in the distribution of preference types of committee members under unanimity voting and find that: 1) players adopt lower acceptance standards if they find themselves among committee members from a more partisan population, and 2) greater preference type heterogeneity, and hence greater uncertainty about other committee members' preference types, leads players to act cautiously and utilize their own privately observed signal to a greater extent when making a decision. Therefore, cutoffs are closer to zero—the sincere voting cutoff.

More general utility functions: The specific parametric form of (1) is not crucial for the results. The equilibrium characterization results of Section 3 extend to additively separable utility functions that are continuously increasing in x_i for all $i \in \mathcal{I}$ and that satisfy the following single-crossing property:

Assumption 1 (SC)**:** For all $i, j \in \mathcal{I}$, $j \neq i$:

$$\frac{\partial v_i}{\partial x_i}(\theta_i, x) \geq \frac{\partial v_j}{\partial x_i}(\theta_j, x) \quad \forall x \in \mathcal{X},\ (\theta_i, \theta_j) \in \Theta_i \times \Theta_j.$$

For the parametric form of (1), this is equivalent to $\theta_i \geq \frac{1}{n-1}(1-\theta_j)$ for all $(\theta_i, \theta_j) \in \Theta_i \times \Theta_j$, $j \neq i$, which implies $\Theta_i \subseteq [1/n, 1]$ for every $i \in \mathcal{I}$.

Generalized majority rules: Section 4 presented results on the uniqueness of symmetric equilibria and comparative statics for the unanimity rule. However, the results should extend to generalized majority rules under some assumptions on the distributions F and G. The following provides some intuition regarding the results that one could expect.

For any generalized majority rule, the number of affirmative votes required to adopt the alternative determines whether cutoff functions are non-positive (as for the unanimity rule) or non-negative in the symmetric equilibrium. If a large majority k is required to approve the proposal, then being pivotal is good news about the expected average signal of other players. Consequently, players react by adopting an acceptance standard that is lower than the sincere voting threshold of zero. By contrast, if the number of affirmative votes necessary to adopt the alternative is small, then being pivotal is bad news about the average expected signal of other players, and committee members react by adopting positive cutoffs.

As discussed, if we consider a first-order shift in the preference type distribution of the population of committee members, we move to a committee constituted of members from a more partisan population. Recall that partisan players adopt acceptance standards closer to the sincere voting threshold. Thus, if being pivotal is good (bad) news about the average expected signal of other players, then being pivotal is better (worse) news when facing a more partisan population. Hence, each individual preference type will adjust his acceptance standard to a greater extent. Equilibrium cutoffs move away from the sincere voting threshold of zero such that the equilibrium cutoff function moves upwards if it is non-negative and downwards if it is non-positive.

For the case of a second-order shift, i.e. committee members stem from a population with more heterogeneous preference types, the event of being pivotal becomes less informative about the other players' preferences. As a result, each player bases his vote more on his own private signal. For each individual preference type, equilibrium cutoffs move closer to zero such that the equilibrium cutoff function shifts downwards if it is non-negative and upwards if it is non-positive.

The results of this work may provide insights into how decisions may be influenced by the member composition of a committee or by how well committee members know each other.[19] For example, a CEO who seeks approval for a new product version, but is less concerned about the approval standard in each dimension, may prefer a less diverse and overall more moderate committee composition. This results in members adopting lower acceptance standards, which yields a higher probability of approval.

[19] This will implicitly determine the heterogeneity of the population, i.e. the uncertainty of players about other members' preference types.

Appendix

Proof of Theorem 1. Consider player $i \in \mathcal{I}$. Given majority rule $k \in \{1, \ldots, n\}$, suppose all other players follow strategy profile σ_{-i}. A best-response of type θ_i of player i is to vote for the alternative if and only if the expected payoff of the alternative conditional on him being pivotal, (5), is greater than the payoff of the status quo. Consequently, type θ_i's best response is to vote affirmatively if and only if $V_i\left((\theta_i,\, x_i); \sigma_{-i}\right) \geq 0$.

