A Tale of Two Organizational Structures

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Abstract

This paper investigates the interplay between the selection of a team of suitable agents and the decision of an appropriate structural framework for the team, and its impact on an organization's performance. Applying a meticulous modeling approach and utilizing an example from university faculty hiring, we systematically explore various complexities organization managers may encounter. Our study reveals several key insights: (1) it outlines general parameters for choosing an effective decision structure with a predetermined team, and for selecting an ideal team when the decision structure is already set; (2) it challenges the belief that a superior team necessarily possesses greater overall project knowledge, emphasizing the vital role of individual evaluator capabilities; (3) it highlights scenarios where faulty decisions can paradoxically benefit the organization at a macro level, offering strategies to leverage such incidents. Our model, along with its nuanced implications, can serve as invaluable tools for the successful constitution of a team of project evaluators, and the determination of an appropriate decision structure for a broad range of tasks, including recruitment, credit card applications, venture capital screenings, and more.

Keywords: decision structure, team structure, specialization, project screening, multi-feature project

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1 Introduction

This study delves into two critical attributes that directly influence organizational success. The first pertains to team structure, which involves the strategic alignment of human resources within an organization. Successful deployment involves assigning projects to personnel with appropriate knowledge to ensure organizational effectiveness (Galbraith, 1977; March & Simon, 1993). The second part involves decision structure, which consolidates individual opinions into a cohesive group decision. A suitably chosen decision structure can effectively mitigate the repercussions of incorrect individual decisions (Sah & Stiglitz, 1985; Csaszar, 2012, 2013). Figure 1 illustrates the correlation between these two structures, and exposes potential challenges an organization may face when devising such structures.

Abstractly speaking, organizations grapple with the following: (1) team structure variants. On one side, assigned agents can be regarded as either homogenous, possessing identical information processing capacities, or heterogeneous, carrying diverse specialties. On the flip side, agents may reflect either a bounded rationality as per Simon's administrative man (Simon, 1976), or full capability in accordance with von Neumann's economic man (Von Neumann & Morgenstern, 1944). (2) Decision structure varieties, which imply that organizations utilize hierarchies, committees, polyarchies, or alternative structures to consolidate agent decisions. (3) Varying types of organizational projects, ranging from single-feature to multi-feature. For instance, during university faculty hiring, an evaluation committee might consider numerous criteria such as teaching ability and research prowess when examining applications. All these evaluations would eventually factor into the final decision to accept or reject an applicant. Here, teaching and research represent two features of the hiring process.

Prevailing literature (refer Section 2) often investigates either (1) or (2) as separate entities. However, both elements can occur simultaneously, interacting with each other. Moreover, real-world projects often fall under (3) or the multi-feature variety, which is commonly abstracted. In this study, we aim to elucidate how team and decision structures elicit reciprocal effects while screening projects featuring two aspects. Following a literary review, we define our model and state our assumptions in Section 3, using the faculty hiring dilemma as a common thread throughout the analysis. Section 4 examines decision-making behavior for a single evaluator, followed by Section 5 that navigates the scenario involving a single evaluator versus a two-specialist team. Thereafter, Section 6 generalizes among teams of diverse structures. In the concluding discussion, we address alternative hypotheses, explore potential extensions, and recap significant managerial insights.

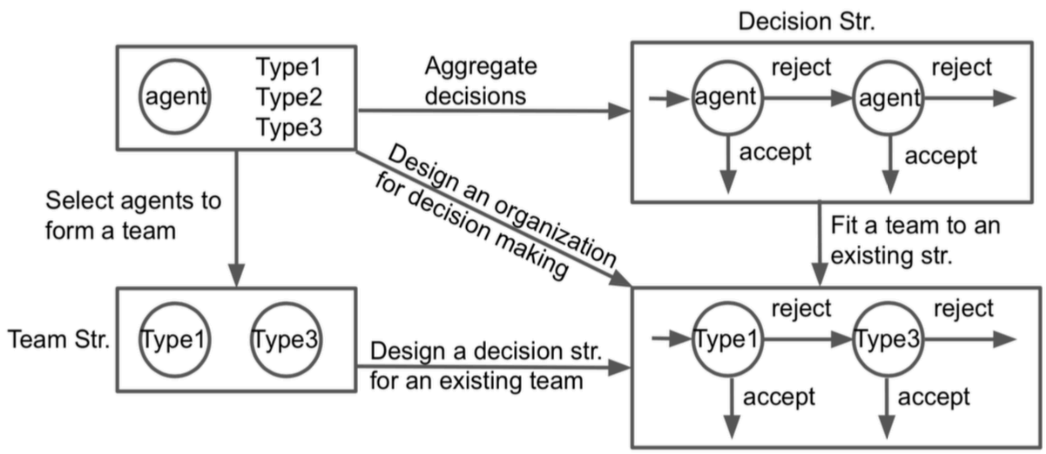

Figure 1: Illustration of team and decision structures in organization design: a team structure shows how a team is formed by a group of agents with different specialities (i.e. Type1, Type2, Type3 in the figure), while a decision structure indicates how a team decision is made given decisions from agents. An organization may face three potential design problems: (1) when changing a decision structure is impossible, how should a team be formed to inherit an existing decision structure? (2) when a group of agents is given, how should a decision structure be designed? (3) when both structures are design variables, how can appropriate agents and a good decision structure be designed at the same time?

2 Studies on Team and Decision Structures

In our increasingly competitive market environment, decision-making often requires processing complex information returned by a team of specialists. This is evident not only in university faculty hiring – unpacked in our model – but also in diverse contexts like product development, where marketing specialists and process engineers must collaborate.

To ensure decisions are well-informed, organizations must strategically assemble teams that can provide relevant knowledge and information (Simon, 1976; Burton, Obel, & DeSanctis, 2011). Several studies have elaborated on this role of organizations within the context of organizational and decision-making structures. Notably, Galbraith (Galbraith, 1977) analyzed organizations as coordinators aimed at diminishing environmental uncertainty and resolving inconsistencies. Others explored the impact of communication patterns on small-group performance (Bavelas, 1948; Leavitt, 1951; Guetzkow & Simon, 1955), and Marschak and Radner (Marschak & Radner, 1972) examined the critical task of structuring teams, considering how agents maximize utility amidst information limitations.

Simon (Simon, 1976) steered this conversation to acknowledge bounded rationality, positioning decision-makers as entities often hindered by incomplete information and cognitive limitations. Recognizing that human error in decision-making is inevitable, he advocated for continued exploration into improving decision-making methods, with a focus on group decision-making. Further studies emphasize the efficiency of hierarchical structures, prevalent in organizations and governments, in aggregating relevant information, reducing errors and decreasing process complexity (Sah & Stiglitz, 1985; Simon, 1996; Cyert & March, 1992; Radner, 1992; Reitzig & Maciejovsky, 2015).

