Is Diversity (Un)Biased? Project Selection Decisions in Executive Committees

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Problem definition: Is a committee comprised of more or less cognitively diverse members better at approving the "good" projects and rejecting the "bad" ones?

Academic/Practical Relevance: We contribute in the operations management literature by accounting for the fact that critical selection decisions are often made by a committee rather than a single decision-maker. Understanding how the magnitude of diversity affects the decision quality of such a committee is an important consideration for practitioners.

Results: We utilize a game-theoretic model to show that diverse perspectives are rarely "averaged out". Instead, diversity leads to systematic biases in project selection. To mitigate the effect of diverse perspectives, managers need to uncover the sources of diversity: do they originate from different individual valuations and preferences, or they express different assimilations of the information that arises during the project execution? We show that this distinction is crucial. Higher preference diversity always leads to higher likelihood of making the wrong decision. Higher interpretive diversity, may be beneficial for the organization.

Managerial Implications: A clear managerial action is the need to identify and reduce such preference diversity. Senior management can achieve this by highlighting the need for more transparency in the pipeline of the business units. Moreover, our analysis shows that interpretive diversity can be a powerful managerial lever to influence the propensity for Type I and II errors. The latter might be easier to manage than the organizational structure.

Key words: project management, project termination decisions, executive committees, strategic voting, diversity

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1. Introduction

Organizations constantly face the challenging decision to continue or terminate risky innovation projects. Such go/no-go decisions lie at the core of the stage-gate process (Cooper 2009). At each gate executive committees evaluate individual projects to determine progress. A context that exemplifies the tradeoffs associated with such decisions is the drug development process (Cook et al. 2014). Pharmaceutical organizations have to decide whether a compound has achieved satisfactory proof of concept (a stage called Phase IIa) to progress to more advanced and expensive clinical trials (Phase IIb). A compound's *efficacy* (i.e., whether or not the drug works) is a necessary but not sufficient evidence for progression. According to Arrowsmith (2011), 29% of compounds are terminated at that stage due to strategic reasons, such as low expected return-on-investment, rather than technical ones, such as their low efficacy or side-effects, etc. This highlights the strategic importance of the decisions made at such milestones, and therefore, the need for senior executives that represent the different divisions of the organization.

Consider GlaxoSmithKline's decision process: "*If a compound survived to the end of Phase IIa, the leadership of the Center of Excellence for Drug Discovery (CEDD) would have the option to present the compound to the centralized Development Investment Board (DIB). Presentation before the DIB represented the first point at which corporate-level R&D executives (i.e., those outside of the CEDD) had the ability to make decisions about the progress of specific compounds through the discovery pipeline. The members of this board -executives from both the R&D and commercial organizations within GSK- would solicit information, as needed, from other individuals and would render a final determination on whether the CEDD had achieved proof of concept (PoC) for the compound... Ultimately, PoC would imply that a CEDD had provided sufficient evidence of safety and efficacy to justify investment in the expensive, late-stage development of a compound.*" (p.9 Huckman and Strick 2010)."

The establishment of such a centralized committee as the key governance structure for making such capital-intensive decisions is typical in the pharmaceutical industry (Behnke and Hueltenschmidt 2010) as well as other industries where major new projects are undertaken (Cooper 2009). By design, a key feature of these committees is their diverse nature: participants often span all functions (from pharmacology to pharmacokinetics) and product lines (therapeutic areas) of the organization. According to a senior executive who heads such a committee, this diversity is essential. It ensures that critical assumptions are scrutinized from different angles (Pangalos 2016).

The discussion about the necessity of diverse perspectives in such committees reveals a fundamental tension: on one hand, diversity in perspectives ensures the inclusion of different viewpoints and criteria, and therefore it enables more comprehensive evaluation, and presumably, better decisions. On the other hand, though, executives that hold diverse business roles, and therefore abide to different strategic priorities, introduce their own biases and objectives, which might challenge the decision-making process. In this paper we address a research question that stems from this tension: is a committee comprised of more or less cognitively diverse members better at approving the "good" projects and rejecting the "bad" ones?

This fundamental tradeoff regarding the role of membership diversity in committees of product development processes has received sparse attention in the extant literature. The new product development (NPD) and innovation literatures, have recognized the effects of information asymmetry within organizational hierarchies for go/no-go decisions in development processes (Chao et al.

2014). However, these earlier studies have not accounted for the key fact that, in many contexts, including the aforementioned major milestones in the pharmaceutical industry, such decisions are made by executive committees rather than a single decision maker. The organizational design literature has contemplated the effects of committee size and selection rules on decision making (Csaszar and Eggers 2013). However, they have not considered the reality of strategic interactions and information asymmetries among the committee members.

We build a game-theoretic model that considers the effects of both strategic interactions and information asymmetries. Accounting for the strategic interactions is critical. It ensures a richer social process of decision making that remains consistent with rationality: each member takes into account the fact that the outcome of the decision process, and therefore, her payoff, does not depend on her choices alone, but also on those of her peers. The literature has termed such rational decision-making as *strategic voting* (Austen-Smith and Banks 1996). This contrasts, *naive* or *sincere* voting whereby a member incorrectly acts as if her vote alone determines her payoff (Austen-Smith and Banks 1996). Our model builds upon the concept of strategic voting, the predominant methodology of formalizing strategic interactions in the extant literature on decision-making committees (Austen-Smith and Banks 1996, Feddersen and Pesendorfer 1997, Hao and Suen 2009).

Moreover, our model accounts for information asymmetries that capture diverse viewpoints amongst the committee members. The seniority of such committee membership implies that the participants bear significantly different views as to what constitutes a successful outcome (Eisenhardt et al. 1997, Smith and Tushman 2005). Eisenhardt et al. (1997) stress that: "*The likelihood of conflict is further exacerbated by the fact that senior executives usually lead their own large and important sectors of the corporation. So, they receive information and pressure from their own unique constituencies within the firm and form objectives that reflect their differing responsibilities.* (p. 43, Eisenhardt et al. 1997) A recent report by the Boston Consulting Group (BCG) for the pharmaceutical industry echoes the same issues for such executive committees: "*...whose [the executives'] natural tendency might be to prioritize the interests of their functions rather than to promote the enterprise view.* (p.19, Tollman et al. 2016). The report also highlights that it is precisely the highly risky and novel nature of the R&D initiatives that allows for the members' interests to remain undetected, particularly when the decision concerns project terminations.

We analyze the effect of diverse viewpoints on a committee's decision making process and outcome accounting for two distinct forms of cognitive diversity: (i) *preference diversity*, which we define as the committee members' different valuations about the project; (ii) *interpretive diversity*, which we define as the different emphasis that the committee members place on their privately observed information signals regarding the project's likelihood of success. The former reflects differences in the perceived opportunity costs and outside options that each committee members face (Eisenhardt et al. 1997). The latter represents the existence of different "*thought worlds*" (Dougherty 1992) among the committee members, which prompt them to filter the new information in different ways. Therefore, some members might assign very high informational value to their signals, while others might choose to ignore them.

Our analysis sheds light on the complex effect of diversity on a committee's selection outcomes. First, we show that diverse perspectives are rarely "averaged out". Instead, it is important for managers to understand whether those diverse perspectives stems from different preferences or different interpretations of new information. Preference diversity is always detrimental for a committee's decision outcome. Specifically, under preference diversity, committees not only become more likely to reject projects that would have succeeded, but also to accept projects that are bound to fail. Interestingly, the effect is intensified in contexts with more reliable information. On the contrary, interpretive diversity may act as a powerful lever to improve the decision making process. We find that interpretive diversity counterbalances the type of decision making error that is more costly for a particular project context. For projects with high opportunity cost, interpretive diversity leads to more conservative decisions that reduce the likelihoods of investing in expensive bad projects. For projects with low opportunity costs, higher interpretive diversity enables more aggressive decisions that reduce the chance of forgoing valuable opportunities.

2. Literature Review

In product development, management is charged with the task of reviewing a project's progress and making selection decisions. Such decision-making rules are among the most widely adopted practices (Cooper 2009). Recent literature recognizes the organizational enablers of such processes and stresses the effects of information asymmetries on such decisions.[1] Chao et al. (2014) develop a model that accounts for the fact that go/no-go decisions are often made by senior executives while project managers are responsible for the project execution. The latter are likely to be more informed about the details of the project, and as such, incentives need to be properly structured to mitigate potential misalignments. When the uncertainty of the value of an idea is high, information asymmetry forces an organization to reject projects that would have been profitable. Unlike this literature, which looks at hierarchical organizational structures (between a principal and an agent), the focus of our paper is on senior executive committees where members have an egalitarian status.

[1] A large body of literature treats go/no-go decisions as optimal stopping problems, where a single project manager optimizes the continuation or not of a project under different uncertainty regimes (e.g., Huchzermeier and Loch 2001) We are not reviewing it here as the tradeoffs discussed in that literature are fundamentally different than ours (e.g., that literature overlooks information asymmetries and their effect on strategic interactions within organizations).

NPD studies have also looked at the effects of group diversity, albeit in settings different than ours. Kavadias and Sommer (2009) study the effect of group diversity on idea generation. They show that a diverse group outperforms a group of individuals who work independently in problems where cross-functional input is required. Wu et al. (2014) study how diversity in the cost salience of the project workers affects the performance of the project. Cost salience refers to the tendency of an individual to perceive the cost of immediate effort to be larger than the cost of future effort, leading to procrastination and project delays. They show the overall cost of the project decreases as the diversity of team with respect to the cost salience of its members increase. While we also address the effects of diverse perspectives due to differing perceptions of value (or equivalently, cost) and information fidelity, we focus on a different managerial decision: to continue or not a strategic project.

The challenge of selecting the right projects and rejecting the wrong ones has also been examined in the literature in organizational design. Sah and Stiglitz (1986, 1988) are among the first who study how the structure of an organization determines the effectiveness of its project selection process which is susceptible to the two fundamental errors in decision-making: rejecting an initiative that would have been successful (a Type I error), or approving a project that is bound to fail (a Type II error). Sah and Stiglitz (1986) compare the two archetypal organizational structures: a *hierarchy*, where a project is reviewed at all the different levels of the organization, and approval is necessary by all levels, versus a *polyarchy*, where a project is selected by the organization as long as it is approved by any one of its members. They show that hierarchies reduce Type II errors at the expense of increasing Type I errors; polyarchies do the reverse. Sah and Stiglitz (1988) extend the analysis to include a committee structure for which a minimum level of consensus is required for a project to be approved. They show that a committee's selection process can be considered a hybrid form of the polyarchy and hierarchy.

More recently, Christensen and Knudsen (2010) extend the work of Sah and Stiglitz (1986) to allow for any hybrid organizational structure between the two archetypes. They characterize the optimal hybrid structure that ensures a symmetrical reduction of Type I and Type II errors. Csaszar (2013) adds to this discussion by accounting for cost and time considerations. He identifies the optimal organizational structure for a given set of goals (e.g., maximizing profits) and constraints (e.g., fixed budget or limited time to reach a decision).

We differ from the aforementioned studies along two critical dimensions: first, prior work focuses on the role of the organizational structure, and as such it assumes a priori identical decisions makers. We focus on the effect of heterogeneous decision-makers, and therefore, we allow individual decision-makers to vary with respect to their perspectives. The only other paper that considers such a degree of heterogeneity is Csaszar and Eggers (2013). Yet, their conceptualization is drastically different than ours. In their setting, heterogeneity represents the different levels of expertise (breadth of knowledge) that are available in an organization. Given that the expertise of each member is observable, they compare the performance of different organizational structures such as delegation to experts, majority voting, and averaging of opinions. In contrast, we focus on a particular organizational structure: an egalitarian committee where no member is considered more (or less) expert than her peers. In our setting, all members receive equally valuable information about the project, which is however, private to each member. Differences in their preferences and interpretations of this information might intervene with the information aggregation process. Our main research question is to explore when such diversity is beneficial or detrimental for the organization.

Second, a common assumption in all of the aforementioned studies is the non-strategic nature of the decisions of the individual members. In other words, individuals decide as if their decisions alone determine the outcome of the selection process, without accounting for the actions of their peers. Based on the pioneering work of Austen-Smith and Banks (1996), the literature on committee decision-making accounts for such strategic considerations through the concept of strategic voting. Despite the extensive literature on committee decision-making (for thorough reviews see Gerling et al. (2005) and Hao and Suen (2009)), the effect of diversity remains rather overlooked. Feddersen and Pesendorfer (1997) consider a setting of diverse preferences where each member knows the cost that she associates with the project (type), but is aware only of the distribution of the type of her peers. Yet, they do not analyze how this uncertainty regarding the distribution of peers' preferences afffects the error probabilities of the committee. The paper closest to our work is Gerardi (2000). He shows that under a specific committee decision rule (unanimous approval), the transition from a setting where all members have identical preferences to one with diverse preferences, makes the committee more conservative, that is, members become less likely to approve a given alternative.