It is easy to see from (5) that $V_i\left((\theta_i,\, x_i); \sigma_{-i}\right)$ is continuous and strictly increasing in x_i. It follows that player i's best response is to follow a cutoff strategy corresponding to the cutoff function c_i^{BR} given by:[20]

$$c_i^{BR}(\theta_i) = \begin{cases} x_i^{\ell} & \text{if } V_i\left((\theta_i,\, x_i); \sigma_{-i}\right) \geq 0 \;\forall x_i \in \left[x_i^{\ell}, x_i^h\right] \\ x_i^h & \text{if } V_i\left((\theta_i,\, x_i); \sigma_{-i}\right) < 0 \;\forall x_i \in \left[x_i^{\ell}, x_i^h\right) \\ -\frac{1-\theta_i}{\theta_i}\mathbb{E}\left[\overline{x}_{-i} \mid piv_k(\sigma_{-i})\right] & \text{otherwise,} \end{cases} \tag{8}$$

where type θ_i votes affirmatively if and only if he observes a signal $x_i \geq c_i^{BR}(\theta_i)$. From now on we assume that players adopt cutoff strategies.

For each $i \in \mathcal{I}$, let $\mathbb{R}^{\Theta_i}$ be the space of functions $f : \Theta_i \to \mathbb{R}$ endowed with the product topology (i.e. the topology of pointwise convergence) and let $\mathcal{X}_i^{\Theta_i} \subseteq \mathbb{R}^{\Theta_i}$ be the subset of functions with range $\mathcal{X}_i$. With this topology, $\mathbb{R}^{\Theta_i}$ is locally convex.[21] We represent cutoff strategies by their corresponding cutoff functions and denote player i's best response function by $\phi_i^{BR} : {\mathcal{X}_1}^{\Theta_1} \times \cdots \times {\mathcal{X}_n}^{\Theta_n} \to {\mathcal{X}_i}^{\Theta_i}$, where ϕ_i^{BR} identifies, for every cutoff function profile (c_i, c_{-i}), a corresponding cutoff-function $\phi_i^{BR}(c_i, c_{-i}) \in {\mathcal{X}_i}^{\Theta_i}$ that is a best-response of player i. Notice that ϕ_i^{BR} is constant in c_i.

Thus, the best response correspondence can be characterized as:

$$\begin{aligned} \Phi :\; {\mathcal{X}_1}^{\Theta_1} \times \cdots \times {\mathcal{X}_n}^{\Theta_n} &\longrightarrow {\mathcal{X}_1}^{\Theta_1} \times \cdots \times {\mathcal{X}_n}^{\Theta_n} \\ \boldsymbol{c} = (c_1, \ldots, c_n) &\longmapsto \left(\phi_i^{BR}(\boldsymbol{c}), \ldots, \phi_n^{BR}(\boldsymbol{c})\right). \end{aligned}$$

By Tychonoff's theorem, since Θ_i and $\mathcal{X}_i$ are compact, so is $\mathcal{X}_i^{\Theta_i}$ for all $i \in \mathcal{I}$ and hence $\mathcal{X}_1^{\Theta_1} \times \cdots \times \mathcal{X}_n^{\Theta_n}$ is compact. It is easily verified that $\mathcal{X}_1^{\Theta_1} \times \cdots \times \mathcal{X}_n^{\Theta_n}$ is non-empty and convex.

The best response function Φ is continuous since each of its coordinate functions is continuous. Indeed, for every $i \in \mathcal{I}$, Φ_i^{BR} is constant in c_i. Moreover, Φ_i^{BR} is continuous in c_{-i} since the expectation operator is linear and bounded in the given setting (cf. (8)). The *Brouwer-Schauder-Tychonoff fixed-point theorem*[22] thus establishes existence of a fixed point and hence equilibrium existence, which completes the proof. □

[20] As discussed in Section 2, each cutoff strategy σ_i of player i corresponds to a cutoff function $c_i : \Theta_i \to \mathcal{X}_i$ where $c_i(\theta_i)$ is the cutoff that player i adopts if his type is θ_i. Moreover, each such cutoff function corresponds to a cutoff strategy where type θ_i accepts iff $x_i \geq c(\theta_i)$.