Sah and Stiglitz's (Sah & Stiglitz, 1986) subsequent deliberation on dichotomous choice situations in project selection introduced an analysis of environmental uncertainty and its associated decision-making processes. They suggested the superiority of hierarchical structures in unfavorable environments, and polyarchy in favorable ones (Sah & Stiglitz, 1986). This prompted Koh (Koh, 1992) to extend their discussion into incentive environments and sequential decision-making, while questioning the efficacy of both hierarchy and polyarchy (Koh, 2005). Their limitations were reconciled by the committee approach, celebrated for reducing both omission and commission errors (Sah & Stiglitz, 1988; Ioannides, 2012). Studies further probed the decision rule of fixed-size committees (Koh, 1994; Ben-Yashar & Nitzan, 1997). Csasza (Csaszar, 2014) researched committee size impacts, considering agents with non-uniform preferences and diverse decision-making accuracy. More recently, researchers investigated broader decision structures (Christensen & Knudsen, 2010; Ioannides, 2012; Csaszar, 2013). Ioannides (Ioannides, 2012) combined hierarchy and polyarchy to theorize a decision structure devoid of errors.

In instances of project selection or recruitment, the multi-faceted environment necessitates teams possessing multi-dimensional expertise. Knudsen and Levinthal (Knudsen & Levinthal, 2007) scrutinized collective decision-making behavior by observing project screening in a multi-feature environment. Prat (Prat, 2002) explored the correlation between team homogeneity and error reduction. Csaszar and Eggers (Csaszar & Eggers, 2013) interrogated how decision policies could counterbalance the cognitive strengths and weaknesses of specialists and generalists in multi-dimensional settings. Though multiple studies offer varied perspectives, the most closely related to ours are by Visser (Visser, 2000), who modeled decision-making in heterogeneous project environments with fully rational agents, and by Ben-Yashar and Nitzan (Ben-Yashar & Nitzan, 1997), who examined decision-making when bounded rational agents encounter single-feature projects. Building upon these pivotal studies, we contribute to this field of study by evaluating decision-making in hierarchical and polyarchic structures by a group of agents with diverse specialties but limited knowledge within multi-feature environments.

3 The Model

To make our model concrete, we employ a university faculty hiring context. Though ostensibly simple, the model encapsulates all focal points of our investigation. First, we delineate the architecture of the model and then engage in a detailed examination of its assumptions.

3.1 The Model Framework

Constructing a complete model of a typical project screening environment requires characterization of the following entities: the project, the organization, the agent (project evaluators), and finally the team and decision structures.

3.1.1 The Project and Organization

In university faculty hiring, universities are organizations, and applicants are projects. This is because applicants will, like project screening, be evaluated and then be accepted or rejected. Each applicant is described by a vector $x = (x_r, x_t)$ specifying its intrinsic true values on research and teaching. Each university is described by a weight vector $w = (w_r, w_t)$ specifying its preference on research and teaching, where $w_r + w_t = 1$ and $0 \leq w_r, w_t \leq 1$. A university w obtains value

$$v := w_r x_r + w_t x_t \tag{3.1}$$

if it accepts an applicant x, and 0 otherwise.

3.1.2 The Agents, Team Structure and Decision Structure

The hiring committee of evaluators plays the role of the agent. Evaluators differ in two aspects: (1) the ability to gather accurate information about x — knowing, and (2) the ability to make correct decisions given the obtained information — judging.

We use E to denote a single evaluator, whose information gathering ability — knowing — is specified by (ϵ_r, ϵ_t), where $0 \leq \epsilon_r, \epsilon_t \leq 1$. An evaluator estimates the value of an applicant as $y_i = f_i(x_i, \epsilon_i)$ for $i = r, t$, where f_i is an increasing function with respect to ϵ. We define three types of evaluators, *research specialist*, *teaching specialist*, and *generalist*, or R, T, and G for short, whose information gathering abilities are: $(\epsilon_r > 0, \epsilon_t = 0)$, $(\epsilon_r = 0, \epsilon_t > 0)$, and $(\epsilon_r > 0, \epsilon_t > 0)$, respectively. In a hiring team, the combination of different types of evaluators is called its *team structure*. For example, $\{T, G\}$ is a two-person team with one teaching specialist and one generalist.

The other aspect of an evaluator E is the so-called screening ability — judging — characterized by a *screening function* $p : \mathbb{R} \to [0, 1]$. It models the evaluator's bias and discriminating capability (see more discussion in (4) in Section 3.2). An applicant with estimated value v_E will be accepted by the evaluator E with probability $p(v_E)$, and be rejected with probability $1 - p(v_E)$. It is worth noting that v_E is not as in equation (3.1), but an information aggregation function which we shall define shortly. In a hiring team, the *decision structure* is a mechanism determining how to combine different evaluators' decisions into a final team decision.

3.2 Assumptions

The following set of assumptions are made for the analysis.

(1) For a random applicant $X = (X_r, X_t)$, we assume random variables X_r and X_t to be independent, and take only binary values: $X_r, X_t \in \{-\rho, \rho\}$ where $\rho > 0$. For example, $x = (\rho, -\rho)$ represents an applicant who is good at research but bad at teaching. Let $\alpha = \Pr[X_r = \rho]$, $\beta = \Pr[X_t = \rho]$ denote the probabilities that a random applicant in the application portfolio is good at research or teaching, respectively. In the following analysis, the portfolio is also called the environment. Since there are two features (research and teaching) that play a role in the environment, we say the environment is *two-feature.*

(2) Assume the information gathering function

$$y_i = \mathbb{E}X_i + \epsilon_i(x_i - \mathbb{E}X_i), \qquad i = r, t. \tag{3.2}$$

This choice reflects the extent to which the evaluator is able to identify an applicant from the average. Null information on factor i ($\epsilon_i = 0$) results in $y_i = \mathbb{E}X_i$, while full information ($\epsilon_i = 1$) results in the true value, $y_i = x_i$. An evaluator with intermediate capability has only limited understanding about the applicant. (3.2) also assumes $\mathbb{E}X_i$ is common knowledge to all evaluators, e.g., historical records can give a good approximation to $\mathbb{E}X_i$.

(3) Universities have their strength known to the public: some universities are particularly productive at delivering cutting-edge research works, others are focusing on in-class educations. Universities tend to reinforce their strength by hiring appropriate personals. We assume all evaluators know the university's weight vector w which reflects the university's hiring preference, and evaluators are forbidden to use their own preferences on researching and teaching. Thus, from an evaluator E's perspective, the estimated value of an applicant x is

$$v_E = w_r y_r + w_t y_t. \tag{3.3}$$

In practice, this assumption is not necessarily always true. However, the weight vector of an organization can be understood as the organization's value by which it requires its members to abide.

(4) Assume the screening function p to be linear in v_E, with a, b chosen such that $p \in (0, 1]$,

$$p = av_E + b. \tag{3.4}$$

Evaluators differ from each other by having different *discriminating capabilities* $a \geq 0$ and *slacknesses* or *bias* $0 \leq b \leq 1$, see (Sah & Stiglitz, 1986). Evaluators with a larger discriminating capability have a higher probability of accepting good applicants and of rejecting bad applicants. On the other hand, b is the probability that evaluators accept an applicant with $v_E = 0$, or evaluators' a priori *bias* (Knudsen & Levinthal, 2007). Higher b corresponds to less conservative agents, where more applicants, both good and bad, are accepted. The terms slackness and bias will be used interchangeably.