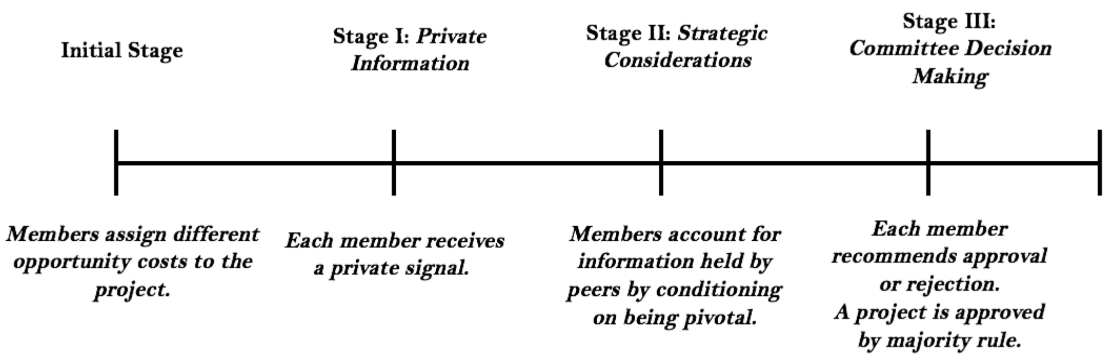
Our contribution to the above literature on diverse preferences under strategic voting is threefold. First, we study how the error probabilities change as the preference diversity of the committee increases, that is, as the variance of the preference distribution increases. None of the aforementioned papers discusses the effect of higher variance on the decision quality. Second, our paper is the first to model the effect of interpretive diversity. We show that while higher preference diversity is always detrimental for the committee's decision-making process, higher interpretive diversity can be beneficial. Third, our paper is the first to compare the effect of diversity under different organizational structures, such as hierarchies and polyarchies. By contrast, all of the aforementioned papers on strategic voting restrict their analysis to the case of a committee.

Lastly, there is an extensive literature on team diversity research in organizational behavior (for a thorough review see van Knippenberg and Mell (2016)). However, the vast majority of this research is focused on characteristics such as demographic background, functional or educational background, or personality (the so-called stable traits), rather than the more malleable attributes, such as preferences, or the processing of information. The studies relevant for our work examine whether diverse groups can aggregate effectively their distributed information. A key finding from this stream is that while more diverse members are likely to collectively have more information, they may lack the social ties and interpersonal knowledge to benefit from it (Gruenfeld et al. 1996).

3. Model Setup

Consider the typical executive committee of an organization. A group of N senior executives are tasked with the approval or rejection of a strategic project. For example executives from different therapeutic areas, such as oncology, but also functional units, like pharmacokinetics, convene regularly to decide which candidate compounds should continue to receive funding in Phase IIb. We represent the committee decision process as a sequence of four distinct stages: (i) the initial stage where individual members form their preferences regarding the project; (ii) the individual signal interpretation stage where each member privately observes his/her signal; (iii) the strategic consideration stage where members form expectations regarding the signals observed by their peers, (iv) the decision-making phase where members turn their individual recommendations into the committee's decision outcome. We delineate schematically the decision process in Figure 1. In the following subsections we elaborate further on each stage of the decision making process.

Figure 1 The committee decision process.



Initial Stage: Initial beliefs and private preferences

At the outset, and prior to any additional information, all executives share some basic common knowledge about the project potential. The actual potential of the project, ω, is unknown and it could either be good or bad, i.e., $\omega \in \Omega = \{G, B\}$. The a priori probability of having a good project is $Pr(\omega = G) = \pi$. If a "good" (G) project is selected, then it realizes net value $V - c$ for the organization where V is the revenue derived from a good project, and c is the irreversible investment required to develop it. In the pharmaceutical industry the parameter V captures a drug's overall earning potential while the parameter c captures the cost of clinical trials and other development efforts. If, however, a "bad" (B) project is selected, then the organization realizes no revenue, but still expends the resources committed, resulting in a loss of c.

Let $a_i \in A = \{YES, NO\}$ with $i \in 1, 2, ..., N$ denote the decision of the i^{th} member and $a^c \in \{YES, NO\}$ denote the collective decision of the entire committee. Then, for a given collective decision and project realization, (a^c, ω), the utility of member i is as follows. If the committee rejects the project ($a^c = NO$), no investment is initiated so the payoff is zero in either state, i.e., $U_i(a^c = NO, \omega = B) = U_i(a^c = NO, \omega = G) = 0$. If the committee approves the project ($a^c = YES$), the corresponding utilities of member i for a good and a bad project are $U_i(a^c = YES, \omega = G) = V - c - t_i$ and $U_i(a^c = YES, \omega = B) = -c - t_i$, respectively, where t_i denotes the i^{th} member's perception of the *opportunity cost*. We refer to this differentiation of opportunity costs as *preference diversity* as it allows us to capture situations where members attach different opportunity costs to the initiative (i.e., the value generated by the estimated resources and organizational support if they were used for alternative project opportunities). Put differently, given that these executives represent different business units or functional divisions, their perspectives may differ with respect to what constitutes a "good enough" ROI/NPV/expected profit outcome (Eisenhardt et al. 1997, Smith and Tushman 2005, Loch and Kavadias 2011 and references therein).[2]

We assume that t_i is private information and only known to member i. Yet, all committee members are aware of the distribution of $t_i's$. Each t_i is drawn from the uniform distribution $U[\mu_t - \varepsilon_t, \mu_t + \varepsilon_t]$. As such, the parameter ε_t captures the dispersion among the committee members' opportunity costs, which we use as a proxy for the magnitude of preference diversity. This conceptualization of diversity follows the typology of Harrison and Klein (2007) as it describes the distribution of differences among the members with respect to a common attribute such as the opportunity cost associated with the initiative.

Stage I: Assimilation of Private Information

Individual members update their prior beliefs regarding the potential of the project based on private signals, $s_i \in \{g, b\}$. The assumption of different signals reflects the key desired feature of such organizational structures, namely, the access to independent viewpoints. It is exactly this ability of accessing multiple signals that has advocated cross-functional committees as a statistically superior

[2] Note that modeling preference diversity as heterogeneity in t, is mathematically equivalent to considering heterogeneity in V or c.

decision-making mechanism. The private information reflects the fact that different individuals resonate differently with the complex information presented during decision meetings (Smith and Tushman 2005). This is particularly so, for selection decisions in the pharmaceutical industry where no single member can comprehend in its entirety the lengthy reports that describe the design and the results of those clinical trials. Instead, different members resonate with the areas that are closer to their expertise. For example, an executive from the marketing department is more likely to assimilate the information on how differentiated the benefits to patients are with respect to existing treatments, whereas an executive from the R&D department is more likely to focus on the pure technical properties of the drug, such as establishing a strong link between the selected target (e.g., the protein or organ that the drug is aiming for) and the disease.

However, at such early stages, uncertainty can never be fully resolved. At best, the new information provides an imperfect signal regarding the project's potential. A key parameter of this updating process is the perceived *fidelity* of the new information (Loch et al. 2001). Let q_i denote the fidelity that member i attributes to the new information. Mathematically, q_i is the conditional probability that the signal reflects the true project potential, i.e., $Pr(s_i = g|\omega = G) = Pr(s_i = b|\omega = B) = q_i \in (\frac{1}{2}, 1)$. We allow executives from different business units to assign different fidelity to the new information. Specifically, the i^{th} member's fidelity, q_i, is drawn from the uniform distribution $U[\mu_q - \varepsilon_q, \mu_q + \varepsilon_q]$. The parameter ε_q represents the dispersion among committee members' fidelities, and it serves as a proxy for the range of interpretive diversity. As with the opportunity costs, fidelity is private knowledge. Each member is aware of the fidelity she attributes to the new information, but she is only aware of the distribution of her peers' fidelities.

Our conceptualization of interpretive diversity reflects the different cognitive lens that each member uses to filter new information, and in turn, the extent to which his or her belief is affected by the new information. Prior literature stresses that the existence of different cognitive lens among executives often results to a lack of common understanding and interpretation of the new information. For example, Dougherty (1992) notes that: "*Departmental thought worlds partition the information and insights. Each has a distinct system of meaning which colors its interpretation of the same information, selectively filters technology-market issues, and produces a qualitatively different understanding of product innovation*" (Dougherty 1992, p.195).

Such lens are common in the biopharmaceutical industry as there is often a lack of agreement on whether the "readout" of a clinical trial provides enough evidence for continuation in the next stage. For instance, a long-standing, but still on-going, debate pertains to whether subgroup analyses in clinical trials provide reliable information for the efficacy of a drug, and if so, under what conditions. Feinstein (1998) refers to it as the "clinico-statistical tragedy" whereby there are two sets of protagonists, both of whom are right: "*The statisticians are right in denouncing* *subgroups that are formed post hoc from exercises in pure data dredging. The clinicians are also right, however, in insisting that a subgroup is respectable and worthwhile when established a priori from pathophysiologic principles. [...] The potential tragedy now is that what may seem to be good statistics will be bad science.*" More recently, Burke et al. (2015) offers some "rules of thumb" to assess whether subgroup analysis should be considered "reasonably credible". The above discussion suggests that for complex projects, the extent to which an executive "believes" the results of a clinical trial, and therefore, decides to act upon them, entails a substantial element of personal judgement, and that is why we assume that each member's fidelity is private information.

To ensure consistency in the way members interpret information, we assume that each member $i \in 1, 2, ..., N$ considers her fidelity, q_i, to be the correct one, that is, reflective of the true value that the information signal carries about the project potential. This is a reasonable assumption and a necessary one to support any formal updating mechanism of individual beliefs. Assuming otherwise, i.e., that members do not trust their own estimations of fidelity, prohibits the use of any formal updating mechanism. In other words, member i considers that member j with $q_j > q_i$ ($q_j < q_i$) overestimates (underestimates) the fidelity of the new information. For example, a pharmacology expert executive, even though she recognizes the value of information related to the efficacy of a compound, she might be concerned that a therapeutic area executive might be "reading too much into it". Moreover, we assume that all non-focal members share a common belief structure about the q_i of focal member i, that is, all non-focal members know that q_i, is drawn from the uniform distribution $U_i[\mu_q - \varepsilon_q, \mu_q + \varepsilon_q]$. Lastly, we assume symmetry across the committee members, so that member $i \in 1, 2, ..., N$ has the same belief structure, $U[\mu_q - \epsilon_q, \mu_q + \epsilon_q]$, for all her peers.

Given the above assumptions, member $i's$ posterior belief upon receiving a signal $s_i \in \{g, b\}$ can be written as follows:

$$Pr(G|s_i = g) = \frac{\Pr(s_i = g|G)\Pr(G)}{\Pr(s_i = g|G)\Pr(G) + \Pr(s_i = g|B)\Pr(B)}$$

and

$$Pr(G|s_i = b) = \frac{\Pr(s_i = b|G)\Pr(G)}{\Pr(s_i = b|G)\Pr(G) + \Pr(s_i = b|B)\Pr(B)}.$$

Note that the above updating scheme is also referred to as *naive* or *sincere* (Austen-Smith and Banks 1996) because each member i updates his/her belief on his/her signal alone, without accounting for the actions of his/her peers. In the following section, we discuss how accounting for peers' actions affects the above formulations.

Stage II: Accounting for peers' actions

Rational members are aware that their payoff is determined by the collective outcome of the voting process rather than their individual decisions. As such, committee members need to account for the actions of their peers. A series of papers (Austen-Smith and Banks 1996, Feddersen and Pesendorfer 1997) capture such strategic considerations through the concept of *strategic voting*, and show that such behavior constitutes a Nash equilibrium: to maximize her expected utility a member needs to account for peer actions, rather than assume that her actions alone determine the outcome (*naive voting*).

Formally, accounting for peers' actions, has the following implication: when comparing whether to recommend approval or rejection, member i has to consider her expected payoff over all possible combinations of her actions and the actions of her peers. In fact, the only eventuality where her individual vote affects her payoff, is when she is pivotal. That is, when all the other members vote in such a way that member $i's$ vote determines the outcome (e.g., under majority rule, half of her peers support YES and the other half NO). In all other cases, her payoff is entirely determined by the votes of her peers, so the choice between YES and NO does not affect member i's decision (i.e., the utility of the two decisions are the same). As such, the pivotal contingency is a direct mathematical consequence of a payoff maximizing strategy that accounts for peers' actions.[3]

This pivotal contingency, in turn, carries information about the signals observed by her peers. Instead of just using only her own signal to update her belief, member i can infer information about what signals her peers might have observed, even though she hasn't observed any of their actual votes, through the likelihood of the pivotal contingency emerging. Mathematically, the posterior beliefs of member i upon receiving signals $s_i \in \{g, b\}$ are as follows:

$$\Pr(G|s_i = g, piv) = \frac{\Pr(s_i = g|G)\Pr(piv|G)\Pr(G)}{\Pr(s_i = g|G)\Pr(piv|G)\Pr(G) + \Pr(s_i = g|B)\Pr(piv|B)\Pr(B)}$$

$$\Pr(G|s_i = b, piv) = \frac{\Pr(s_i = b|G)\Pr(piv|G)\Pr(G)}{\Pr(s_i = b|G)\Pr(piv|G)\Pr(G) + \Pr(s_i = b|B)\Pr(piv|B)\Pr(B)}.$$

These formulas reflect that each member recognizes the richer informational landscape, namely the different signals held by her peers, and accordingly that information affects her posterior belief. Therefore, compared to the updating formulas on p.10, the pivotal-based updating carries more informational value than naive updating. Such social learning plays an important role in the setting that motivated our study because the highly complex nature of the projects under consideration, prohibit a member from being able to fully absorb all the relevant information by herself. Instead, members of such committees realize that, despite the potential differences in preferences and interpretations, their peers hold valuable information, which they should somehow account for in their decision making.

[3] A simple illustration of this can be found in the online Appendix.

Ideally, each member would observe all signals; or equivalently, have her peers truthfully reveal their signals. However, truthful revelation is not an equilibrium (Austen-Smith and Banks 1996), especially when members have diverse preferences (Coughlan 2000), as in our setting. Thus, the second-best for a member is to infer the likelihood that certain combinations of signals give rise to the pivotal contingency. Even though such information is imperfect, it offers a richer information basis to make a decision.