[21] See e.g. Aliprantis and Border (2006), Lemma 5.74.

[22] cf. Aliprantis and Border (2006), Corollary 17.56

Proof of Proposition 1.

(i): A player with preference type $\theta_i = 1$ has private values, and hence $V_i\left((1, x_i); \sigma^*_{-i}\right) = x_i$, $\forall x_i \in X_i$. Thus, from (8) it follows directly that $c^*_i(1) = 0$. That is, in equilibrium, preference type $\theta_i = 1$ always votes sincerely.

(ii): Consider any equilibrium strategy profile σ^*. Notice that, for every player i, $\mathbb{E}\left[\overline{x}_{-i} \mid piv_k(\sigma^*_{-i})\right]$ is constant in θ_i, and $-\frac{1-\theta_i}{\theta_i} < 0$ for all $\theta_i \in [1/n, 1)$. It then follows directly that equilibrium cutoffs $c^*_i(\theta_i)$ given by (6) have the same sign for all types $\theta_i \in \Theta_i \backslash \{1\}$:

$$sign\, c^*_i(\theta_i) = -sign\, \mathbb{E}\left[\overline{x}_{-i} \mid piv_k(\sigma^*_{-i})\right].$$

(iii): Continuity follows immediately from (6) since $\mathbb{E}\left[\overline{x}_{-i} \mid piv_k(\sigma^*_{-i})\right]$ is constant in θ_i for any $i \in \mathcal{I}$, $-\frac{1-\theta_i}{\theta_i}$ is continuous in θ_i on $[1/n, 1]$, and the min/max of two continuous functions is continuous. Additionally, since $\mathbb{E}\left[\overline{x}_{-i} \mid piv_k(\sigma_{-i})\right]$ is constant and $-\frac{1-\theta_i}{\theta_i}$ is twice continuously differentiable in θ_i, it follows that $c^*_i(\theta_i)$ is continuously differentiable in θ_i whenever the cutoffs are interior, $c^*_i(\theta_i) \in \left(x^\ell_i, x^h_i\right)$. Now, if $c^*_i(\theta_i) \in \{x^\ell_i, x^h_i\}$ for some $\theta_i \in \Theta_i$, then it is easy to see from (6) that all types $\theta'_i \leq \theta_i$ adopt the same extremal cutoff. Thus, if any types of player i adopt extremal cutoffs in $\{x^\ell_i, x^h_i\}$ in equilibrium, then the set of types that does so is a closed interval $[\underline{\theta}, \hat{\theta}]$. The equilibrium cutoff function is constant on this set and is thus twice continuously differentiable on $\left(\underline{\theta}, \hat{\theta}\right)$. However, $c^*(\theta_i)$ is not differentiable at $\hat{\theta}$, and hence equilibrium cutoff functions are only differentiable almost everywhere.

(iv): Since $\mathbb{E}\left[\overline{x}_{-i} \mid piv_k(\sigma_{-i})\right]$ is constant in θ_i, we obtain:

$$\frac{\partial}{\partial \theta_i} |c^*_i| = -\frac{1}{\theta_i^2} \cdot \left|\mathbb{E}\left[\overline{x}_{-i} \mid piv_k(\sigma_{-i})\right]\right| \leq 0,$$

for all θ_i such that $c^*_i(\theta) \in \left(x^\ell_i, x^h_i\right)$. It follows that $|c^*_i(\theta_i)|$ is non-increasing in θ_i whenever cutoffs are interior. Moreover, by (iii), $|c^*_i(\theta_i)|$ is constant on the (possibly empty) set of types $[\underline{\theta}, \hat{\theta}]$ that adopts extremal cutoffs. Since $c^*_i(\cdot)$ is continuous, this completes the proof that $|c^*_i(\theta_i)|$ is non-increasing in θ_i. □