(5) In this article, a team has at most two evaluators, denoted by E_1 and E_2. Hence, the

team structure is a choice from two types among three: R, T and G. As for the decision structure, we consider hierarchy (H) and polyarchy (P) (although extremely simple, they are often seen in practice and can serve as building blocks for more complicated decision structures). Hierarchy accepts an applicant if both evaluators say yes, and rejects otherwise; whereas polyarchy rejects an applicant if both evaluators say no, and accepts otherwise. Let p_1 and p_2 be the screening functions of E_1 and E_2, respectively, so that the accepting probability in a hierarchy is simply $p_1 p_2$, whereas in a polyarchy it is $1-(1-p_1)(1-p_2)$. These two expressions can be understood as the team's screening function under the corresponding decision structures.

Under these assumptions, the expected utility for the university is

$$U = \rho(\alpha\beta p_{++} + (1-\alpha)\beta(-w_r + w_t)p_{-+} + \alpha(1-\beta)(w_r - w_t)p_{+-} + (1-\alpha)(1-\beta)(-1)p_{--}), \tag{3.5}$$

where p_{++} is the team's screening function when the applicant is good at both research and teaching, the notation extends naturally to other parts in (3.5). It is worth noting that the information of both team and decision structure is contained in p. For convenience, the essential parameters in our model is listed in Table 1.

4 A Single Evaluator

Suppose the university has only one single evaluator E. Following assumption (2) and (4) in Section 3.2, E can be parametrized as a quadruple $(\epsilon_r, \epsilon_t, a, b)$ specifying the information gathering capability and screening capability. We further introduce the following notation: (1) the variances

$$\Delta_r = 4\rho^2\alpha(1-\alpha), \quad \Delta_t = 4\rho^2\beta(1-\beta), \tag{4.1}$$

Table 1: Model Parameters

Parameter	Description	Parameter	Description
$x = (x_r, x_t)$	An applicant (a project), and its research value and teaching value, respectively	$X = (X_r, X_t)$	A random applicant (a random project)
α, β	The probability that a random applicant is good at research, teaching, respectively	$w = (w_r, w_t)$	University's (organization's) weights on research and teaching, respectively
$E = (\epsilon_r, \epsilon_t)$	An agent (a project evaluator), and her information gathering capability on research and teaching, respectively	$p = av + b$	The screening function for an evaluator, or the probability of accepting a project given value v
a	Discriminating capability of an evaluator: the higher a, the more good projects the evaluator will accept, the more bad project the evaluator will rejects	b	Bias of an evaluator: the higher b, the more projects the evaluator will accept
R	Research specialist ($\epsilon_r > 0, \epsilon_t = 0$)	T	Teaching specialist ($\epsilon_r = 0, \epsilon_t > 0$)
G	A single generalist ($\epsilon_r > 0, \epsilon_t > 0$)	(E_1, E_2)	a team of two evaluators where $E_i \in \{R, T, G\}$
$\epsilon_i = \epsilon_{r_i} + \epsilon_{t_i}$	the *absolute* information gathering capability of evaluator E_i	$\epsilon_i^w = \epsilon_{r_i} w_r^2 + \epsilon_{t_i} w_t^2$	the *weighted* information gathering capability of evaluator E_i
$\epsilon = \epsilon_1 + \epsilon_2$	the *total* information gathering capability of team (E_1, E_2)	$\epsilon^w = \epsilon_1^w + \epsilon_2^w$	the *weighted total* information gathering capability of team (E_1, E_2)
H	Hierarchy decision structure	P	Polyarchy decision structure
U	Expected utility for an organization		

(2) the sum of *the expected quality in teaching and research of a random applicant*

$$\Omega = \rho w_r(2\alpha - 1) + \rho w_t(2\beta - 1), \tag{4.2}$$

(3) the difference of *the expected quality in teaching and research of a random applicant*

$$\Theta = \rho w_r(2\alpha - 1) - \rho w_t(2\beta - 1). \tag{4.3}$$

Here, Ω is the sum of the expected quality of a random applicant, weighted by the preference of the university. Θ signifies how much *more* value a random applicant is expected to contribute to the university that is attributed to research than that of attributed to teaching. Note that $\Delta_r, \Delta_t, \Omega$ and Θ are all determined by the preference of the university and the environment. Furthermore, $\Delta_r, \Delta_t \geq 0$, but Ω and Θ are not necessarily positive: *a random applicant can be either good* ($\Omega > 0$) *or bad* ($\Omega < 0$).

Based on equation (3.5), the expected utility with one evaluator can be expressed as a sum of two parts: $U = V_I + V_0$, i.e., the expected utility with and without information, as follows,

$$V_I(\epsilon_r, \epsilon_t) = a\epsilon_r w_r^2 \Delta_r + a\epsilon_t w_t^2 \Delta_t, \quad V_0 = (a\Omega + b)\Omega. \tag{4.4}$$

Here, $V_I \geq 0$, also known as *the value of team structure*, is an increasing function of the variances Δ_r and Δ_t, which are the variance of information with respect to the quality of a random applicant. V_I is also increasing with the team structure ϵ_r and ϵ_t. To increase V_I, one should choose an evaluator whose specialty aligns with the university's preference, as one naturally expects. Nevertheless, V_I is *not* a linear combination of ϵ_r and ϵ_t: the coefficient for ϵ_r is w_r^2. On the other hand, V_0 is the expected utility that can be gained from random guessing, without any extra information.

An interesting observation from (4.4) is that the discriminating capability a and the slackness b of the evaluator play different roles. The slackness b does not interact directly with team structure ϵ: as long as Ω (i.e., the expected quality of a random candidate) is positive, a university should always choose an evaluator with larger slackness. In contrast, the discriminating capability a directly interacts with the team structure, as shown in V_I: inaccurate information can be compensated for by better discriminating capability, and vice versa. The fact that slackness and discriminating capability play different roles in the evaluation process will be further revealed and explored in Section 6.1.