A number of experimental studies have demonstrated that information elicited from the pivotal condition can significantly impact the subjects' decision (Guarnaschelli et al. 2000, Battaglini et al. 2008, Battaglini et al. 2010, Goeree and Yariv 2011). For example, Goeree and Yariv (2011) show that, for any voting rule, subjects may vote against their private information when the information elicited from the pivotal contingency suggests that they do so.

It is worth highlighting here that strategic voting endogenizes a specific type of cross influence amongst committee members. It is a form of social learning where the focal member elicits information from her peers, and incorporates such information in her belief. At the same time, we acknowledge that in some situations such informational considerations may be dominated by other types of cross influences among the committee members, such as career concerns or peer pressure (see Discussion section).

Stage III: The committee decision

Once members integrate all the available information, both from their individual private signals and the pivotal contingency, they proceed with their individual recommendations, $a_i \in A = \{YES, NO\}$, regarding the project. We capture the conversion of the individual recommendations to a collective decision through the following general decision rule: the project is pursued if approval is recommended by at least r out of the N members. In the remainder of the paper we focus on the case of majority rule such that $r = \frac{N-1}{2}$. Before presenting the results of our analysis, we summarize the assumptions of our model in the normal form of a Bayesian game.

Summary of key model components

1. There are N committee members, $i \in \{1, 2, ..., N\}$ who must decide whether to approve or reject a project. The project can be either good or bad, $\omega \in \Omega = \{G, B\}$

2. The type of each committee member i is $\theta_i = (s_i, t_i, q_i)$. Thus, the set of possible types is $\Theta \equiv \{b, g\} \times U(\mu_t - \varepsilon_t, \mu_t + \varepsilon_t) \times U(\mu_q - \varepsilon_q, \mu_q + \varepsilon_q)$.

3. Each committee member votes $a_i \in A = \{YES, NO\}$ given his/her type θ_i.

4. The decision of the committee is $a^c = YES$ if $|\{i : a_i = YES\}| \geq r$ and $a^c = NO$ otherwise.

5. Given the decision of the committee and the state of nature, the utility of member i is as follows: $U_i(a^c = YES, \omega = G) = V - c - t_i$, $U_i(a^c = YES, \omega = B) = -c - t_i$, $U_i(a^c = NO, \omega = B) = U_i(a^c = NO, \omega = G) = 0$.

4. Analysis

In this section we characterize the effects of diverse perspectives on the committee decision. First, we discuss the effects of diverse preferences (Section 4.1), and then the effects of diverse interpretations of project information (Section 4.2). We disentangle these effects to illustrate how different types of diversity give rise to different effects, and therefore, they affect differently the decision quality of the committee. Thus, in Section 4.1 we assume that all committee members interpret the information through the same $q_i = q$, whereas in Section 4.2 we consider the case where they share a common opportunity cost $t_i = t$. For each case, we first characterize the optimal decision of each committee member, and then, we analyze the effect of higher diversity on the collective decision quality of the committee. Project evaluation decisions can suffer from the two fundamental errors of rejecting good projects (a Type I error) and approving bad ones (a Type II error). As such, we use the Type I and Type II error probabilities as our key decision quality metric. We present our analysis for committees that decide based on a majority rule, but where appropriate we discuss the implications from a unanimous acceptance rule (detailed results for this case are available from the authors upon request). Finally, our analysis corresponds to the case where the prior belief about the project potential is $Pr(\omega = G) = \pi = 0.5$. This assumption is done only for notational simplicity and it does not affect qualitatively any of the results.

4.1. Diverse screening due to preference diversity

Diverse preferences correspond to the situation where committee members differ with respect to their opportunity cost, as captured by the minimum expected value they require to recommend project approval. Formally, member i recommends approval when $EU_i(a_i = YES) \geq EU_i(a_i = NO)$, or equivalently, when $P'(G)V - c > t_i$ where t_i is drawn from the distribution $U(\mu_t - \varepsilon_t, \mu_t + \varepsilon_t)$ and $P'(G)$ is the posterior likelihood of success, as defined on p.11. Proposition 1 characterizes the equilibrium decision strategy for the i^{th} member contingent on her opportunity cost, t_i, and her private signal $s_i \in \{g, b\}$.

Proposition 1 (individual member's optimal strategy). *There exist signal-contingent opportunity cost thresholds t_g and t_b, with $t_b < t_g$, such that member i recommends approval if $s_i = g$ ($s_i = b$) and $t_i < t_g$ ($t_i < t_b$).*

As we would intuitively expect, a member recommends approval for the project when her opportunity cost is "low enough", i.e., below a threshold value. Otherwise, she recommends rejection. Clearly, this threshold depends on her observed signal: a good signal indicates a promising project, and therefore, a member should have a relatively high opportunity cost to reject it. On the other hand, in light of a bad signal, a member's posterior valuation might become so low, that even a relatively low opportunity cost triggers rejection of the initiative. As such, the threshold under a good signal always lies above the corresponding threshold under a bad signal, i.e., $t_b < t_g$. It is a straightforward extension to show that Proposition 1 holds for any decision rule, that is, for any value of $r \leq N$. To facilitate the explanation of our next set of results (Propositions 2 and 3), it instructive to define the following three type of projects (Definition 1) and to disentangle how strategic considerations affect a member's posterior belief (Corollary 1).

DEFINITION 1. For a committee whose members have an average opportunity cost $E[t_i] \equiv \mu_t$, we define a project (π, V, c) to be: *neutral*, when $\pi V - c = \mu_t$; *attractive*, when $\pi V - c > \mu_t$; *unattractive*, when $\pi V - c < \mu_t$.

Definition 1 classifies projects with respect to the average a priori predisposition of the committee to approve. For example, in the case of a neutral project, the a priori likelihoods, for an arbitrary member, of recommending approval or rejection are the same, i.e., $Pr(t_i < \pi V - c) = Pr(t_i > \pi V - c) = 0.5$. On the other hand, for an unattractive project, an arbitrary member is more likely to recommend rejection than approval.

Also, let γ_G denote the probability that a member supports the project, given that the project's true state is good. To derive γ_G note that a member may receive a good signal with probability q, in which case she only approves the project if her type is below t_g, or receive a bad signal, with probability $1-q$, in which case she only approves the project if her type is below t_b. Thus, $\gamma_G = Pr(s_i = g|\omega = G)Pr(t_i < t_g) + Pr(s_i = b|\omega = G)Pr(t_i < t_b) = qF(t_g) + (1-q)F(t_b)$. Similarly, let γ_B be the probability that a member recommends approval given that the project's true state is bad. Then, by the same token, $\gamma_B = (1-q)F(t_g) + qF(t_b)$. Given the above definitions of γ_G and γ_B, and that under majority rule, member i is pivotal when $\frac{N-1}{2}$ members have recommended approval and $\frac{N-1}{2}$ members have recommended rejection, we can write the posterior belief of member i upon receiving a good signal as follows:

$$\Pr(G|s_i = g, piv) = \frac{q\gamma_G^{\frac{N-1}{2}}(1-\gamma_G)^{\frac{N-1}{2}}\pi}{q\gamma_G^{\frac{N-1}{2}}(1-\gamma_G)^{\frac{N-1}{2}}\pi + (1-q)\gamma_B^{\frac{N-1}{2}}(1-\gamma_B)^{\frac{N-1}{2}}(1-\pi)}, \text{ or equivalently,}$$

$$\Pr(G|s_i = g, piv) = \frac{1}{1 + \frac{(1-\pi)}{\pi}\frac{(1-q)}{q}\left(\frac{\gamma_B(1-\gamma_B)}{\gamma_G(1-\gamma_G)}\right)^{\frac{N-1}{2}}}.$$

COROLLARY 1. *For an attractive (unattractive) project, the existence of strategic considerations lowers (raises) the members' posterior beliefs. The effect is amplified as the size of the committee, N, increases. For a neutral project, strategic considerations do not affect the members' beliefs.*

First note that in the absence of strategic considerations (non-strategic voting), the terms γ_G and γ_B do not affect a member's posterior belief. According to Corollary 1, the effect of the pivotal contingency (captured in the term $\frac{\gamma_B(1-\gamma_B)}{\gamma_G(1-\gamma_G)}^{\frac{N-1}{2}}$), depends on the ex-ante predisposition of the committee. Consider a committee where the focal member i knows that her peers, a priori, favor approval of the project. Under such favorable predisposition, the event of a pivotal contingency (i.e., half of her peers recommend rejection), is associated with a substantial number of bad signals having been observed by her peers. As such, the pivotal condition prompts to a lower posterior belief compared to the case of non-strategic voting. Mathematically, $\Pr(G|s_i, piv) < \Pr(G|s_i)$ for any $s_i \in \{g, b\}$. Conversely, for an a-priori unattractive project, the pivotal contingency would lead to a higher posterior belief compared to the non-strategic voting case. Clearly, larger committees are associated with a larger number of signals, and thus, the effect of the pivotal contingency becomes stronger as N increases.

Proposition 2 (effect of preference diversity on member strategy). *For a neutral project, t_g and t_b are invariant in the magnitude of diversity, ε_t. For an attractive project, t_g and t_b increase in ε_t. For an unattractive project, t_g and t_b decrease in ε_t.*

Proposition 2 highlights the moderating role that the committee predisposition has on the effect of diverse preferences. When the committee members are a priori more likely to recommend approval (case of attractive project), higher preference diversity leads to higher threshold values, which in turn, make the members adopt an even more favorable (for the project) approval decision strategy. On the other hand, when members are a priori more likely to recommend rejection (case of unattractive projects), higher preference diversity makes members adopt an even more conservative strategy. Thus, in either case, preference diversity reinforces the committee's predisposition towards the project.

This result can be explained as follows. Consider the case of an unattractive project. For the focal member i, the pivotal contingency implies that despite the unfavourable predisposition, half of his peer members recommend approval. Then, the key consideration for the focal member is whether the peers' support stems from the observation of positive signals, or is due to their own member-specific preferences (e.g., low opportunity costs always prompt approval irrespective of information updates). When the preference diversity, ε_t, is low, the former effect dominates the latter: peer support is more likely to be driven by good signals, and therefore, strategic considerations raise the focal member's posterior belief.

As the preference diversity, however, increases, the preferences of the committee members become more symmetrically distributed, and the probability mass below the threshold converges to the probability mass above the threshold.[4] As a result, the pivotal contingency becomes less informative: it is no longer an event that is associated with positive signals. Instead, it could emerge from

[4] To see why, imagine the extreme scenario where $\varepsilon_t \to \infty$, and therefore, the likelihoods would converge to 0.5.

an equal distribution of good and bad signals. Hence, higher dispersion leads to lower posterior beliefs, and in turn, to lower decision thresholds t_g and t_b.

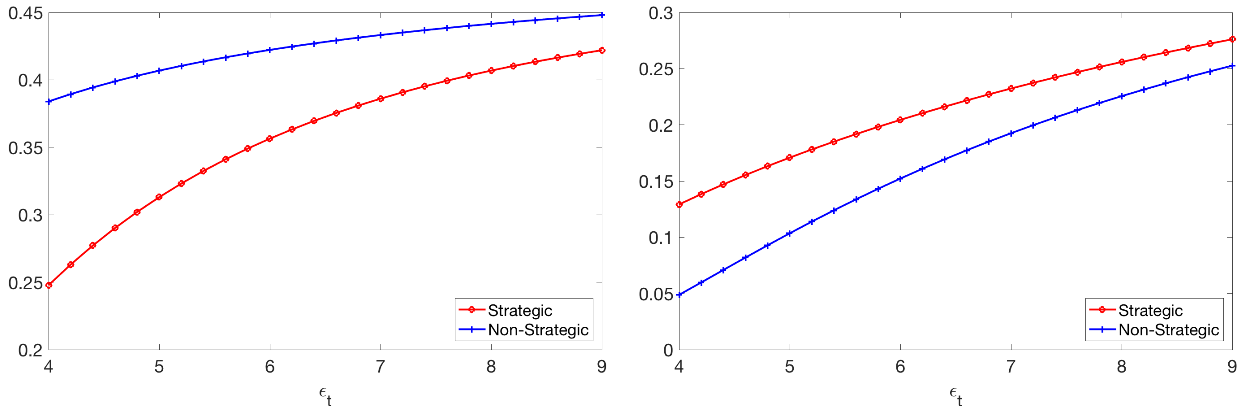
Conversely, when a member considers her peers a priori favorable towards the project (attractive project), the pivotal contingency is associated with numerous negative signals. Again, as the dispersion increases, the predisposition becomes less pronounced, and the focal member associates fewer negative signals with the pivotal contingency. As such, her posterior beliefs, along with her decision thresholds values increase. Lastly, for neutral projects, higher preference diversity does not affect the members' strategies as peer influences are "canceled out" due to symmetry.

This result bears insightful organizational implications about the effect of preference diversity on members' decision strategies along two dimensions. First, committees constitute an effective selection mechanism due to the effective information aggregation that peer inferences enable. Through the pivotal contingency, individual members can assimilate information beyond their individual signal. Second, the benefit from the above information aggregation process diminishes as the dispersion among the members' preferences increases. Thus, preference diversity hinders a major advantage of committees: the aggregation of peer perspectives for effective decisions. A higher dispersion among preferences increases the uncertainty that members face with respect to peer preferences, and therefore, reduces the information that can be elicited from a pivotal contingency. In turn, members rely more on their own private information, a decision approach that manifests a silo perspective.