Proof of Corollary 1. The result follows directly from Proposition 1, specifically $c^*_i(1) = 0$ and continuity of $c^*_i(\cdot)$. □

Proof of Proposition 2. By Proposition 1, $c^*_i(\cdot)$ is twice continuously differentiable on $\left(\hat{\theta}_i, 1\right)$ and from (6) we obtain:

$$\left(c^*_i\right)' \cdot \left(c^*_i\right)'' (\theta_i) = -\frac{2}{\theta_i^5} \mathbb{E}\left[\overline{x}_{-i} \mid piv_k(\sigma^*_{-i})\right]^2 \leq 0 \quad \forall \ \left(\hat{\theta}_i, 1\right).$$

The result about concavity/convexity of equilibrium cutoff functions follows by combining this with the result of Proposition 1 (iv). □

Proof of Proposition 3. Consider a symmetric setting, that is, $F_i = F_j$ and $G_i = G_j$ for all $i, j \in \mathcal{I} = \{1, \ldots, n\}$. In a symmetric equilibrium, all players adopt the same cutoff strategy (cf. Theorem 1) with corresponding cutoff function $c: \ \Theta_i \to \mathcal{X}_i$, for all $i \in \mathcal{I}$ (here, we drop the subscript of c).

For the unanimity rule $k = n$, define the function Γ that maps a cutoff function $c: \Theta_i \to \mathcal{X}_i$ to the expected value of the average signal of other players conditional on being pivotal (4) if all players adopt a cutoff strategy that corresponds to the cutoff function c:

$$\begin{aligned}\Gamma: \ & \mathcal{X}_i^{\Theta_i} \to \mathbb{R} \\ & c \mapsto \gamma(c) := \mathbb{E}\left[\bar{x}_{-i}|piv_n(c)\right] := \mathbb{E}\left[\bar{x}_{-i}|piv_n(\sigma_{-i})\right]\end{aligned} \tag{9}$$

Notice that for a symmetric cutoff strategy profile with corresponding cutoff function c, the expected signal of other players conditional on being pivotal is the same for all committee members. That is, every cutoff strategy induces a unique $\gamma(c) := \mathbb{E}\left[\bar{x}_{-i}|piv_n(c)\right] \in \mathcal{X}_i$.

Now, define the function:

$$\begin{aligned}\Lambda: \ & \mathcal{X}_i \ \to \mathcal{X}_i^{\Theta_i} \\ & \gamma \ \mapsto c: \Theta_i \to \mathcal{X}_i \\ & \textit{with} \ \ c_\gamma(\theta_i) := \max\left\{x_i^\ell, \min\left\{-\frac{1-\theta_i}{\theta_i}\cdot\gamma, x_i^h\right\}\right\},\end{aligned} \tag{10}$$

which maps an expected value of the average signal conditional on being pivotal, γ, to a cutoff function that represents a best-response of a player to γ (cf. (6)).

Consider the following composite function:

$$\begin{aligned}\Psi: \ & \mathcal{X}_i \xrightarrow{\Lambda} \mathcal{X}_i^{\Theta_i} \xrightarrow{\Gamma} \mathcal{X}_i \\ & \gamma \longmapsto \ \ c \ \ \longmapsto \widetilde{\gamma} := \mathbb{E}\left[\bar{x}_{-i}|piv_n(c)\right].\end{aligned}$$

We will now show that this function has a unique fixed point γ^*.