5 One Generalist versus Two Specialists

We now discuss the case in which the university must choose between a team of two specialists or a single generalist. By Section 4, the expected utility under hierarchy for a team of two evaluators is $U^H = V_0^H + V_I^H$, where

$$V_0^H = (a_1\Omega + b_1)(a_2\Omega + b_2)\Omega. \tag{5.1}$$

and

$$\begin{aligned} V_I^H &= a_1\epsilon_{r_1} w_r^2 \Delta_r (a_2\Omega + b_2) + a_2\epsilon_{r_2} w_r^2 \Delta_r (a_1\Omega + b_1) \\ &+ a_1\epsilon_{t_1} w_t^2 \Delta_t (a_2\Omega + b_2) + a_2\epsilon_{t_2} w_t^2 \Delta_t (a_1\Omega + b_1) \\ &- a_1 a_2 \epsilon_{r_1}\epsilon_{r_2} w_r^2 \Theta\Delta_r + a_1 a_2 \epsilon_{t_1}\epsilon_{t_2} w_t^2 \Theta\Delta_t. \end{aligned} \tag{5.2}$$

The expected utility under polyarchy is $U^P = V_0^P + V_I^P$, where

$$V_0^P = [1 - (1 - a_1\Omega - b_1)(1 - a_2\Omega - b_2)]\Omega, \tag{5.3}$$

and

$$\begin{aligned} V_I^P &= a_1\epsilon_{r_1} w_r^2 \Delta_r (1 - a_2\Omega - b_2) + a_2\epsilon_{r_2} w_r^2 \Delta_r (1 - a_1\Omega - b_1) \\ &+ a_1\epsilon_{t_1} w_t^2 \Delta_t (1 - a_2\Omega - b_2) + a_2\epsilon_{t_2} w_t^2 \Delta_t (1 - a_1\Omega - b_1) \\ &+ a_1 a_2 \epsilon_{r_1}\epsilon_{r_2} w_r^2 \Theta\Delta_r - a_1 a_2 \epsilon_{t_1}\epsilon_{t_2} w_t^2 \Theta\Delta_t. \end{aligned} \tag{5.4}$$

Let us define some notation,

- **G**: A team consists of only one generalist G specified by $(\epsilon_r, \epsilon_t, a, b)$; and
- **H**: A team consists of one research specialist R specified by $(\epsilon_{r'}, 0, a, b)$, and one teaching specialist T specified by $(0, \epsilon_{t'}, a, b)$, using hierarchy.
- **P**: the same team as **H** but using polyarchy decision structure.

Evaluators G, R, and T will use the same decision function, but they have different information gathering capabilities. Let V_0, V_I and Ω be as in (4.4) and (4.2), respectively, using parameters from G. For notation simplicity, $\mathbf{G}$, $\mathbf{H}$, and $\mathbf{P}$ also denote the utility of the corresponding structures.

Proposition 5.1. *Let $p := a\Omega + b \in (0,1)$. If the specialists and the generalist differ by a ratio $c > 0$, by this we mean $(\epsilon_{r'}, \epsilon_{t'}) = (c\epsilon_r, c\epsilon_t)$, then the comparative performance among the three structures is illustrated in Figure 2.*

$$0 < c \leq 2 \qquad \mathbf{H} \geq \mathbf{G} \geq \mathbf{P} \;\Big|_{cp-1}\; \mathbf{G} \geq \mathbf{H} \geq \mathbf{P} \;\Big|_{cp-c/2}\; \mathbf{G} \geq \mathbf{P} \geq \mathbf{H} \;\Big|_{cp+1-c}\; \mathbf{P} \geq \mathbf{G} \geq \mathbf{H} \longrightarrow (1-p)V_0/V_I$$

$$c > 2 \qquad \mathbf{H} \geq \mathbf{G} \geq \mathbf{P} \;\Big|_{cp+1-c}\; \mathbf{H} \geq \mathbf{P} \geq \mathbf{G} \;\Big|_{cp-c/2}\; \mathbf{P} \geq \mathbf{H} \geq \mathbf{G} \;\Big|_{cp-1}\; \mathbf{P} \geq \mathbf{G} \geq \mathbf{H} \longrightarrow (1-p)V_0/V_I$$

Figure 2: Comparative performance of $\mathbf{G}$, $\mathbf{H}$, and $\mathbf{P}$. Parameter c captures the different information gathering capability between the generalist and specialists. A lower c favours the generalist (1st axis) whereas a higher c (2nd axis) puts specialists really deep and narrow in domain specialities. It is seen that the relative advantage among the three structures varies as, $(1-p)V_0/V_I$, or the scaled ratio between the expected utility with common sense and the expected utility with extra information changes and lies in four different intervals.

The parameter c is introduced so as to capture the different information gathering capability between the generalist and specialists. A specialist is seen to be more deep and narrow, knowing everything about something so to speak, on the other hand, a generalist is seen to be more shallow and wide, knowing something about everything. Here c measures the relative degree of that capability difference. In Figure 2, the value of c determines which reference axis to use. For example, if $c > 3$ (i.e., $\epsilon_{r'} = 3\epsilon_r$, $\epsilon_{t'} = 3\epsilon_t$), that is, specialists have much better information than the generalist, then the second graph tells us that a two-specialist team can always choose a decision structure to outperform a single generalist. On the other hand, if $c = 1.5$, any one among $\mathbf{G}$, $\mathbf{H}$, and $\mathbf{P}$ can be the best choice.

Table 2 summarizes the managerial insights drawn from Proposition 5.1 when environmental uncertainty is high ($\alpha, \beta \approx 1/2$), suggesting the appropriate team under different

Table 2: Interpretation of Proposition 5.1

Specialty ratio (c)	Condition (Evaluator or Environment)	Dominator
Weak specialists vs. Strong generalist ($0 < c < 1$)	All conditions	**G**
Moderately strong Specialists vs. Moderately weak generalist ($1 \leq c \leq 2$)	Conservative evaluator	**P**
	Unbiased evaluator	**G**
	Progressive evaluator	**H**
Strong specialists vs. Weak generalist ($c > 2$)	Environment is mild ($\alpha, \beta \gtrapprox 1/2$)	**P**
	Environment is harsh ($\alpha, \beta \lessapprox 1/2$)	**H**

conditions. Here, a conservative evaluator is one with $b \ll 1/2$, while a progressive evaluator is $b \gg 1/2$. The most illuminating point from our analysis is: there are *two* thresholds[1] of the ratio c instead of only one, a two-specialist team *do not* always dominate a single generalist even if the team has better information (i.e., $c > 1$). For example, Table 2 shows that a moderately weak generalist is still better than teams of moderately strong specialists when evaluators are unbiased.

6 Interaction Between Team Structure and Decision Structure

We will use parameters and notions defined in Table 1. For simplicity, we consider three types of generalists: weak (G_w), average (G_a), and strong (G_s), whose information gathering capability (see definition in Table 1) is $\frac{1}{2}, 1$, and $\frac{3}{2}$, respectively. We also consider a research specialist $R = (1, 0)$ and a teaching specialist $T = (0, 1)$. Hence, the research specialist R, the teaching specialist T, and the average generalist G_a all have the same absolute information gathering capability equal to 1. Finally, an evaluator E_i is said to be *slack* if $b_i > 1/2$, and *strict* otherwise.

The interaction between decision structure and team structure in the two-feature environment, not thoroughly explored in the existing literature as we demonstrated in Section

[1]The threshold $c = 1$ is natural. The threshold $c = 2$ depends on our modeling hence should not be regarded as a generally applicable constant. Adapting our model to a specific problem one may obtain such a threshold for the given situation.

2, turns out to be very interesting, sometimes surprising. To improve the reading experience we describe the analysis in a Socratic fashion.