Proposition 3 (effect of preference diversity on error probabilities). *For a neutral project, the likelihoods of both Type I and Type II errors increase in ε_t, i.e., $\frac{\partial \Pr(NO|G)}{\partial \varepsilon_t} > 0$ and $\frac{\partial \Pr(YES|B)}{\partial \varepsilon_t} > 0$. Moreover, these effects of preference diversity are pronounced in a high fidelity project as $\frac{\partial^2 \Pr(NO|G)}{\partial \varepsilon_t \partial q} > 0$ and $\frac{\partial^2 \Pr(YES|B)}{\partial \varepsilon_t \partial q} > 0$.*

Proposition 3 illustrates the detrimental effects of preference diversity on the selection performance of the committee.[5] As the dispersion ε_t increases, the committee becomes more likely to reject good projects and more likely to approve bad projects. For any neutral project, members who observe positive information (i.e., $s_i = g$) are divided between those with opportunity costs below t_g (who approve the project), and those above t_g (who reject the project). Moreover, the threshold t_g lies above the mean, μ_t, as a member that observes a good signal is more likely to approve the project than to reject it. However, as the dispersion ε_t increases, the preferences become more evenly distributed (in a manner similar to our argument in Proposition 2), and the likelihood that an arbitrary member has opportunity cost below the threshold t_g, i.e., $\Pr(t_i < t_g)$ declines (and

[5] When $\pi V - c \neq \mu_t$, the complex dependance of the thresholds t_b and t_g on ε_t prohibits an analytical derivation; through numerical analysis (available from the authors upon request) we confirmed that Proposition 3 holds.



(a) Type I: Pr(NO|G) (b) Type II: Pr(YES|B)

Figure 2 Error probabilities under strategic and non-strategic voting. $N = 5, V = 12, c = 1, q = 0.75, \mu_t = 6.0$

$\Pr(t_i > t_g)$ increases). As a result, the likelihood of a member, who observes a good signal, to approve the project declines.

By the same exact logic, members who observe negative information ($s_i = b$), have a decision threshold, t_b, that always lies below μ_t. In that case, as ε_t increases, all else being equal, recommending approval becomes more likely. Taken together, these results show that as the dispersion in preferences increases, recipients of a good signal become *less likely* to approve the project, while recipients of a bad signal become *more likely* to approve the project. In short, higher preference diversity makes members less likely to make decisions consistent with the signals they observe, and that is why, both Type I and Type II error probabilities increase.

The main result of Proposition 3 regarding the effect of preference diversity on the error probabilities remains robust across all types of projects. Furthermore, it is worth noting the effect of strategic considerations on the error probabilities. To that end, Figure 2 plots the error probabilities under strategic and non-strategic voting. Note that the specific project is an unattractive project (Definition 1), and as such, an arbitrary member is ex-ante more likely to reject the project. Accounting for the pivotal contingency, raises the posterior beliefs of the committee members (Corollary 1), and that is why under strategic voting members are more likely to approve an initiative than under non-strategic voting. As a result, strategic voting leads to lower Type I errors, but higher Type II errors compared to non-strategic voting. Yet, as the dispersion ε_t increases, the error probabilities of the two cases converge since the pivotal contingency becomes less informative.

Another useful benchmark for the error probabilities discussed in the extant literature, is that of the *full information equivalent* where all members reveal truthfully their signals and share the same average opportunity cost. In this case, the corresponding error probabilities are $Pr(NO|G) = Pr(YES|B) = 0.1$. Thus, while more information lowers significantly the Type I error probability, it leads to higher Type II errors than the case of non-strategic voting, for low values of diversity. This happens because, for the specific (unattractive) project depicted in Figure 2, non-strategic voting leads to an overly conservative approach in the project selection (this can be also seen in the high Type I errors of such a committee). On the contrary, when members reveal truthfully their signals, the committee is more likely to accept the specific project, leading to higher Type II errors. However, as the interpretive diversity increases, the full information case outperforms the strategic and non-strategic voting for both Type I and II errors.

One might expect that the distorting effect of preference diversity can be mitigated through more reliable project information (i.e., higher signal fidelity). Interestingly, our analysis indicates that the opposite is true. The detrimental effect of preference diversity is pronounced for higher information fidelity q, i.e., the increase in both Type I and Type II error probabilities is steeper for higher q. When the members attribute higher value to the new information, i.e., q is high, the thresholds t_b and t_g deviate even further away from the average, μ_t. This reflects the importance of the informational value of the private signal. However, as the preference diversity increases, members become less responsive to their signals (as per Proposition 3) and the new information, of admittedly high value, is now lost. Consider, for example, the case of a good project. Higher fidelity q implies that members are more likely to observe good signals (i.e., signals are more accurate indications of the true project potential), but unfortunately the higher dispersion ε_t, makes them more likely to overlook these signals (Proposition 3). Thus, even though more accurate signals are observed, those signals are overlooked, leading to even higher likelihood for errors.

Our findings extend Gerardi (2000) who examines the effect of diverse preferences under the unanimity decision rule ($r = N$). He shows that the existence of private preferences makes committee members less likely to approve the project. Similar to our analysis, this happens because the support expressed by the peers (under the pivotal contingency) might be driven by the peers' private preferences, and not necessarily by their positive signals. Yet, we show that this result requires further qualification under a majority rule: committees not only become more likely to reject good projects, but they also become more likely to accept projects that are bound to fail. Therefore, preference diversity is detrimental not only towards Type I errors (the one-side effect), but towards both types of errors, and particularly so in environments characterized by information of high fidelity.

4.2. Diverse screening due to interpretive diversity

In this section we examine the effect of diverse perspectives due to different interpretations of the new information on the members' decisions. Interpretive diversity implies that different committee members assign different values on the fidelity of the information source. Specifically, member i

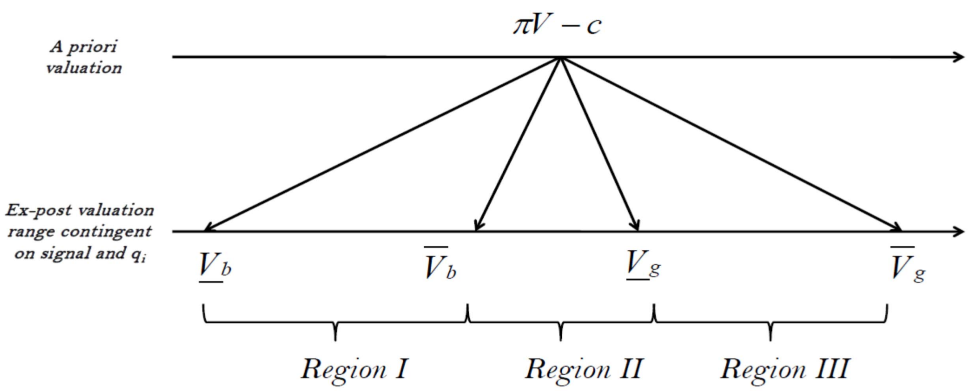
assigns probability q_i to the event that the observed signal is representative of the true project potential of the project, i.e., $q_i = Pr(s_i = g|\omega = G) = Pr(s_i = b|\omega = B)$. The fidelity assigned to the new information is private knowledge to each member. Yet, all members are aware that their fidelity values are realized from the uniform distribution $U(\mu_q - \varepsilon_q, \mu_q + \varepsilon_q)$, where ε_q captures the magnitude of the interpretive diversity as measured by the dispersion of interpretations among the committee members.

In order to analyze each member $i's$ optimal policy, it is useful to understand how the parameters of the distribution affect the range of the ex-post project valuations. Let $q_H \equiv \mu_q + \varepsilon_q$ and $q_L \equiv \mu_q - \varepsilon_q$ denote the maximum and minimum possible fidelity realizations, respectively. Then, for a given project, described by the triplet (V, c, π), we define the following posterior project valuation quantities:

Definition 2. We define the project ex-post valuations to be:

- $\overline{V}_g$: for a member with type q_H that observes a good signal;
- $\underline{V}_g$: for a member with type q_L that observes a good signal;
- $\overline{V}_b$: for a member with type q_L that observes a bad signal;
- $\underline{V}_b$: for a member with type q_H that observes a bad signal.

Figure 3 Opportunity cost t regions.



For example, $\overline{V}_g = \Pr(G|s_i = g, q_H, piv)V - c$, is the valuation of member i who receives a good signal $(s_i = g)$ and assigns the maximum fidelity to it $(q_i = q_H)$. Then, member i approves the project if the opportunity cost is less than the ex-post valuation $\overline{V}_g$, that is, $t < \overline{V}_g$, and rejects it otherwise. The defined ex-post valuations divide the opportunity cost space into three regions of interest.[6] As expected, a good signal always leads to higher ex-post project valuation than a bad

[6] There are two more regions that emerge, but they represent trivial cases. In the event that the opportunity cost is extremely high $t > \overline{V}_g$, no member would recommend approval regardless of their interpretive type and signal. Conversely, when the opportunity cost is extremely low $t < \underline{V}_b$, all members would recommend approval.

signal. Thus, the range of ex-post valuations after observing a good signal $(\underline{V}_g,\overline{V}_g)$ always lies above the range of ex-post valuations after observing a bad signal, $(\underline{V}_b,\overline{V}_b)$. Moreover, the higher the i^{th} member's q_i, the more drastic the change in her ex-post belief, and thus, in her perceived project valuation. The above quantities and their relationship to the a priori project value are illustrated in Figure 3. Proposition 4 characterizes the i^{th} member's equilibrium strategy contingent on the common opportunity cost t, her information signal s_i, and her fidelity q_i.

PROPOSITION 4 (INDIVIDUAL'S MEMBER OPTIMAL STRATEGY).

- *When* $\underline{V}_b < t < \overline{V}_b$ *(Region I), there exists* $q_b \in (\frac{1}{2}, 1)$ *such that:*
  — if $s_i = g$*, then member* i *always approves the project;*
  — if $s_i = b$*, then member* i *only approves the project if* $q_i < q_b$ *and rejects it otherwise.*
- *When* $\overline{V}_b < t < \underline{V}_g$ *(Region II),*
  — if $s_i = g$*, then member* i *always approves the project;*
  — if $s_i = b$*, then member* i *always rejects the project.*
- *When* $\underline{V}_g < t < \overline{V}_g$ *(Region III), there exists* $q_g \in (\frac{1}{2}, 1)$ *such that:*
  — if $s_i = g$*, then member* i *only approves the project if* $q_i > q_g$ *and rejects it otherwise;*
  — if $s_i = b$*, then member* i *always rejects the project.*

Proposition 4 highlights that each member's equilibrium strategy is contingent on the project's opportunity cost. In Region I, the project under consideration faces an opportunity cost low enough to prompt all members with a positive signal to approve the project regardless of their interpretive perspective. Members who observe a negative signal still approve the project, unless they consider this information highly relevant ($q_i > q_b$). In that case, a bad signal drives a steep drop in the ex-post project valuation, which leads them to reject the project. The exact opposite dynamics take place in Region III where the opportunity cost is high. All members who observe negative signals recommend rejection regardless of their interpretive perspective, while members who observe a good signal are now divided between those who consider it relevant ($q_i > q_g$), and recommend approval, and those who assign less value to it ($q_i < q_g$), and therefore, recommend rejection.

Finally, for an intermediate range of values for the opportunity cost (Region II), members who observe negative signals recommend rejection (regardless of their type), and members who observe positive signals recommend project approval. Interestingly, for those projects the members' decisions are determined solely based on their private signal despite the presence of both interpretive diversity and strategic considerations. This happens because for these mid-range t values, there is a lack of any strong predisposition, and therefore, members are entirely responsive to their signals: even if a member assigns low fidelity to his signal, a good signal is enough to make him recommend approval, and a bad one to make him recommend rejection. As a result, in Region II, the pivotal contingency arises through a balanced number of good and bad signals, and as such, it does not affect members' posterior beliefs. In other words, peer influences "cancel out", and members decide solely on their private signals. This result is important because it identifies limiting (but realistic) cases for the presence of strategic voting: non-strategic voting behaviors might emerge as equilibrium strategies *endogenously* for certain types of projects.

COROLLARY 2. *In Region I (III) strategic considerations lower (raise) the members' posterior beliefs. The effect is amplified as the size of the committee increases.*

Similarly to the case of preference diversity, the pivotal contingency allows the committee members to infer information about the signals of their peers. For example, consider Region I. Projects are expected to be approved due to the low t. Accounting for the pivotal contingency, however, implies that peer members received an abundance of negative information about the project, and thus, strategic considerations lower the members' beliefs. In Region III, a similar reasoning shows that strategic considerations lead to higher posterior beliefs. Both effects are amplified for larger committees as the pivotal contingency is associated with a larger number of peer signals.

We proceed by examining how the magnitude of the interpretive diversity affects the individual member's decision strategy. Recall that given the opportunity cost, t, a project (V, c, π) can be classified in one of the three regions discussed in Proposition 4. Hence, for a given t, there exists at most one threshold, q_b or q_g. In the discussion of our results below, we omit cases of projects that are so promising (i.e., V much higher than c) that even when a member receives a bad signal, she is still more likely to approve rather than reject the project. Similarly, we do not discuss cases where a project is so challenging (i.e., V close to c) that even when a member receives a good signal, he is still more likely to reject it rather than approving. Results for these cases are available from the authors upon request, but are not presented here in the interest of brevity.

PROPOSITION 5 (EFFECT OF INTERPRETIVE DIVERSITY ON MEMBER STRATEGY). *For $\frac{t+c}{\Pr(G|s_i=g,q=\mu_q,piv)} < V < \frac{t+c}{\Pr(G|s_i=b,q=\mu_q,piv)}$, both q_b and q_g decrease in ε_q.*

To understand the intuition behind Proposition 5, recall that the information that committee members can extract from the pivotal contingency, is particularly valuable when the pivotal contingency reflects more of the members' signals rather than their interpretive biases. In Region I, members who receive a good signal always recommend approval. As such, each member knows that peer members who would recommend rejection must have observed a negative signal. The inference for a potential project supporter is less straightforward: a member may recommend approval either because she actually observes a positive signal, or because she overlooks a negative signal due to her interpretive type (i.e., she assigns low fidelity to the signal).