First, it is easy to see that Λ and Γ are each continuous, and hence Ψ is continuous in γ.[23] Consequently, Ψ is a continuous function between compact convex spaces and hence Brouwer's fixed point theorem establishes the existence of a fixed point (which needs not be unique). In the one-dimensional case that we consider, these fixed points correspond to intersection points of the graph of Ψ with the 45°-line (i.e. the graph of the function $f(\gamma) = \gamma$).

To obtain equilibrium uniqueness, we show that $\Psi: \mathcal{X}_i \to \mathcal{X}_i$ is weakly decreasing and hence crosses the 45°-line only once. Indeed, for the unanimity rule, a player i is pivotal if and only if all other players vote affirmatively. This yields:

$$\mathbb{E}[\bar{x}_{-i}|piv_n(c_{-i})] = \int_{\Theta_{-i}} \frac{1}{n-1}\sum_{j\neq i}\mathbb{E}\left[x_j|x_j \geq c(\theta_j)\right] \, \mathrm{d}G(\theta_{-i}).$$

Thus, we obtain:

$$\frac{\partial\mathbb{E}[\bar{x}_{-i}|piv_n(c_{-i})]}{\partial\gamma} = \int_{\Theta_{-i}} \frac{1}{n-1}\sum_{j\neq i}\left[\frac{f(c(\theta_j))}{1-F(c(\theta_j))}\cdot\left(\mathbb{E}\left[x_j|x_j \geq c(\theta_j)\right] - c(\theta_j)\right)\cdot\left(-\frac{1-\theta_j}{\theta_j}\right)\right] \mathrm{d}G(\theta_{-i}) < 0,$$

[23] Recall that $\mathcal{X}_i^{\Theta_i}$ is the space of functions endowed with the product topology, i.e. the topology of pointwise convergence.

since $\frac{f(c(\theta_j))}{1-F(c(\theta_j))} \cdot (\mathbb{E}[x_j|x_j \geq c(\theta_j)] - c(\theta_j)) > 0$ and $-\frac{1-\theta_j}{\theta_j} < 0$ for every j and every θ_j. Thus, the mapping Ψ is decreasing in γ, which completes the proof that there exists a unique fixed point γ^*.

Now, notice that any such fixed point uniquely determines a cutoff function $c_{\gamma^*}(\cdot) = \Lambda(\gamma^*)$ that is a fixed point of $\Lambda \circ \Gamma$ and hence corresponds to a symmetric equilibrium in cutoff strategies. Moreover, it is straightforward to verify that for any fixed point c^* of the mapping $\Lambda \circ \Gamma$, $\Gamma(c^*)$ is a fixed point of Ψ. In other words, there is a one-to-one relation between fixed points of Ψ and fixed points of $\Lambda \circ \Gamma$, where the latter are cutoff functions that characterize a symmetric equilibrium in cutoff strategies. □

Proof of Corollary 2. For unanimity voting, player i is pivotal if and only if all other committee members vote affirmatively. Hence, for any cutoff function $c: \ \Theta_i \to \mathcal{X}_i$ we obtain:

$$\begin{aligned}\mathbb{E}[\bar{x}_{-i}|piv_n(c)] =& \frac{1}{n-1}\sum_{j\neq i}\mathbb{E}_{\Theta_j}\left[\mathbb{E}_{\mathcal{X}_j}\left[x_j \mid x_j \geq c(\theta_j)\right]\right] \\ \geq& \frac{1}{n-1}\sum_{j\neq i}\mathbb{E}_{\Theta_j}\left[\mathbb{E}_{\mathcal{X}_j}\left[x_j \mid x_j \geq x_j^\ell\right]\right] = 0.\end{aligned} \tag{11}$$

The last equality follows from $\mathbb{E}[x_j] = 0$ for all $j \in \mathcal{I}$. Moreover, in equilibrium we obtain the strict inequality since by Corollary 1 there is a positive mass of types that adopt strictly interior cutoffs.