6.1 The Neutral Environment

The environment is said to be *neutral* if $\alpha = \beta = 1/2$, in another words, a random candidate is equally possible to be a good researcher (resp. teacher) or a bad one. Hence, a neutral environment has the maximal uncertainty. Analysis of this special case will already help us to gain valuable, sometimes seemingly counter-intuitive managerial insights.

Since $\alpha = \beta = 1/2$ implies $\Omega = \Theta = 0$, without loss of generality assume $\rho = 1$, then $\Delta_r = \Delta_t = 1$. By (5.1)-(5.4), the expected utility

$$U^j = a_1 b_2^j \epsilon_1^w + a_2 b_1^j \epsilon_2^w, \quad j = P, H, \tag{6.1}$$

where

$$b^j = \begin{cases} b, & j = H, \\ 1 - b, & j = P. \end{cases} \tag{6.2}$$

Equation (6.1) again verifies that some of our intuitions are correct: similar to the single evaluator case in Section 4, two general principles are: (1) one should try to fit the specialty of the team to the preference of the university, and (2) team structure and decision structure can compensate one another.

6.1.1 Adapting Decision Structure to a Team

Suppose the decision structure in an organization is amenable when a team changes.

Question 1. *When should a manager change the decision structure if the team members change?*

By (6.1), $U^H - U^P = a_1(2b_2 - 1)\epsilon_1^w + a_2(2b_1 - 1)\epsilon_2^w$. Generalizing the theory of (Sah &

Stiglitz, 1986) where only one single evaluator is considered, it can be directly verified in our model that hierarchy should *always* be employed if both evaluators are slack ($b_1, b_2 > 1/2$), whereas polyarchy should *always* be employed if both evaluators are strict. The intuition behind this is that hierarchy structure tends to be too strict in accepting applicants, and this is compensated for by the slackness of the team, producing a balance that outperforms the polyarchy structure.

Answer 1. *The team structure can influence the optimal decision structure only if one of the evaluators is strict while the other is slack.*

When the two evaluators are indeed of opposite slackness, this leads to a second question.

Question 2. *How should a manager change the decision structure?*

Our model answers Question 2 precisely in the following proposition.

Proposition 6.1. *If $b_1 > \frac{1}{2} > b_2$, then $U^H \geq U^P$ if and only if $\frac{\epsilon_1^w}{\epsilon_2^w} \leq \frac{a_2(2b_1-1)}{a_1(1-2b_2)}$.*

The above discussion sends a first message: the *slackness* of evaluators (i.e., b_1, b_2) plays a more important role in choosing the decision structure, than does the discriminating capabilities (i.e., a_1, a_2). To better appreciate and gain insights about the mathematical condition in Proposition 6.1, we do further analysis as follows.

An analysis of a comprehensive university ($w_r = w_t = 1/2$). The mathematical condition in this case is simplified as: $\frac{\epsilon_1}{\epsilon_2} \leq \frac{a_2(2b_1-1)}{a_1(1-2b_2)}$. We analyze the change of a team in two cases.

Case 1: only one team member changes. *In this case, the type of the individual evaluator does not matter* (i.e., whether the evaluator is a specialist or a generalist), it is the evaluator's information gathering capability $\epsilon_i := \epsilon_{r_i} + \epsilon_{t_i}$ that decides, as exhibited by the mathematical condition. For example, team (R, G_s) shares the same optimal decision structure with team (G_a, G_s), because both R and G_a have the information gathering capability that is equal to 1. Hence, given one evaluator is G_s, the manager needs not to change the decision structure if the other evaluator changes from R to G_a.

Case 2: both team members change. *In this case, the type of individual evaluator does matter.* In another words, when considering the whole team as an entirety, the total information gathering capability $\epsilon = \epsilon_1 + \epsilon_2$ does *not* suffice to determine the decision structure. For instance, team (R, T) and (G_w, G_s) have the same total information gathering capability that is equal to $1+1 = 1/2+3/2$, but they may require different optimal decision structures. For example, consider $b_1 = 3/4$, $b_2 = 1/4$, and $a_1 = 2a_2$. Then, the mathematical condition says that hierarchy is better if and only if $\frac{\epsilon_1}{\epsilon_2} \leq \frac{a_2(2b_1-1)}{a_1(1-2b_2)} = 1/2$. Hence, the manager should apply polyarchy to the team (R, T), but hierarchy to the team (G_w, G_s).

An analysis of an oriented university (either $w_r > 1/2$ or $w_t > 1/2$). As we analyzed before, in a comprehensive university, when E_1 is fixed, whether E_2 is an average generalist G_a or a teaching specialist T does not affect the optimal decision structure. However, this stops being true in an oriented university. The fact that the weighted information gathering capability depends on the *square* of w (recall $\epsilon_i^w := \epsilon_{r_i} w_r^2 + \epsilon_{t_i} w_t^2$) further strengthens the importance of specialists in an oriented university. See Table 3 for an example. In the example, $R, G_{a''}, G_a, G_{a'}$ and T all have the same absolute information gathering capability. When E_1 is fixed to be a research specialist, increasing the information gathering capability on the teaching component alters the optimal decision structure from hierarchy to polyarchy. Since the university prefers research over teaching, in a hierarchy structure the fact that E_2 is strict on evaluating teaching capability would potentially enable E_2 to reject too many valuable applicants who are strong researchers.

Table 3: An example within a research-oriented university $w_r = 3/4$. Here, $a_1 = a_2$, $b_1 = 5/6$, $b_2 = 1/4$; and $G_a = (1/2, 1/2)$, $G_{a'} = (1/4, 3/4)$ and $G_{a''} = (3/4, 1/4)$. Evaluator E_1 is fixed to be a research specialist R, while evaluator E_2 gradually changes from a research specialist to a teaching specialist. Hierarchy performs better if $\frac{\epsilon_1^w}{\epsilon_2^w} \leq \frac{4}{3}$.

Team Structure	(R, R)	$(R, G_{a''})$	(R, G_a)	$(R, G_{a'})$	(R, T)
$\epsilon_1^w / \epsilon_2^w$	9/9	9/7	9/5	9/3	9/1
Decision Structure	H	H	P	P	P

To sum up, there is one important message: except in some special cases (e.g., when the university is comprehensive and only one team member is replaced), the type of the individual evaluator matters. The manager, hence, not only needs to understand the team as an entirety, but also should understand each of its members in terms of the member's slackness, and the member's information gathering capability.

6.1.2 Choosing a Better Team for a Fixed Decision Structure

Decision structures in large organizations, whether public or private, tend to be inertially conservative, especially considering that changes in relevant policy may entail great cost and risk. In light of this, it is important to understand how the team structure affects a team's performance under a fixed decision structure. Assume that the university has a pre-determined decision structure j = H or P. Consider two team structures (E_1, E_2) and (E'_1, E'_2). We will study how the information gathering capability of a team affects its performance. Specifically, E_1 and E'_1 have the same decision function parametrized by a_1 and b_1, and E_2 and E'_2 have the same decision function parametrized by a_2 and b_2. We adopt the convention that all parameters relevant to the second team are attributed by the symbol $'$. Hence, by (6.1), $U^j - U'^j = a_1 b_2^j(\epsilon_1^w - \epsilon_1'^w) + a_2 b_1^j(\epsilon_2^w - \epsilon_2'^w)$, for j = H or P, where b^j is defined as in (6.2).