For example, in a committee of five members, the pivotal contingency emerges when two members are supportive of the project and two reject it. Therefore, under the pivotal contingency, the focal member infers that the two members who oppose the project, would have observed bad signals. At the same time, the two members who support the project, could have observed good signals with some likelihood. This likelihood is determined by the equilibrium threshold q_b (Proposition 4). However, as the dispersion ε_q increases, the probability masses around q_b converge to equal values (for the same reason as in the discussion of Proposition 2). As such, peer members become equally likely to recommend approval and rejection of the project, simply because of their types, and not necessarily because they observed a positive signal. This implies that the pivotal contingency becomes less indicative of positive signals. Consequently, the posterior belief of the focal member i decreases, which, in turn, lowers the value of q_b: for a given q_i a member becomes more likely to reject the project. Similarly, in Region III, following a mirroring logic, we see that higher interpretive diversity lowers the value of q_g: for a given q_i a member becomes more likely to approve the project.

The effect of interpretive diversity on error probabilities

We now discuss the effect of interpretive diversity on the quality of the committee decision as this is captured by the error probabilities for Type I and Type II errors. Note that to calculate these error probabilities we need to consider the effect of ε_q on both the threshold policies of each member (Proposition 5) as well as its effect on the distribution from where the q_i's are drawn. The complex dependance of the thresholds q_b and q_g on the interpretive diversity ε_q, makes any closed-form analysis intractable. As such, we conduct an extensive numerical study for every meaningful combination (i.e., cases where not all members approve (reject) the initiative due to extremely high (low) difference between V and c) of the parameter values $V \in [5, 10, 20, 30]$, $c \in [1, 2, 5, 10]$, $N \in [3, 5, 7, 9]$, $\mu_q \in [0.60, 0.75, 0.80]$, and $\varepsilon_q \in [0.05, 0.10, 0.15, 0.20, 0.25]$. Table 1 summarizes the directional effects of higher dispersion ε_q on the Type I and Type II error probabilities.

Table 1 Effect of higher diversity ε_q on Type I and Type II error probabilities.

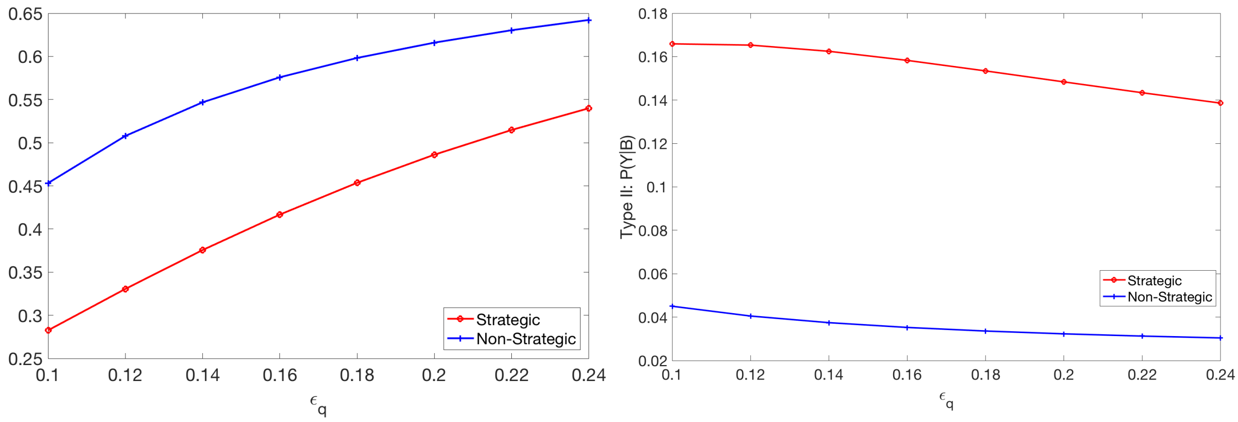
	Region I (low t)	Region II (medium t)	Region III (high t)
Type I: $\Pr(NO\|G)$	$\searrow$	invariant	$\nearrow$
Type II: $\Pr(YES\|B)$	$\nearrow$	invariant	$\searrow$

Table 1 illustrates that the effect of interpretive diversity is contingent on the opportunity cost, t, of the project under consideration. For projects with high opportunity cost (e.g., projects which compete with other opportunities for the same resources, or projects of low strategic priority), higher interpretive diversity makes approval less likely, leading to higher Type I errors, but lower Type II errors (region III). For projects with relatively low opportunity cost, t, higher interpretive diversity makes approval more likely, leading to lower Type I errors, but higher Type II errors (region I). Lastly, for projects of medium opportunity cost, higher interpretive diversity does not affect the error probabilities as the members' decision are solely determined by the realization of their private signals regardless of their interpretive type q_i. Yet, it is worth noting, that as the interpretive diversity increases, and members become likely to ignore their signals (lower $\mu_q - \varepsilon_q$), $\overline{V}_b$ increases and $\underline{V}_g$ decrease (see Figure 3). As such, region II shrinks, and interpretive diversity affects the error probabilities throughout the value set of the opportunity thresholds. These results can be explained as follows.

In region I, higher interpretive diversity does not affect how a member responds to a good signal: she always approves the project, regardless of her q_i. By contrast, for those members who observe a bad signal, higher interpretive diversity makes them more likely to ignore their signal and approve the project. This happens because a higher ε_q, creates a more balanced distribution around the threshold value q_b, creating more probability mass below the value q_b. Thus, higher diversity is more likely to induce more members to ignore their bad signal rather than act according to their signal. Taken together, higher interpretive diversity dilutes a member's response to a bad signal, while it leaves the response to a good signal unaffected. As a result, a member becomes more likely to approve the project. This leads to lower Type I error probabilities, but higher Type II errors probabilities. The opposite dynamics take place in region III: higher interpretive diversity does not affect a member's response to a bad signal, but it dilutes the response to a good signal. As such, members become more likely to reject a project, leading to higher Type I errors, but lower Type II errors.

Figure 4 plots the error probabilities for a project in Region III under the case of strategic and non-strategic voting. Note that because of the high opportunity cost of any project Region III relatively to the value V, the pivotal contingency is associated with a majority of positive signals. Therefore, the beliefs of the committee members under strategic voting are higher than the corresponding belief under non-strategic voting, as every committee member infers more positive signals through their strategic considerations compared to the informational content of only one signal. This, in turn, implies that strategic considerations lead to lower Type I errors, but higher Type II errors.

Naturally, the question to address next is whether these results imply that interpretive diversity is beneficial for an organization with respect to the eventual decision outcome, and if so when. Clearly, this depends on the risk appetite of an organization, and specifically, the weights assigned to losses stemming from Type I and II errors. In general, when the opportunity cost, t, is very low compared to the value, V, of the project, the firm is better off under a more aggressive policy that minimizes Type I errors (so as to minimize regret from forgoing promising opportunities). At



(a) Type I: Pr(NO|G) (b) Type II: Pr(YES|B)

Figure 4 **Error probabilities under strategic and non-strategic voting.** $N = 5, \mu_q = 0.75; \frac{c+t}{V} = 0.7$

the other extreme, for very high opportunity cost, the firm is better off under a more conservative approach that minimizes Type II errors (because even a successful project yields low returns). Under such considerations, interpretive diversity plays a beneficial role in the firm's total expected profitability. It reduces the likelihood for the type of error that is more costly: Type I for region I and Type II for region III. Lastly, note that under the case where all members reveal truthfully their signals, and they share the same average fidelity, the corresponding error probabilities are $Pr(NO|G) = Pr(YES|B) = 0.1$. Those error probabilities are the same as in Figure 2 because they only depend on the average fidelity, the size of the committee, and the voting rule (majority).

5. Extensions

Our analysis so far has focused on a specific decision-making structure: an egalitarian committee that decides based on a majority rule. In this section we extend our analysis to alternative decision-making structures to identify the limitations or advantages that committees exhibit when compared to these structures. Specifically, we explore the effects of preference and interpretive diversity under the two archetypal structures discussed in Sah and Stiglitz (1986, 1988): a *hierarchy* in which projects need to be approved by all the successive ranks of an organization, and a *polyarchy* in which projects are approved within an organization as soon as they are supported by any one member. The former captures more hierarchical contexts with reporting lines and authority, whereas the latter offers an approximation of more "flat" organizational environments with distributed approval power across multiple project champions. We briefly describe the corresponding model formulation for each structure, and then we compare numerically the error probabilities of those structures to our benchmark case of a committee.

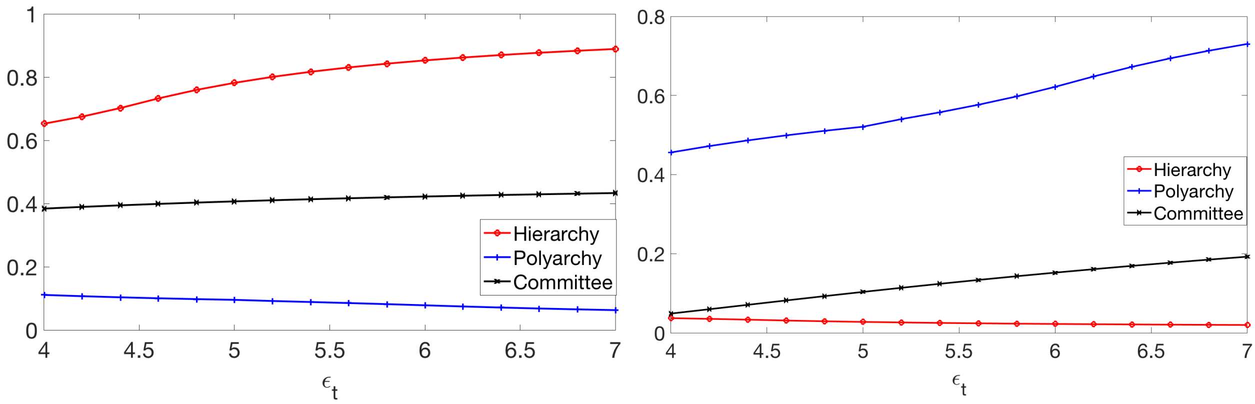
5.1. Preference diversity

As before, we define the probability that member i recommends approval for a good (bad) project as follows: $\gamma_G^i = qF(t_g^i) + (1-q)F(t_b^i)$ ($\gamma_B^i = (1-q)F(t_g^i) + qF(t_b^i)$). As a parallel concept to the pivotal contingency, in a hierarchy, we define the contingency where all members before member i have supported the project, i.e., $a_1 = YES, a_2 = YES, ..., a_{i-1} = YES$. As a result, the posterior belief of the members depends not only on their own signal, but also on their hierarchical position (please see Online Appendix for the exact mathematical expressions of the posterior beliefs). Thus, each member has his/her own threshold values t_g^i and t_b^i. The latter are determined by solving recursively the system of equations $V\Pr(G|s_i = g, piv) - c = t_g^i$ and $V\Pr(G|s_i = b, piv) - c = t_b^i$ for every $i = 1,2,...N$. Given the thresholds t_g^i and t_b^i, we calculate the probabilities γ_G^i and γ_B^i for $i = 1,2,...,N$. Finally, the error probabilities for the entire hierarchy will be $\Pr(NO|G) = 1 - \Pr(YES|G) = 1 - \gamma_G^1\gamma_G^2...\gamma_G^N$ and $\Pr(YES|B) = \gamma_B^1\gamma_B^2...\gamma_B^N$.

In a polyarchy, we define the pivotal contingency for member i as the event where members $1,2,...,i-1$ have rejected the project.[7] Following a similar procedure to derive the threshold values (please see Online Appendix), we can calculate the probabilities γ_G^i and γ_B^i for $i = 1,2,...,N$, and in turn, the error probabilities for the polyarchy $\Pr(NO|G) = (1-\gamma_G^1)(1-\gamma_G^2)...(1-\gamma_G^N)$ and $\Pr(YES|B) = 1 - \Pr(NO|B) = 1 - (1-\gamma_B^1)(1-\gamma_B^2)...(1-\gamma_B^N)$.

Given the recursive nature of the thresholds and the complex updating scheme, we rely on a numerical analysis to derive insights about the performance of the different organizational structures. Specifically, we examine all meaningful combinations (i.e., cases where thresholds exist) for the following parameter values: $N \in [3,5,7,9]$, $V \in [6,8,12,14,16,18,20]$, $c \in [1,2,5,10]$, $q \in [0.65, 0.7, 0.75, 0.80, 0.85]$. Our key findings are illustrated in Figure 5. First, as we would intuitively expect, a hierarchy has higher Type I (false negatives) error probabilities than a committee, while a polyarchy has lower Type I error probabilities than a committee. The opposite relationships hold for the Type II errors. Second, higher preference diversity reinforces the error predisposition of each organizational structure. Specifically, a hierarchy tends to reject a lot of projects leading to high likelihood of a Type I error and a low likelihood of Type II error. As, the preference diversity increases, the former increases to even higher values, making the hierarchy even more prone to a Type I error, while the latter decreases to even lower values, making the hierarchy even less likely to commit a Type II error. Conversely, higher preference diversity makes a polyarchy even more prone to Type II errors, and less prone to Type I errors.

[7] Note that this corresponds to a setting where a project is assessed sequentially by the different members, as opposed to the case of a committee with a decision rule of $r = 1$ in which assessment by all members is simultaneous.