For equilibrium cutoffs this implies $c^*(\theta_i) := \max\left\{x_i^\ell, \min\left\{-\frac{1-\theta_i}{\theta_i} \cdot \mathbb{E}[\bar{x}_{-i}|piv_n(c^*)], x_i^h\right\}\right\} \leq 0$. That $c^*(\theta_i)$ is increasing in θ_i for every $i \in \mathcal{I}$ then follows directly from Proposition 1 (iii). □

Proof of Proposition 4. Recall from Proposition 3 that symmetric equilibria correspond to fixed points of $\Lambda \circ \Gamma$ and notice that a change in the cdf of players' preference types only affects the operator Γ, whereas the mapping Λ remains unchanged.

Given any distribution G of preference types, we define an operator Γ_G given by:

$$\begin{aligned}\Gamma_G : \ \mathcal{X}_i^{\Theta_i} &\to \mathcal{X}_i \\ c &\mapsto \mathbb{E}_{\Theta_{-i}}\left[\mathbb{E}_{\mathcal{X}_{-i}}\left[\bar{x}_{-i}|x_j \geq c(\theta_j)\forall j \neq i\right]\right].\end{aligned} \tag{12}$$

This is the operator Γ from (9) that maps cutoff functions $c: \ \Theta_i \to \mathcal{X}_i$, to a player's expected average signal of other players conditional on being pivotal if they all follow a cutoff strategy with cutoff function c, decisions require unanimity and G is the cdf of preference types.

Under unanimity voting, any equilibrium cutoff function is non-positive and increasing in θ_i (Corollary 2). Now, notice that if $H \succsim_1 G$, then for any increasing function $c: \ \Theta_i \to \mathcal{X}_i$, it holds that:

$$\Gamma_H(c) \geq \Gamma_G(c).$$

This follows simply since $\mathbb{E}[x|x \geq z]$ is increasing in z, and from linearity of the expectation operator. Since Λ remains unchanged, and $\Lambda(\gamma)$ is increasing in θ_i whenever $\gamma \geq 0$ (which is always the

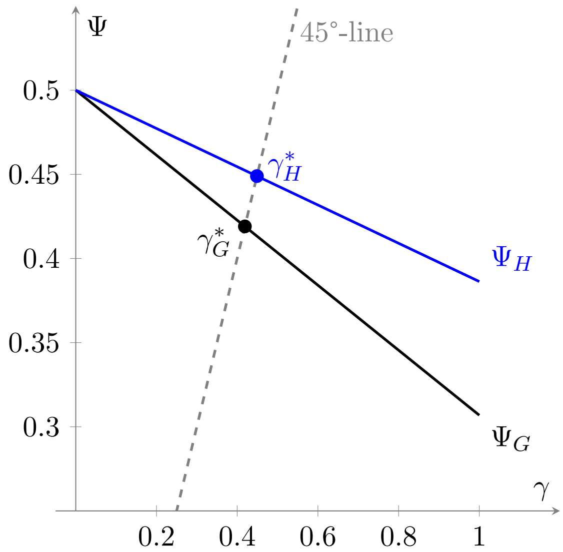


Figure 5: Graphs of Ψ_G and Ψ_H and fixed points γ_G^*, γ_H^* for $H \succsim_1 G$.
(Here, $n = k = 2$, $H(\theta) = 1 - 4\theta + 4\theta^2$ and G is the uniform distribution on $[1/2, 1]$, the same as in the example in Section 4.)

case for the unanimity rule, cf. Corollary 2), it follows that:

$$\Psi_H(\gamma) = \Gamma_H(\Lambda(\gamma)) \geq \Gamma_G(\Lambda(\gamma)) = \Psi_G(\gamma) \quad \forall\, \gamma \geq 0. \tag{13}$$

Notice that Ψ_G and Ψ_H are functions from the unit interval to $\mathbb{R}$. Hence, a fixed point of these mappings (existence was established in Theorem 1) is simply an intersection point of the graph $\Psi_G(\gamma)$ (resp. $\Psi_H(\gamma)$) with the 45°-line. We denote these points by γ_G^* and γ_H^*, respectively.