Perhaps an immediate question is the following.

Question 3. *Does a team always perform better if each of its members is better (i.e., $\epsilon_1^w \geq \epsilon_1'^w$ and $\epsilon_2^w \geq \epsilon_2'^w$)?*

Answer 3. *Yes.*

The answer is, of course, not a surprise. This intuition can also be simply verified in our model. A second intuition might be that one expects the optimal team structure could be different in hierarchy versus in polyarchy.

Question 4. *When is the optimal team structure different in hierarchy versus in polyarchy?*

This is a little harder to answer. However, as in Section 6.1.1, our model again answers this question precisely.

Answer 4. *There exists a precise condition* [2] *under which the optimal team structure could be different for hierachy and polyarchy. In particular, if* $b_1 = b_2$ *then the optimal team structure is the same for both hierarchy and polyarchy.*

Similarly as we saw in Section 6.1.1, we notice again that the slackness parameters play an important role here.

When managing a team, it is natural for a manager to consider the whole team's relative strength compared to another team. In our model, one such measure is the team's weighted total information gathering capability (see definition in Table 1): $\epsilon^w = \epsilon_1^w + \epsilon_2^w$.

Question 5. *Does a team always perform better if it has a larger total information gathering capability* ϵ^w*?*

The answer is perhaps surprising.

Answer 5. *No.*

This is not obvious. After all, we are comparing teams' performance. If a team has larger total information gathering capability, it is only natural to guess that it should perform better. However, the above answer implies that a team with weaker total information gathering capability sometimes can outperform. We give a precise condition that can be used to choose a better team[3].

Proposition 6.2. *If* $\epsilon_1^w > \epsilon_1'^w$ *and* $\epsilon_2^w < \epsilon_2'^w$*, then* $U^j \geq U'^j$ *if and only if* $\frac{\epsilon_1^w - \epsilon_1'^w}{\epsilon_2'^w - \epsilon_2^w} \geq \frac{a_2 b_1^j}{a_1 b_2^j}$*, where* $j \in \{H, P\}$*.*

For example, if the existing decision structure is hierarchy, then the condition says that $U \geq U'$ if and only if $\frac{\epsilon_1^w - \epsilon_1'^w}{\epsilon_2'^w - \epsilon_2^w} \geq \frac{a_2 b_1}{a_1 b_2}$. However, we wish to put forward that the existence of such a condition under which a team with weaker total information gathering capability can still outperform, is more striking than what the mathematical condition is. See Table 4 for an example.

[2] The condition is: if the ratio $\frac{\epsilon_1^w - \epsilon_1'^w}{\epsilon_2'^w - \epsilon_2^w}$ lies in between the interval defined by the two numbers $\frac{a_2 b_1}{a_1 b_2}$ and $\frac{a_2(1-b_1)}{a_1(1-b_2)}$.

[3] It might be possible to derive a condition that characterizes the *optimal* team structure. We refrain from doing so, because in practice a manager is more likely to face the problem that whether a set of new

Table 4: A comparison between (R,T) and $(G_w, G_{\hat{a}})$ in a comprehensive university. Here $G_{\hat{a}} = (1/2, 2/3)$. Hence, team (R,T) has strictly larger total information gathering capability as $\epsilon_1 + \epsilon_2 = 1 + 1 > \epsilon_1' + \epsilon_2' = 1/2 + 7/6$. However, $(G_w, G_{\hat{a}})$ outperforms (R,T) if $\frac{a_2 b_1^j}{a_1 b_2^j} > \frac{\epsilon_1 - \epsilon_1'}{\epsilon_2' - \epsilon_2} = 3$.

Decision Structure	H or P		H		P	
a b	$a_2 \leq 3a_1$ $b_1 = b_2$	$a_2 > 3a_1$ $b_1 = b_2$	$a_1 = a_2$ $b_1 \leq 3b_2$	$a_1 = a_2$ $b_1 > 3b_2$	$a_1 = a_2$ $1 - b_1 \leq 3(1 - b_2)$	$a_1 = a_2$ $1 - b_1 > 3(1 - b_2)$
Team Structure	(R,T)	$(G_w, G_{\hat{a}})$	(R,T)	$(G_w, G_{\hat{a}})$	(R,T)	$(G_w, G_{\hat{a}})$

A careful analysis of the above example is illuminating: it helps to gain intuitive understanding of why and when a team with weaker total information gathering capability can perform better. This also helps a manager to choose a better team when facing complicated situations. We summarize our analysis into two cases.

Case 1: $a_2 \gg a_1$. From Table 4, we saw that in both polyarchy and hierarchy, when a_2 is much larger than a_1, $(G_w, G_{\hat{a}})$ outperforms (R,T). *This shows that, when one evaluator has a much better discriminating capability than the other, it is better to design the team structure such that the more discriminating (e.g., more experienced) evaluator can gather more information (e.g., $G_{\hat{a}}$ has larger total information gathering capability than T), instead of simply maximizing the total information gathering capability of the team.*

Case 2: $a_2 \approx a_1$. In hierarchy, $(G_w, G_{\hat{a}})$ outperforms (R,T) if $b_1 > 3b_2$, that is, evaluator E_1 is very slack compared to E_2. Since a hierarchy structure is better at rejecting bad applicants (Sah & Stiglitz, 1985), the fact that E_1 is too slack implies this advantage of hierarchy structure will then mostly rely on the work of evaluator E_2. Since $G_{\hat{a}}$ is more informative than T, this makes it possible for $(G_w, G_{\hat{a}})$ to outperform (R,T) overall. In polyarchy, $(G_w, G_{\hat{a}})$ outperforms (R,T) if $1 - b_1 > 3(1 - b_2)$, that is, evaluator E_1 is very strict compared to E_2. Since a polyarchy structure is better at accepting good applicants (Sah & Stiglitz, 1985), the fact that E_1 is too strict implies this advantage of polyarchy will mostly rely on the work of evaluator E_2, and one can reason as before. These analysis can be summarized as follows: *When two evaluators are similar in their discriminating capability*

potential evaluators should replace the existing team, instead of finding the optimal team.

but one is much more slack than the other, then in a hierarchical environment it is better to choose a team structure where the strict evaluator has more information, while in a polyarchy environment it is better to choose a team structure such that the slack evaluator has more information. And finally, maximizing the total information gathering capability is not decisive, nor necessary.

6.2 The General Environment

It is natural to imagine that applicants to a famous research-oriented university on average have good research capabilities ($\alpha \gg 1/2$). Hence, the environment usually is not neutral (either α or β is not equal to $1/2$). We call this the general environment. We will focus on analyzing new phenomena that are not present in the neutral environment.