(a) Type I: Pr(NO|G)

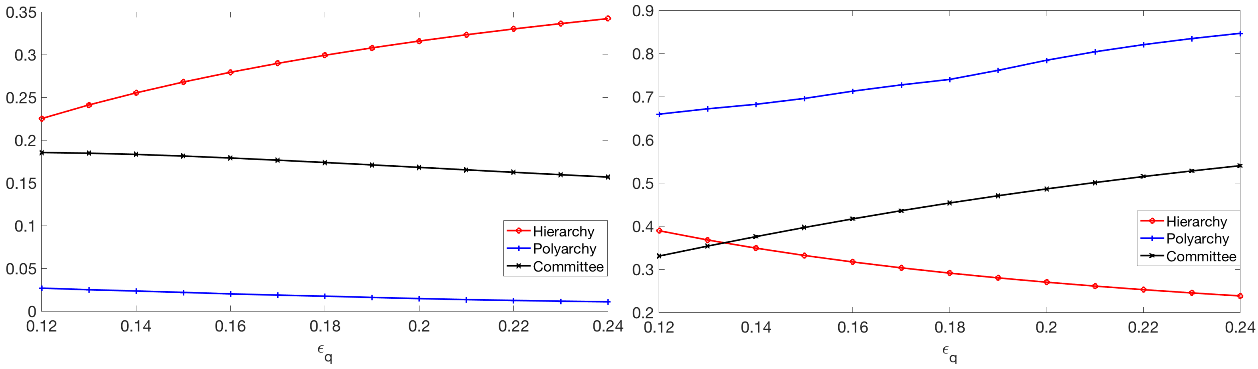
(b) Type II: Pr(YES|B)

Figure 5 **Error probabilities under hierarchy, polyarchy, and committee.** $N = 5, V = 12, c = 1, q = 0.75, \mu_t = 6$;

Intuitively, in a hierarchy, when member i receives a project proposal from member $i-1$, she knows that all members before her have recommended approval. This contingency leads to a higher posterior belief than the case where member i ignored the actions of the other members. However, as the preference diversity increases, the informational value of this contingency is lost: previous members might have recommended approval because of their biases rather than because of observing a good signal. Therefore, higher preference diversity leads to lower posterior beliefs, which in turn, all else equal, make all members with $i > 1$ less likely to recommend approval for a project. As such, Type I errors increase and Type II errors decrease. By contrast, in the case of a polyarchy, when member i receives a project proposal from member $i-1$, she knows that all members before her have recommended rejection. As such, the effect of learning from previous members is to lower her posterior belief. As preference diversity increases, this effect is diluted, and the posterior belief increases. As a result, all else equal, member i becomes more likely to recommend approval, leading to lower Type I errors and higher Type II errors.

5.2. Interpretive diversity

In this section we present our findings for the effect of interpretive diversity under different organizational structures (please see Online Appendix for the model formulation). Again, we rely on a numerical analysis conducted for meaningful combinations of the following parameter values: $N \in [3, 5, 7, 9]$, $\frac{c+t}{V} \in [0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8]$, $\mu_q \in [0.65, 0.7, 0.75, 0.80, 0.85]$. As can be seen in Figure 6, the committee structure tends again to balance the high propensity of a hierarchy for Type I errors and of a polyarchy for Type II errors. Yet, for low value values of interpretive diversity, a hierarchy might (for some parameter values) become more prone than a committee for both Type I and II errors. This results highlights the importance of understanding the role of interpretive diversity- a critical factor that might overturn the standard assumption that a hierarchy is less likely to approve a project than a committee. Moreover, Figure 6 shows that, just like the case of preference diversity, interpretive diversity tends to reinforce the predisposition of both hierarchies for even higher Type I errors and polyarchies for even higher Type II errors.



(a) Type I: Pr(NO|G) (b) Type II: Pr(YES|B)

Figure 6 Error probabilities under hierarchy, polyarchy, and committee. $N = 5, \mu_q = 0.75; \frac{c+t}{V} = 0.3.$

6. Conclusions and Managerial Insights

Even the most successful organizations invariably face the challenge of initiating new projects without complete information. To tackle the challenge of such selection decisions, organizations often rely on committees formed with senior executives that represent diverse functional and business units. We develop a formal model to examine under what conditions such diverse perspectives are truly beneficial for the approval and continuation of projects within organizations. We distinguish between diverse perspectives that stem from different preferences about the value of the project, and those that stem from diverse interpretations of new information about the project.

Our results develop managerial intuition along three dimensions. First, we show that diverse perspectives are rarely "averaged out". Instead, diversity leads the committees to systematic biases in their decision making. To mitigate the effect of diverse perspectives, managers need to uncover the sources of diversity: does diversity originate from different individual valuations and preferences, or does it express different perceptions about the information that arises during the project execution? We show that this distinction is crucial. Higher preference diversity always leads to higher likelihood of making the wrong decision. Higher interpretive diversity, instead, can become a powerful lever in improving the project decision making process.

Second, we show that the implications of higher preference diversity are not limited to a more conservative selection process as prior research has suggested (Gerardi 2000). We show that diverse committees not only become more likely to reject good projects that would have succeeded, but also more likely to accept projects that are bound to fail. One might suggest that a more reliable information source mitigates these effects. Yet, the opposite is true: these negative implications worsen when the committee members have access to more reliable information. This is precisely when preference diversity prevents members from realizing the substantial informational benefits, and leads to a steeper drop in the performance of a committee's selection process.

A clear managerial action is the need to identify and reduce such preference diversity. For instance, in the pharmaceutical industry, such committees consist of executives that represent different therapeutic areas (TA) such as cardiovascular, oncology, neuroscience etc., which reflect the different product lines of the company. The opportunity cost of pursuing the development of a new compound, depends largely on the other projects in the TAs pipeline. As such, it can vary significantly across the TAs. For example, approval of a new oncology project might mean that another oncology project might have to be placed on hold (or even abandoned). In that case, the opportunity cost for the new project will be relatively high. This effect has been empirically shown in Girotra et al. (2007) who find that that the value of a compound is smaller when the firm has more projects in its portfolio that require the same resources as the current project (even if they are aimed at different markets). Senior management can intervene and reduce the extent of preference diversity by highlighting the need for more transparency in the pipeline of the TA, and specifically, in the resources that are required. It is important to note here, that given the highly technical nature of these projects, appropriate group incentives might be required to reinforce such collaborative behaviors (Schlapp et al. 2015).

Lastly, our numerical analysis shows how management can leverage interpretive diversity to improve the project decision-making process. Interpretive diversity in our paper accounts for settings where some executives might interpret the new evidence as highly relevant while others as rather irrelevant. An ongoing debate in drug development investment decisions is whether evidence from early stage clinical trials helps to infer meaningful information about the "payer's" perceptive (i.e., whether the reimbursement bodies will see enough value for money). Executives from R&D tend to argue that at that early stage such information is highly inconclusive, while executives from the market access department tend to consider such information highly critical for any funding decision.

A key managerial implication from our work is that diverse perspectives in the interpretation of new information are valuable. In settings with low opportunity cost, such diversity results in more aggressive approvals: lower Type I errors at the expense of higher Type II errors. This would be particularly beneficial for a small biotech company with very limited alternative options to deploy its resources (low opportunity cost). The same could also be particularly beneficial in settings of drug patents running out (patent cliffs) where companies would need to aggressively populate their pipelines. On the other hand, when the opportunity cost is very high, approving the current project implies forgoing other promising ones. Then, higher interpretive diversity leads to a more conservative decision: lower Type II errors at the expense of higher Type I. For example, in a large pharmaceutical company, it could be argued that avoiding Type II errors is more important than making Type I errors, because a large firm can deploy their capital in other ways to increase the company's value (more marketing, in-licensing efforts, etc.). As discussed above, there are many ways that the firm can affect the composition of such executive committees depending on the type of project under consideration and the policy that it would like to reinforce. Our model provides directional guidelines that inform these decisions.

7. Discussion

The process of making selection decisions in executive committees is a complex topic and subject to the specific characteristics of the project under consideration. While we believe that our assumptions and model formulation are relevant for a wide range of projects, alternate specifications might be more relevant for certain types of projects. First, throughout our paper, we assume that committee members receive different signals. This assumption aimed to capture the multi-faceted nature of projects, but clearly, some projects might have a much narrower scope or performance metric. For those projects, the signals that the members receive might be correlated, or at the extreme, identical to each other. In the latter case, there is no informational value to be gained from the pivotal contingency as all members observe the same signal. Thus, strategic voting degenerates to naive voting. From a mathematical standpoint, all our key results regarding the effect of preference and interpretive diversity remain valid. At the same time, in such a setting, it remains an open question whether a committee is the right decision-making structure. Alternatively, the go/no-go decision could be delegated to the member whose area of expertise better matches the nature of the project.

Second, our model assumes that both the opportunity cost as well as the fidelity of each member's signal is private knowledge. This assumption reflects not only the different "agendas" that are present is such committees, but more importantly, that such agendas are rarely transparent to the rest of the committee. In cases, however, where the members' types are publicly observable, a critical question arises: would the members "average out" their different perspectives or would they agree to disagree? In the former case, the existence of an "average member" implies that, on expectation, diversity does not affect the performance of the committee (similarly to the full information equivalent case discussed in our analysis). In the latter case, our model formulation remains relevant, but members' response functions are no longer symmetric. In fact, each member has a unique best response function which takes into account the exact realized types (opportunity costs or signal fidelities) of his/her peers. Although such a model is clearly intractable, it is worth noting that those realized values will only affect the magnitude of the focal member's posterior belief, and not its monotonicity with respect to the opportunity cost or the signal fidelity. As such, we would expect our threshold policies to still hold. Moreover, because our results on the error probabilities hold for any threshold value (subject to the conditions identified in the respective propositions) we believe that our key findings for the role of preference and interpretive diversity would still remain valid.

Third, our model captures a specific type of cross influence among the committee members. While this assumption might be a reasonable approximation for settings where eliciting information from other members' is a critical factor, there are clearly other type of peer influences that can affect a member's voting behaviour. For instance, Levy (2007) focuses on reputation and career concerns and finds that the latter give rise to a conformity effect among the committee members. Our model could be modified to include such considerations, and we believe that doing so would be a promising avenue for future work. Lastly, our analysis focuses on a specific performance metric, namely, the error probabilities. While we believe that this a key objective of the executive committees that motivated our study, one could envision committees with alternative ones (e.g., brainstorming about the design of a new product). Understanding the effects of preference and interpretive diversity in those settings remains an open question and a fruitful avenue for future research.

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Electronic Appendix to: "Is Diversity (Un)Biased? Project Selection Decisions in Executive Committees"

Illustrative example of the pivotal contingency Consider a committee of three members that decides based on a unanimous acceptance rule, e.g., a compound gets approved for funding during the Phase IIb, only if all three members support it. Focal member 1 recommends approval only if $EU_1(YES) > EU_1(NO)$ where the expectation accounts for the possible recommendations of the other two members, and the fact that the member 1's payoff depends on these recommendations. With a slight abuse of notation, let $Pr(a_2 a_3)$ denote the probability that members 2 and 3 recommend $a_2 = \{YES, NO\}$ and $a_3 = \{YES, NO\}$, respectively. Then, we can write member 1's expected utilities from voting YES and NO, respectively, as follows:

$$EU_1(YES) = Pr(YES,YES)U_1(YES|YES,YES) + Pr(YES,NO)U_1(YES|YES,NO) + Pr(NO,YES)U_1(YES|NO,YES) + Pr(NO,NO)U_1(YES|NO,NO)$$

and

$$EU_1(NO) = Pr(YES,YES)U_1(NO|YES,YES) + Pr(YES,NO)U_1(NO|YES,NO) + Pr(NO,YES)U_1(NO|NO,YES) + Pr(NO,NO)U_1(NO|NO,NO).$$

However, since unanimous acceptance is required for the project to be approved, $U_1(YES|YES,NO) = U_1(YES|NO,YES) = U_1(YES|NO,NO) = U_1(NO|YES,YES) = U_1(NO|YES,NO) = U_1(NO|NO,NO) = 0$, as in all of the above contingencies the project is rejected irrespective of the focal member's decision. In short, the condition $EU_1(YES) > EU_1(NO)$ is equivalent to $U_1(YES|YES,YES) > U_1(NO|YES,YES)$ which represents the pivotal contingency: the other two members express support for the project. Proposition 1 below shows more formally how a utility maximization strategy results in the pivotal contingency.

Proof of Proposition 1. The proof follows the same logic as in Lemmas 1 and 2 in Gerardi (2000). Similarly, we focus on symmetric Bayesian Nash equilibria in which players do not use weakly dominated strategies. Let $\Psi(z,\omega)$ be the probability that exactly z members (out of the remaining $N-1$) recommend approval when the state is $\omega \in \{G,B\}$. Then, the expected utility of member i, if she recommends approval is:

$$EU_i(a_i = YES) = \Pr(G|s_i)\sum_{z=r-1}^{N-1}\Psi(z,G)(V-c-t_i) + \Pr(B|s_i)\sum_{z=r-1}^{N-1}\Psi(z,B)(-c-t_i),$$

as the project gets approved when more than $r-1$ peer members have supported it, while if she recommends rejection is:

$$EU_i(a_i = NO) = \Pr(G|s_i)\sum_{z=r}^{N-1}\Psi(z,G)(V-c-t_i) + \Pr(B|s_i)\sum_{z=r}^{N-1}\Psi(z,B)(-c-t_i),$$

as the project gets approved when more than r peer members have supported it.