By (13), $\Psi_H(\gamma) \geq \Psi_G(\gamma)$ for all $\gamma \geq 0$, that is, the graph of Ψ_H lies above the graph of Ψ_G for all γ. Additionally, Ψ_H and Ψ_G are decreasing in γ (cf. Theorem 1). It follows that the intersection point of Ψ_H with the 45°-line must lie above the intersection point of Ψ_G with the 45°-line. That is, $\gamma_H^* = \Psi_H(\gamma_H^*) \geq \Psi_G(\gamma_G^*) = \gamma_G^*$. Figure 5 illustrates this.

For the equilibrium cutoff functions (6), it follows that:

$$c_H^*(\theta_i) = c_{\gamma_H^*}(\theta_i) \leq c_{\gamma_G^*}(\theta_i) = c_G^*(\theta_i), \tag{14}$$

which completes the proof. □

Proof of Proposition 5. We use the same approach as in Proposition 4. For two preference type distributions H and G, with $H \succsim_{MPS} G$, we determine and compare the fixed points of Ψ_H and Ψ_G in order to then derive the induced effect on symmetric voting equilibria.

By (11), under unanimity $\mathbb{E}\left[\bar{x}_{-i} | piv_n(c)\right] \geq 0$ and we can restrict attention to $\gamma \geq 0$. Hence, under unanimity voting, $\Lambda(\gamma)$ is increasing and concave (cf. Proposition 2 and Corollary 2). Let Γ_G, Γ_H be defined as in (12). Then, if $H \succsim_{MPS} G$, for any increasing and concave function $c : \Theta_i \to \mathcal{X}_i$, it holds that:

$$\Gamma_H(c) \leq \Gamma_G(c).$$

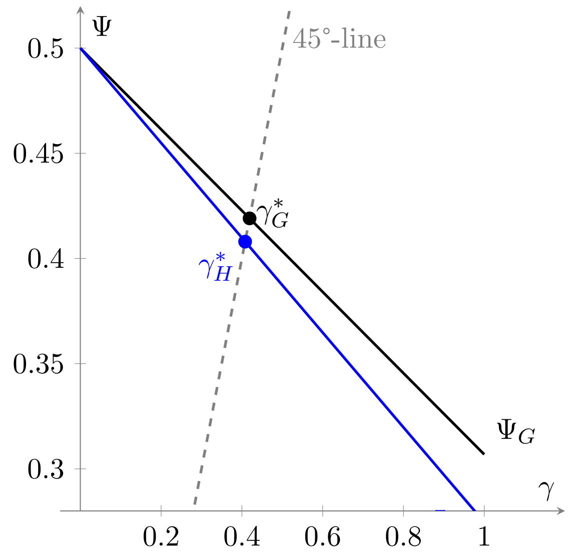


Figure 6: Graphs of Ψ_G and Ψ_H and fixed points γ_G^*, γ_H^* for $H \succsim_{MPS} G$.
(Here, $n = k = 2$, H is the adjusted $Beta(1/5, 1/5)$ distribution and G is the uniform distribution on $[1/2, 1]$; the same as in the example in Section 4.)

Since Λ is not affected by a change in the distribution of types, it follows that for every $\gamma \geq 0$:

$$\Psi_H(\gamma) = \Gamma_H(\Lambda(\gamma)) \leq \Gamma_G(\Lambda(\gamma)) = \Psi_G(\gamma). \tag{15}$$

The fixed points of the functions Ψ_G and Ψ_H are the intersection points of the graph $\Psi_G(\gamma)$ (resp. $\Psi_H(\gamma)$) with the 45°-line. If $H \succsim_{MPS} G$, by (15), the graph of Ψ_H lies below Ψ_G for all $\gamma \geq 0$. Since Ψ_G and Ψ_H are decreasing in γ, it follows that the intersection point of Ψ_H with the 45°-line lies below the intersection point of Ψ_G with this same line. Consequently, $\gamma_H^* = \Psi_H(\gamma_H^*) \leq \psi_G^*(\gamma_G^*) = \gamma_G^*$. Figure 6 illustrates this.