6.2.1 Adapting Decision Structure to a Team and the Environment

In the neutral environment, we have shown that, similar to the theory for one-feature environment by (Sah & Stiglitz, 1986), hierarchy should always be employed when both evaluators are slack ($b_1, b_2 > 1/2$).

Question 6. *In a general environment, is it still true that a manager needs not to change the decision structure as long as the two evaluators have similar slackness (either they are both strict, or are both slack)?*

Answer 6. *No. Even if two evaluators have equal slackness ($b_1 = b_2$), a manager might still need to reconsider the decision structure if any other parameters change, such as the environment, or the team's speciality.*

This answer can be easily verified using the model. Following this answer, one may ask an immediate question.

Question 7. *How should a manager adapt the decision structure of a team to a changing environment and a changing team?*

A general treatment for this question is possible using our model. However, it is more enlightening to inspect illuminating examples[4]. For simplicity we assume both evaluators use the same decision function parametrized by $a = b = 1/2$. A team structure is said to be *symmetric* if $\epsilon_{r_1} + \epsilon_{r_2} = \epsilon_{t_1} + \epsilon_{t_2}$, that is, the information gathering capabilities in both the research and teaching are balanced. Otherwise, a team is said to be *asymmetric*.

We say the research (resp. teaching) environment is good if $\alpha > 1/2$ (resp. $\beta > 1/2$), and is bad otherwise. First of all, our model verifies the following simple intuition that can also be viewed as a natural generalization of the theory of (Sah & Stiglitz, 1986) into two-features environment.

Answer 7. (partially) *The polyarchy should be applied if both the research and teaching environment are good, and hierarchy if both are bad.*

When the environment is good in one feature but bad in the other, we demonstrate the answer to **Question 7** in Figure 3 (a), where a symmetric team is considered. As the university gradually moves its preference from teaching to research (w_r gradually increases from 0 to 1), the indifference line moves from l_1, gradually through l_2, l_3 and l_4, to l_5, and the area where hierarchy performs better changes accordingly, from AMJG, through BMJI etc, eventually to CMLE. For example, when $\alpha < 1/2$ and $\beta > 1/2$ (the rectangle CAOE, i.e., the research environment is bad but the teaching environment is good), we see that hierarchy gradually outperforms polyarchy when the university has a greater preference for research.

A further response to **Question 7** is illustrated in Figure 3 (b), where asymmetric teams are considered. The change of indifference lines (curves) follows a similar pattern as the symmetric team. Here we focus on comparing the dashed curve BCOJI and the solid curve BDOKI. Any point (environment) in the area BCOD should use a polyarchy if the team structure is teaching rich, but a hierarchy if the team structure is research rich. The reasoning is: if the team's specialty aligns with the environment, the team is worth trusting and therefore it is better to encourage accepting by utilizing the polyarchy

[4] The full mathematical analysis on a dynamic team composition is available from the authors.

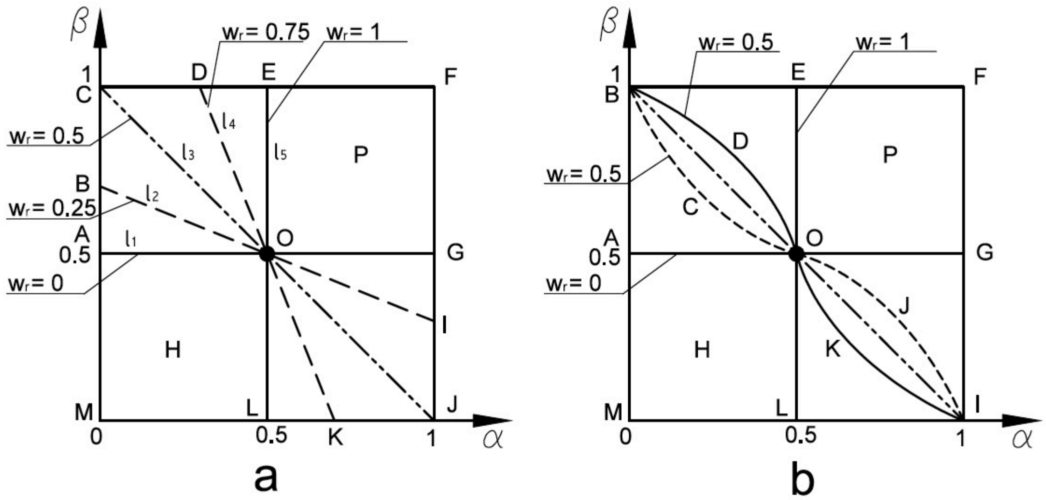

Figure 3: Relative merits of hierarchy versus polyarchy in a two-feature environment with various university's preferences. Every point (α, β) in the plane represents an environment: a random applicant is good in research (resp. teaching) with probability α (resp. β). Each line l_i in (a) is called an *indifference line* on which hierarchy is equally good as polyarchy. Hierarchy should be applied to those environments that are left and below an indifference line for the corresponding university's preference, while polyarchy dominates the right and upper part. (a) corresponds to a symmetric team, while (b) corresponds to an asymmetric team in which the indifference lines become curves. The dashed curve BCOJI corresponds to a teaching-rich team structure (e.g., (T, T), (T, G)), while the solid curve BDOKI corresponds to a research-rich team structure (e.g., (R, R), (R, G)). The diagonal indifference line BI in (b) is the same as CJ in (a) where the team is symmetric.

structure. However, hierarchy can still outperform polyarchy if the environment is not good enough on the team's specialty (e.g., the area AOCB for the teaching rich team).

Answer 7. (informally) *Generally speaking, hierarchy wins if the environment is relatively bad on the university's preference, otherwise polyarchy wins. The winning territory of polyarchy should be further extended if the team's specialty aligns with the environment. However, these general principles should be applied with caution: a manager should study the given situation carefully in order to make a good decision.*

6.2.2 Choosing a Better Team for a Fixed Decision Structure

The main message from Section 6.1.2, where the environment is neutral, is that the (weighted) total information gathering capability of a team is not decisive for choosing the optimal team structure. This generalizes to the general environment. Is there any new phenomena in the general environment?

For simplicity, we focus on hierarchy decision structure in this section. The results for polyarchy can be derived analogously. We simply use U to mean U^H as given in (5.1)-(5.2). Also, since research and teaching have symmetric behaviour in the system, we focus on research only. We only study one evaluator E_1, as the analysis could be symmetrically applied to E_2.

Recall that Ω, as given in (4.2), denotes the expected quality of a random applicant, weighted by the preference of the university.

Question 8. *In a general environment, should a manager always prefer slack evaluators when a random applicant is good (i.e., $\Omega > 0$)? Should a manager always prefer strict evaluators when a random applicant is bad (i.e., $\Omega < 0$)?*

A first impression would be to answer yes for both questions. Consider the neutral environment first, where $\Omega = 0$. Let U_0 denote the expected utility of a hierarchy team, as given by (6.1). Then, $\frac{\partial U_0}{\partial b_1} \geq 0$ always holds. This implies that, in the neutral environment, slack evaluators are always preferred in a hierarchy decision structure. This seems reasonable since the advantage of hierarchy is to counterbalance slackness.