Member i recommends approval, i.e., $a_i = YES$, if and only if :

$$EU_i(a_i = YES) \geq EU_i(a_i = NO), \text{ or equivalently,}$$

$$\Pr(G|s_i)\Psi(r-1,G)(V-c-t_i) + \Pr(B|s_i)\Psi(r-1,B)(-c-t_i) \geq 0, \text{ or equivalently,}$$

$$t_i \leq \tfrac{\Pr(G|s_i)\Psi(r-1,G)}{\Pr(G|s_i)\Psi(r-1,G)+\Pr(B|s_i)\Psi(r-1,B)}V - c, \text{ or equivalently,}$$

$$t_i \leq \Pr(G|s_i,piv)V - c$$

where $\Pr(G|s_i,piv)$ denotes the posterior belief about the project being good ($\omega = G$) of a member that receives a signal s_i and conditions on the event of being pivotal ($r-1$ members recommend approval). Therefore, an expected utility maximization strategy is equivalent to a member accounting for the pivotal contingency. Also note that, given that we are looking at equilibria in which players do not use weakly dominated strategies (i.e., before observing her signal or her type a member has a positive probability to approve or reject the project), the probability that a member's vote is pivotal is strictly positive. Moreover, the posterior belief of member i upon receiving signal s_i can be written as:

$$\Pr(G|s_i,piv) = \frac{\Pr(s_i|G)\Pr(piv|G)\Pr(G)}{\Pr(s_i|G)\Pr(piv|G)\Pr(G) + \Pr(s_i|B)\Pr(piv|B)\Pr(B)}$$

which satisfies $0 < \Pr(G|s_i,piv) < 1$, given that $\Pr(piv|G) > 0$ and $\Pr(piv|B) > 0$. Thus, there exist threshold values t_g and t_b such that a member recommends approval when the opportunity cost she assigns to the project, t_i, is below the cutoff determined by the posterior values for a good and bad signal, respectively, that it, $t_i \leq t_g = \Pr(G|s_i = g, piv)V - c$ and $t_i \leq t_b = \Pr(G|s_i = b, piv)V - c$.

Proof of Corollary 1. In Proposition 1 we showed that a symmetric Bayesian Nash equilibrium is completely characterized by the pair (t_g, t_b) which denote the cutoff thresholds associated with a good and a bad signal, respectively. We can now formally derive those thresholds by solving the following equations: $\Pr(G|s_i = g, piv)V - c = t_g$ and $\Pr(G|s_i = b, piv)V - c = t_b$, or equivalently,

$$t_g = \frac{1}{1+\frac{(1-\pi)}{\pi}\frac{(1-q)}{q}\left(\frac{\gamma_B(1-\gamma_B)}{\gamma_G(1-\gamma_G)}\right)^{\frac{N-1}{2}}}V - c \text{ and } t_b = \frac{1}{1+\frac{(1-\pi)}{\pi}\frac{q}{(1-q)}\left(\frac{\gamma_B(1-\gamma_B)}{\gamma_G(1-\gamma_G)}\right)^{\frac{N-1}{2}}}V - c.$$

From the last two equations, we get $t_b = k(t_g) \equiv \frac{(1-q)^2(c+t_g)V}{(1-q)^2(c+t_g)+(V-(c+t_g))q^2}$.

Moreover, under strategic voting, the posterior belief of member i upon receiving a good signal is:

$$\Pr(G|s_i = g, piv) = \frac{1}{1 + \frac{(1-\pi)}{\pi}\frac{(1-q)}{q}\left(\frac{\gamma_B(1-\gamma_B)}{\gamma_G(1-\gamma_G)}\right)^{\frac{N-1}{2}}}$$

while under non-strategic voting, the corresponding belief is:

$$\Pr(G|s_i = g) = \frac{1}{1 + \frac{(1-\pi)}{\pi}\frac{(1-q)}{q}}.$$

It is straightforward to show (by substitution) that for neutral projects ($\mu_t = \pi V - c$), the threshold values are $t_g = qV - c$ and $t_b = (1-q)V - c$, in which case, again by simple substitution, we get $\gamma_G + \gamma_B = 1$. As such, $\frac{\gamma_B(1-\gamma_B)}{\gamma_G(1-\gamma_G)} = 1$ and both strategic and non-strategic voting lead to the same posterior belief. We now show that $(\frac{\gamma_B}{\gamma_G})(\frac{1-\gamma_B}{1-\gamma_G})$ decreases in μ_t. First note that,

$$\frac{d(\frac{\gamma_B}{\gamma_G})}{d\mu_t} = -\frac{4(t_g+c)(V-t_g-c)((1-2q)(t_g+c)+q^2V)(q-0.5)^2}{[(-2q^2+q)(t_g+c)^2+(3q^2V+(-3V-2\varepsilon_t+2\mu_t)q+V+\varepsilon_t-\mu_t)(t_g+c)+Vq^2(\varepsilon_t-\mu_t)]^2}$$

which is negative, because $V - t_g - c > 0$ and $q^2 > 2q - 1$. Thus $\frac{\gamma_B}{\gamma_G}$ decreases in μ_t. Similarly,

$$\frac{d(\frac{1-\gamma_B}{1-\gamma_G})}{d\mu_t} = -\frac{4(t_g+c)(V-t_g-c)((1-2q)(t_g+c)+q^2V)(q-0.5)^2}{[(2q^2-q)(t_g+c)^2+(-3q^2V+(3V-2\varepsilon_t-2\mu_t)q-V+\varepsilon_t+\mu_t)(t_g+c)+Vq^2(\varepsilon_t+\mu_t)]^2}$$

is negative, and therefore, $\frac{1-\gamma_B}{1-\gamma_G}$ also decreases in μ_t. Thus, $(\frac{\gamma_B}{\gamma_G})(\frac{1-\gamma_B}{1-\gamma_G})$ decreases in μ_t.

Lastly, recall that for an unattractive project, $\mu_t > \pi V - c$, therefore, $(\frac{\gamma_B}{\gamma_G})(\frac{1-\gamma_B}{1-\gamma_G}) < 1$, and as such, the posterior belief is higher than the case of non-strategic voting where $(\frac{\gamma_B}{\gamma_G})(\frac{1-\gamma_B}{1-\gamma_G}) = 1$.

Similarly, for an attractive project, $\mu_t < \pi V - c$, therefore, $(\frac{\gamma_B}{\gamma_G})(\frac{1-\gamma_B}{1-\gamma_G}) > 1$, and the posterior belief is lower than the case of non-strategic voting.

Proof of Proposition 2. From Corollary 1 we know that $t_b = k(t_g) \equiv \frac{(1-q)^2(c+t_g)V}{(1-q)^2(c+t_g)+(V-(c+t_g))q^2}$. Since t_b monotonically increases in t_g, it is sufficient to focus only on t_g. Let the function $V(t) = \Pr(G|s_i = g, piv)V - c - t$ denote the total value that a member with threshold t anticipates from the project. Applying the Implicit Function Theorem (IFT) at t_g, we get $\frac{dt_g}{d\varepsilon_t} = -\frac{\frac{\partial V(t_g)}{\partial \varepsilon_t}}{\frac{\partial V(t_g)}{\partial t}}$.

We begin by showing that $\frac{\partial V(t_g)}{\partial t} < 0$. To show the latter, it is sufficient to show that $\Pr(G|s_i = g, piv)$ decreases in t. Note that, $\Pr(G|s_i = g, piv) = \frac{1}{1+\frac{(1-\pi)}{\pi}\frac{(1-q)}{q}\left(\frac{\gamma_B(1-\gamma_B)}{\gamma_G(1-\gamma_G)}\right)^{\frac{N-1}{2}}}$. Thus, it it is sufficient to show that $(\frac{\gamma_B}{\gamma_G})(\frac{1-\gamma_B}{1-\gamma_G})$ increases in t. To show the latter, we start by showing that $\frac{\gamma_B}{\gamma_G}$ increases in t. Taking the derivative w.r.t. t we have $(\frac{\gamma_B}{\gamma_G})' = (\frac{(1-q)F(t)+qF(k(t))}{qF(t)+(1-q)F(k(t))})' = \frac{(1-2q)[F'(t)F(k(t))-F(t)F'(k(t))]}{[qF(t)+(1-q)F(k(t))]^2}$. We only need to examine the sign of the numerator. After substituting and some algebraic manipulation: $F'(t)F(k(t)) - F(t)F'(k(t)) = (1-2q)\Phi(t)$ where $\Phi(t) = (Vq^2 + (V + \varepsilon_t - \mu_t)(1-2q)(c+t)^2 + 2Vq^2(\varepsilon_t - \mu_t)(c+t) - V^2q^2(\varepsilon_t - \mu_t)$. But, $\Phi''(t) = (Vq^2 + (V + \varepsilon_t - \mu_t)(1-2q) > 0$, so $\Phi(t)$ is convex in t with minimum value $\Phi\min = \frac{V^2q^2(1-q)^2(\mu_t-\varepsilon_t)(V-\mu_t+\varepsilon_t)}{(1-q)^2V+(2q-1)(\mu_t-\varepsilon_t)} > 0$, and thus, $\Phi(t) > 0$ for every t. Therefore, $F'(t)F(t_b(t)) - F(t)F'(t_b(t)) < 0$, and $(\frac{\gamma_B}{\gamma_G})'$, so $\frac{\gamma_B}{\gamma_G}$ increases in t. We now show that $\frac{1-\gamma_B}{1-\gamma_G}$ also increases in t. Note that $\left(\frac{1-\gamma_B}{1-\gamma_G}\right)' = \frac{-\gamma_B'(1-\gamma_G)+(1-\gamma_B)\gamma_G'}{(1-\gamma_G)^2} = \frac{\gamma_G'\gamma_B+\gamma_B'\gamma_G+\gamma_G'-\gamma_B'}{(1-\gamma_G)^2}\frac{(1-2p)^2\Phi_1(t)}{[\Phi_2(t)]^2}$ where $\Phi_1(t) = (q^2V + (\mu_t + \varepsilon_t - V)(2q-1)(c+t)^2 - 2q^2V(\mu_t + \varepsilon_t)(c+t) + q^2V^2(\mu_t + \varepsilon_t)$ and $\Phi_2(t) = q(1-2q)(c+t) + (3q^2V + (2\mu_t + 2\varepsilon_t - 3V)q - (\mu_t + \varepsilon_t))(c+t) - Vq^2(\mu_t + \varepsilon_t)$. By differentiating twice it is easy to show that $\Phi_1(t)$ is convex in t with minimum value $\Phi_1\min = \frac{V^2q^2(1-q)^2(\mu_t+\varepsilon_t)(V-\mu_t-\varepsilon_t)}{(1-q)^2V+(2q-1)(\mu_t-\varepsilon_t)} > 0$, so $\left(\frac{1-\gamma_B}{1-\gamma_G}\right)' > 0$. Since both $\frac{\gamma_B}{\gamma_G}$ and $\frac{1-\gamma_B}{1-\gamma_G}$ increase in t, $(\frac{\gamma_B}{\gamma_G})(\frac{1-\gamma_B}{1-\gamma_G})$ also increases in t. Thus, $\frac{\partial V(t)}{\partial t} < 0$.

We now examine the sign of $\frac{\partial V}{\partial \varepsilon_t}$. Let $t_0 \equiv \pi V - c$. Note that when $\mu_t = t_0$, we can derive a closed form solution for the system defined by the equations $\Pr(G|s_i = g, piv)V - c = t_g$ and $\Pr(G|s_i = b, piv)V - c = t_b$. In particular, the only feasible solution is $t_g = qV - c$. Let $\lambda = (\frac{\gamma_B}{\gamma_G})(\frac{1-\gamma_B}{1-\gamma_G})$. After some algebraic manipulation, we get $\frac{\partial \lambda}{\partial \varepsilon_t} = \frac{16(q-\frac{1}{2})^2[(1-2q)(c+t)+q^2V]^2(V-c-t)\varepsilon_t t\Phi_3(\mu_t)}{[\Phi_4(\mu_t)]^2}$ where $\Phi_3(\mu_t) = 2\mu_t q^2V + 2V(c+t)[q(1-q) - V - 4\mu_t q + 2q(c+t) + 2\mu_t - (c+t)]$ and $\Phi_4(\mu_t) = [(q(2q-1)(c+$

$t)^2 + (-3q^2V + (-2\mu_t + 3V - 2\varepsilon_t)q + \mu_t - V + \varepsilon_t)(c+t) + Vq^2(\mu_t + \varepsilon_t)][(q(1-2q)(c+t)^2 + (3q^2V + (2\mu_t - 3V - 2\varepsilon_t)q - \mu_t + V + \varepsilon_t)(c+t) + Vq^2(\varepsilon_t - \mu_t)]$. Note that $\frac{\partial \Phi_3}{\partial \mu_t} = 2q^2V - 2(c+t)(2q-1) > 0$ because $V > c+t$ and $q^2 > 2q-1$. So, $\Phi_3(\mu_t)$ increases in μ_t. Also note, that $\Phi_3(\mu_t = t_0) = 0$, so $\Phi_3(\mu_t) < 0$, for $\mu_t < t_0$, and $\Phi_3(\mu_t) > 0$ for $\mu_t > t_0$. Thus, for $\mu_t < t_0$, $\frac{\partial \lambda}{\partial \varepsilon_t} < 0$, and $\frac{\partial V}{\partial \varepsilon_t} > 0$. Similarly, for $\mu_t > t_0$, $\frac{\partial V}{\partial \varepsilon_t} < 0$. To conclude, by applying the IFT, $\frac{dt_g}{d\varepsilon_t} > 0$ for $\mu_t < t_0 \equiv \pi V - c$, and $\frac{dt_g}{d\varepsilon_t} < 0$ when $\mu_t > t_0 \equiv \pi V - c$. Thus, t_g (and t_b) increase in ε_t when $\mu_t > t_0 \equiv \pi V - c$, and decrease in ε_t when $\mu_t < t_0 \equiv \pi V - c$.