For the equilibrium cutoff functions it follows that:

$$c_H^*(\theta_i) = c_{\gamma_H^*}(\theta_i) \geq c_{\gamma_G^*}(\theta_i) = c_G^*(\theta_i) \quad \forall\, \theta_i \in \Theta_i,$$

which proves the result. □

References

Aliprantis, C. D., and K. C. Border (2006): *Infinite Dimensional Analysis: A Hitchhiker's Guide*. Springer, Berlin.

Austen-Smith, D., and J. S. Banks (1996): "Information Aggregation, Rationality, and the Condorcet Jury Theorem," *The American Political Science Review*, 90(1), 34–45.

Austen-Smith, D., and T. J. Feddersen (2006): "Deliberation, Preference Uncertainty, and Voting Rules," *American Political Science Review*, 100, 209–217.

Bardhi, A., and N. Bobkova (2021): "Local Evidence and Diversity in Minipublics," working paper.

Börgers, T. (2004): "Costly Voting," *American Economic Review*, 94(1), 57–66.

Chemmanur, T. J., and V. Fedaseyeu (2018): "A Theory of Corporate Boards and Forced CEO Turnover," *Management Science*, 64(10), 4798–4817.

Chen, J., W. S. Leung, W. Song, and M. Goergen (2019): "Why Female Board Representation Matters: The Role of Female Directors in Reducing Male CEO Overconfidence," *Journal of Empirical Finance*, 53, 70–90.

Condorcet, M. d. (1785): "Essai sur l'application de l'analyse a la probabilite des decisions rendues a la pluralite des voix," in *Classics of Social Choice. (transl.)*, pp. 91–112. University of Michigan Press (1995), Ann Arbor.

Feddersen, T., and W. Pesendorfer (1997): "Voting Behavior and Information Aggregation in Elections with Private Information," *Econometrica*, 65, 1029–1058.

Feddersen, T., and W. Pesendorfer (1998): "Convicting the Innocent: The Inferiority of Unanimous Jury Verdicts," *American Political Science Review*, 92, 23–35.

Grüner, H. P., and A. Kiel (2004): "Collective Decisions with Interdependent Valuations," *European Economic Review*, 48, 1147–1168.

Hofstede, G. (1991): *Cultures and Organizations: Software of the Mind*. McGraw-Hill UK, London.

Kim, D., and L. T. Starks (2016): "Gender Diversity on Corporate Boards: Do Women Contribute Unique Skills?," *American Economic Review*, 106(5), 267–71.

Li, H., S. Rosen, and W. Suen (2001): "Conflicts and Common Interests in Committees," *American Economic Review*, 91, 1478–1497.

Li, H., and W. Suen (2009): "Decision-making in Committees," *Canadian Journal of Economics*, 42, 359–392.

Meyer, M., and B. Strulovici (2013): "The Supermodular Stochastic Ordering," working paper, University of Oxford.

Moldovanu, B., and X. Shi (2013): "Specialization and Partisanship in Committee Search," *Theoretical Economics*, 8, 751–774.

Name Correa, A. J., and H. Yildirim (2021): "Biased Experts, Majority Rule, and the Optimal Composition of Committee," *Games and Economic Behavior*, 127, 1–27.

Rosar, F. (2015): "Continuous Decisions by a Committee: Median versus Average Mechanisms," *Journal of Economic Theory*, 159, 15–65.

Triandis, H. C. (2001): "Individualism-Collectivism and Personality," *Journal of Personality*, 69(6), 907–924.

Yildirim, H. (2012): "Time-Consistent Majority Rules and Heterogeneous Preferences in Group Decision-Making," working paper, Duke University.