Proof of Proposition 3. We are interested in the sign of $\frac{\partial \gamma_G}{\partial \varepsilon_t} = q\frac{\partial F(t_b)}{\partial \varepsilon_t} + (1-q)\frac{\partial F(t_g)}{\partial \varepsilon_t}$ where $\frac{\partial F(t_g)}{\partial \varepsilon_t} = -(t_g - \mu_t)\frac{1}{2\varepsilon_t^2}$ and $\frac{\partial F(t_b)}{\partial \varepsilon_t} = -(t_b - \mu_t)\frac{1}{2\varepsilon_t^2}$. Also, for $\mu_t = \pi V - c$, the threshold values are $t_g = qV - c$ and $t_b = (1-q)V - c$. After substitution and some algebraic manipulation: $\frac{\partial \gamma_G}{\partial e_t} = -\frac{(2q-1)^2 V}{4\varepsilon_t^2} < 0$ which implies that membes who receive good signals become less likely to approve a good project. Similarly, we derive $\frac{\partial \gamma_B}{\partial e_t} = \frac{(2q-1)^2 V}{4\varepsilon_t^2} > 0$ which implies that members who receive a bad signal become more likely to approve a bad project. The error probabilities are given by: $\Pr(NO|G) = \sum_{j=r*N}^{N} \binom{N}{j} (1-\gamma_G)^j {\gamma_G}^{N-j}$ and $\Pr(YES|B) = \sum_{j=r*N}^{N} \binom{N}{j} {\gamma_B}^j (1-\gamma_B)^{N-j}$ and because $\gamma_G > \frac{1}{2}$ and $\gamma_B < \frac{1}{2}$ they both increase in ε_t.

Proof of Proposition 4. Similarly to the case of preference diversity, which was discussed in Proposition 1, we focus our attention on symmetric Bayesian Nash equilibria in which players do not use weakly dominated strategies. Again, a member votes in favor of the project if $\Pr(G|s_i, q_i, piv)V - c \geq t$, but in this case the type of a member determines the value q_i that he assigns to the signal s_i. If $s_i = g$, $\Pr(G|s_i = g, q_i, piv)$ increases in q_i, and thus, there is a unique threshold q_g such that $\Pr(G|s_i = g, q_g, piv)V - c = t$. If $s_i = b$, $\Pr(G|s_i = b, q_i, piv)$ decreases in q_i, and thus, there is a unique threshold q_b such that $\Pr(G|s_i = b, q_b, piv)V - c = t$.

To determine the above thresholds q_g and q_b we need to solve the following system: $\Pr(G|s_i = g, q_g, piv)V - c = t$ and $\Pr(G|s_i = b, q_b, piv)V - c = t$ Note, however, that for a given t and a distribution $q_i \sim U(\mu_q - e_q, \mu_q + e_q)$, $\Pr(G|s_i = g, q_i, piv) > \Pr(G|s_i = b, q_i, piv)$, and hence, at most one of the above equations can be satisfied.

In particular, a member that receives a good signal has a minimum ex-post valuation of $\underline{V}_g$, and therefore when the threshold t falls into Region I, he always approves the project. The decision of a member that receives a bad signal, however, depends on his interpretive type as in that range members with relative high q_i will reject the project ($\Pr(G|s_i = b, q_H, piv)V - c < t$), but members with relatively low q_i will approve the project ($\Pr(G|s_i = b, q_L, piv)V - c > t$) as they still see sufficient value in it. From the last two inequalities, and given that the ex-post project valuation is continuous in q_i, there exists q_b in Region I, such that $\Pr(G|s_i = g, q_b, piv)V - c = t$. When t falls into Region II, however, $\Pr(G|s_i = g, q_i, piv)V - c > t$ and $\Pr(G|s_i = b, q_i, piv)V - c < t$ for every q_i, so members decide based on their signals alone, regardless of their interpretive type. Lastly, when the threshold t falls into Region III, a member that receives a bad signal has a maximum ex-post valuation of $\overline{V}_b$, and therefore always rejects the project. On the other hand, the decision of a member who receives a good signal depends on his interpretive type: for relatively high q_i he approves the project (i.e., $\Pr(G|s_i = g, q_H, piv)V - c > t$), while for relatively low q_i he recommends rejection (i.e., $\Pr(G|s_i = g, q_L, piv)V - c < t$). From the last two inequalities, and the continuity of the ex-post project valuation in q_i, there exists q_g in Region III, such that $\Pr(G|s_i = g, q_g, piv)V - c = t$.

Proof of Corollary 2.

In region I, under strategic voting, the belief of member i upon receiving a bad signal is:

$$\Pr(G|s_i = b, piv) = \frac{1}{1 + \frac{(1-\pi)}{\pi}\frac{q}{(1-q)}\left(\frac{\gamma_B(1-\gamma_B)}{\gamma_G(1-\gamma_G)}\right)^{\frac{N-1}{2}}}$$

while under non-strategic voting, the corresponding belief is:

$$\Pr(G|s_i = g) = \frac{1}{1 + \frac{(1-\pi)}{\pi}\frac{q}{(1-q)}}.$$

Thus, all we need to show is that $\frac{\gamma_B(1-\gamma_B)}{\gamma_G(1-\gamma_G)} > 1$. Note that in region I a member that receives a good signal always accepts a project, while a member i that receives a bad signal approves the project if $q_i < q_b$. Thus, $\gamma_G = q + (1-q)F(q_b)$ and $\gamma_B = (1-q) + qF(q_b)$. So, $\frac{\gamma_B(1-\gamma_B)}{\gamma_G(1-\gamma_G)} =$

$\frac{q(q+(1-q)F(q_b))}{(1-q)(1-q+qF(q_b))} = \frac{q^2+(1-q)qF(q_b)}{(1-q)^2+(1-q)qF(q_b)} > 1$ because $q > 1-q$. The proof for region III follows exactly the same steps.

Proof of Proposition 5. Recall that q_b denotes the threshold value for which $\Pr(G|s_i = b, q_b, piv)V - c = t$, that is, $\frac{1}{1+\frac{(1-\pi)}{\pi}\frac{q_b}{(1-q_b)}\left(\frac{\gamma_B(1-\gamma_B)}{\gamma_G(1-\gamma_G)}\right)^{\frac{N-1}{2}}} = \frac{c+t}{V}$. The proof follows steps with that of proposition 2: we first define the appropriate function, and then apply the implicit function theorem at $q = q_b$. Let $G(q) \equiv \frac{1}{1+\frac{(1-\pi)}{\pi}\frac{q}{(1-q)}\left(\frac{\gamma_B(1-\gamma_B)}{\gamma_G(1-\gamma_G)}\right)^{\frac{N-1}{2}}} - \frac{c+t}{V}$. We first show that $\frac{\partial G}{\partial q} < 0$, and then we derive the sign of $\frac{\partial G}{\partial \varepsilon_q}$. To show that $\frac{\partial G}{\partial q} < 0$, it is sufficient to show that $\delta \equiv \frac{\gamma_B(1-\gamma_B)}{\gamma_G(1-\gamma_G)}$ increases in q. But $\frac{\partial \delta}{\partial q} = -\frac{2}{(1-q)^2}\frac{q^4+(2(\varepsilon_q-\mu_q)-1)q^3+(\mu_q^2-\varepsilon_q^2-3\varepsilon_q+2\mu_q)q^2+(\varepsilon_q^2-\mu_q^2)q+\varepsilon_q(\mu_q-\varepsilon_q)}{(-q^2+\mu_q q-\mu_q+\varepsilon_q+q(\varepsilon_q-c))^2}$ so we need to show that $\Phi_5(q) \equiv q^4 + (2(\varepsilon_q - \mu_q) - 1)q^3 + (\mu_q^2 - \varepsilon_q^2 - 3\varepsilon_q + 2\mu_q)q_b^2 + (\varepsilon_q^2 - \mu_q^2)q + \varepsilon_q(\mu_q - \varepsilon_q) < 0$. First note that, $\frac{\partial \Phi_5}{\partial \mu_q} = 2q(1-q)(q-\mu_q) + \varepsilon_q$. If $q > \mu_q$ then clearly $\frac{\partial \Phi_5}{\partial \mu_q} > 0$. If $q < \mu_q$, then since $q > \mu_q - \varepsilon_q$, or equivalently $\varepsilon_q > -(q-\mu_q) > 0$ and $1 > 2q(1-q) > 0$, by multiplying the last two inequalities, we get $\varepsilon_q > -2q(1-q)(q-\mu_q)$, or equivalently, $2q(1-q)(q-\mu_q) + \varepsilon_q > 0$. Thus, $\frac{\partial \Phi_5}{\partial \mu_q} > 0$ for every q. Also, for $\mu_q = 1$, $\Phi_5(q) \equiv q^4 + (2\varepsilon_q - 3)q^3 + (3 - \varepsilon_q^2 - 3\varepsilon_q)q^2 + (\varepsilon_q^2 - 1)q + \varepsilon_q(1-\varepsilon_q)$. It is trivial to show that the latter function decreases in ε_q, and is negative at $\varepsilon_q = 0$ for every $q \in (\frac{1}{2}, 1)$. Thus, $\Phi_5(q) < 0$, $\frac{\partial \delta}{\partial q} > 0$, and $\frac{\partial G}{\partial q} < 0$.

We now study the sign of $\frac{\partial G}{\partial \varepsilon_q}$. As before it is easier to examine the sign of $\frac{\partial \delta}{\partial \varepsilon_q} = \frac{2q(1-2q)(\mu_q-q)}{[(1-q)(q(\varepsilon_q-\mu_q)+\varepsilon_q-q^2+q)]^2}$, so the sign of $\frac{\partial \delta}{\partial \varepsilon_q}$ is determined by the sign of $\mu_q - q$. Define $\widehat{V}_b$ such that when $t = \widehat{V}_b$, then $q_b = \mu_q$. Intuitively, for that specific value of the opportunity cost, a member who observes a bad signal is equally likely to accept or reject the project. We are interested in cases, where members who receive a bad signal are more likely to recommend rejection rather than approval, such that $t > \widehat{V}_b$. Thus, for $t > \widehat{V}_b$, $\mu_q > q_b$, and therefore $\frac{\partial \delta}{\partial \varepsilon_q} > 0$. Given that $\frac{\partial G}{\partial \varepsilon_q} < 0$, from the IFT, q_b decreases in ε_q. The proof for q_g follows identical steps as Regions I and III are symmetrical.

Extensions: Model Formulations

Preference Diversity

Hierarchy: Recall that the posterior probability of member i is:

$$\Pr(G|s_i, piv) = \frac{\Pr(s_i, piv|G)\Pr(G)}{\Pr(s_i, piv|G)\Pr(G) + \Pr(s_i, piv|B)\Pr(B)}.$$

Therefore, in a hierarchy, the posterior beliefs of member i upon receiving a good and a bad signal are respectively:

$$\Pr(G|s_i = g, piv) = \frac{q\gamma_G^1\gamma_G^2...\gamma_G^{i-1}}{q\gamma_G^1\gamma_G^2...\gamma_G^{i-1} + (1-q)\gamma_B^1\gamma_B^2...\gamma_B^{i-1}}$$

$$\Pr(G|s_i = b, piv) = \frac{(1-q)\gamma_G^1\gamma_G^2...\gamma_G^{i-1}}{(1-q)\gamma_G^1\gamma_G^2...\gamma_G^{i-1} + q\gamma_B^1\gamma_B^2...\gamma_B^{i-1}}$$

where for $i = 1$ the expressions simplifies to $\Pr(G|s_1 = g) = q$ and $\Pr(G|s_1 = b) = 1 - q$.

Polyarchy

In a polyarchy, the posterior beliefs of member $i = 2, ..., N$ upon receiving a good and bad signal are respectively:

$$\Pr(G|s_i = g, piv) = \frac{q(1-\gamma_G^1)(1-\gamma_G^2)...(1-\gamma_G^{i-1})}{q(1-\gamma_G^1)(1-\gamma_G^2)...(1-\gamma_G^{i-1}) + (1-q)(1-\gamma_B^1)(1-\gamma_B^2)...(1-\gamma_B^{i-1})}$$

and

$$\Pr(G|s_i = b, piv) = \frac{(1-q)(1-\gamma_G^1)(1-\gamma_G^2)...(1-\gamma_G^{i-1})}{(1-q)(1-\gamma_G^1)(1-\gamma_G^2)...(1-\gamma_G^{i-1}) + q(1-\gamma_B^1)(1-\gamma_B^2)...(1-\gamma_B^{i-1})}.$$

Interpretive diversity Note that the formulas for the posterior belief of member i, with $i = 1, ..., N$ remain the same as in the case of preference diversity. The only difference with the analysis of the previous subsection, is that now the decision of each member i is determined by how her type q_i compares to her thresholds q_g^i and q_b^i. These thresholds are determined by solving recursively the system of equations $V\Pr(G|s_i = g, q_g^i, piv) - c = t$ and $V\Pr(G|s_i = b, q_b^i, piv) - c = t$ for every $i = 1, 2, ...N$. Once the thresholds q_g^i and q_b^i are derived, the probabilities of member i recommending approval for a good and a bad project are respectively, $\gamma_G^i = \bar{q}(1 - F(q_g^i) + (1-\bar{q})F(q_b^i)$ and $\gamma_B^i = (1-\bar{q})(1 - F(t_g^i)) + \bar{q}F(q_b^i)$ where $\bar{q}$ is the actual probability of member i receiving the correct signal. Note that unlike the committee case where only one threshold existed at a time, in this case it is possible for both thresholds to exist. Finally, the error probabilities for the hierarchy and polyarchy are calculated using the same formulas as in the case of preference diversity.