Answer 8. *Yes, if a random applicant is good. No, if a random applicant is bad.*

We do a little mathematics here. By the formula in Section 5, $\frac{\partial U}{\partial b_1} = (a_2\Omega + b_2)\Omega + a_2\epsilon_{r_2} w_r^2 \Delta_r + a_2\epsilon_{t_2} w_t^2 \Delta_t$. The particular form of this equation is not so important here. What is interesting is: the sign of $\frac{\partial U}{\partial b_1}$ does not depend on evaluator E_1 at all! Instead, it is completely determined by the university's preference, the environment, and the *other* evaluator E_2. Table 5 gives an example on how the change of the information gathering capability of evaluator E_2 affects the choice of the slackness on E_1.

Answer 8. *When a random applicant is bad, choosing either a slack or strict evaluator depends critically on the choice of other evaluators.*

Regards to the discriminating capability a, evaluators with better discriminating capa-

Table 5: The choice on slackness of E_1 depending on the information gathering capability of E_2. Here, $\rho = 1, w_r = 1/2, \alpha = 1/4, \beta = 1/2$, hence $\Omega = -1/4 < 0$. The decision function of evaluator E_2 is $(a_2, b_2) = (2/5, 1/2)$. One has $\frac{\partial U}{\partial b_1} > 0$ iff $\frac{3}{4}\epsilon_{r_2} + \epsilon_{t_2} > 1$.

$E_2 = (\epsilon_{r_2}, \epsilon_{t_2})$	$R = (1, 0)$	$G = (1/2, 1/2)$	$T = (0, 1)$	$G = (1/2, 1)$
$\frac{\partial U}{\partial b_1}$	< 0	< 0	$= 0$	> 0
Choice of b_1	strict	strict	insensitive	slack

bility (larger a) are normally preferred. However, similar to the slackness, there also exists condition under which this general intuition fails to be true. As the analysis is more complicated, we do not discuss furthermore on this parameter.

Finally, how does the information gathering capability affect a team's performance? As we saw from the neutral environment, the total information gathering capability ϵ^w is not decisive: a team with smaller total information gathering capability but with specialties match better to a specific situation, can outperform. This generalizes to the general environment too. Nevertheless, in the neutral environment, given that one evaluator has been selected, to select the other evaluator to have better information gathering capability is always profitable.

Question 9. *In a general environment, given that one evaluator has been selected, is it true that the other evaluator has the higher information gathering capability always the better?*

Answer 9. *No.*

This is again counterintuitive at first sight. The main reasoning behind is that different errors incur asymmetrical costs, an information gathering or evaluation error does *not* necessarily lead to a decrease of total performance. *In a multi-feature environment, sometimes erroneous estimations can increase the probability of making correct decisions.* Specifically, there are four types of information gathering errors: overestimate good applicants, underestimate good applicants, overestimate bad applicants, and underestimate bad applicants. It is in fact profitable to overestimate good applicants or to underestimate bad applicants, as clearly demonstrated in Table 6.

In Table 6 there are two teams both having two evaluators, and the second evaluator in both teams are identical, the first evaluator in Team 1 has inferior information gathering

Table 6: Utility calculation breakdown: comparison between two hierarchy teams whose only difference is the information gathering capability in teaching. A "weaker" team performs better. Here, $w_r = 0.9$, $\alpha = 0.1$, $\beta = 0.5$, i.e., the university prefers research but most applicants' are weak researchers. All evaluators have $a = b = 0.5$. Team 1 ($\epsilon_{r_1} = 1$, $\epsilon_{t_1} = 0.5$, $\epsilon_{r_2} = 1$, $\epsilon_{t_2} = 1$), and team 2 ($\epsilon_{r_1} = 1$, $\epsilon_{t_1} = 1$, $\epsilon_{r_2} = 1$, $\epsilon_{t_2} = 1$). That is, the second evaluators are identical. In the table, Type means applicants' type, GrBt means good research bad teaching. Env. means environment. EEV means evaluator estimated value(eval 1, eval 2). The under-est means underestimate, and over-est means overestimate. EAP means evaluator accept probability. HAP means hierarchy accept probability. The bold font indicates where the gain happens for Team 1 compared with Team 2.

Type	Env	EEV		Team 1 Error	EAP		HAP		Utility	
		Team1	Team2		Team1	Team2	Team1	Team2	Team1	Team2
GrGt	5%	(0.95, 1)	(1, 1)	under-est	(0.975, 1)	(1, 1)	0.975	1	0.04875	0.05
GrBt	5%	(**0.85**, 0.8)	(**0.8**, 0.8)	**over-est**	(**0.925**, 0.9)	(**0.9**, 0.9)	**0.8325**	**0.81**	**0.0333**	**0.0324**
BrGt	45%	(**-0.85**, -0.8)	(**-0.8**, -0.8)	**under-est**	(**0.075**, 0.1)	(**0.1**, 0.1)	**0.0075**	**0.01**	**-0.0027**	**-0.0036**
BrBt	45%	(-0.95,-1)	(-1, -1)	over-est	(0.025, 0)	(0, 0)	0	0	0	0
								Total	**0.07935**	**0.0788**

capability than the first evaluator in Team 2. However, under a hierachy decision structure, Team 1 yields a better performance. To understand how this happens, consider for example the row GrBt (i.e., good in research bad in teaching). The 5% means that type GrBt takes up 5% among four different types. The two evaluators in Team 1 yield 0.85 and 0.8 estimation values about type GrBt, respectively. Since the true value for GrBt is 0.8, as per (3.1), Team 1 overestimates this type of applicants due to the first evaluator. The two evaluators of Team 1 accept with probabilities of 0.925 and 0.9, respectively. Hence, in a hierarchy structure Team 1 accepts with a probability $0.925*0.9 = 0.8325$. Therefore, the final expected utility is $0.8325*0.05*0.8 = 0.0333$. The numerical values for Team 2 are calculated in the same way. Since the university has a strong preference on research ($w_r = 0.9$), accepting applicants of type GrBt is beneficial. In other words, overestimating GrBt is beneficial, as clearly shown in the second row of Table 6. Similarly, underestimating BrGt is also beneficial, as shown in the third row. The gain of Team 1 in overestimating GrBt and underestimating BrGt outweighs the loss in the other types, leading to a total performance better than Team 2.

6.2.3 Some Discrete Examples

To either build a new team or to optimize an existing team, both the team structure and decision structure should be considered together at the same time. To find the optimal solution for any given situation is generally a complex matter. Figure 4 contains a set of discrete examples to illustrate optimal solutions in some given situations. As we saw before, the two structures' close dependence on each other is crucial for the successful design of a decision-making team. In some cases we have identified conditions under which an *appropriate* level of specialty complements the decision structure in a changing environment.

We can see that Figure 4 is an extension to Figure 3 where the optimal team and decision structures are marked over the environment space. Without much quantitative analysis, managers can simply get the team design blueprint by referring to the figure with an estimation about the environment variables α and β, and the organization preference.

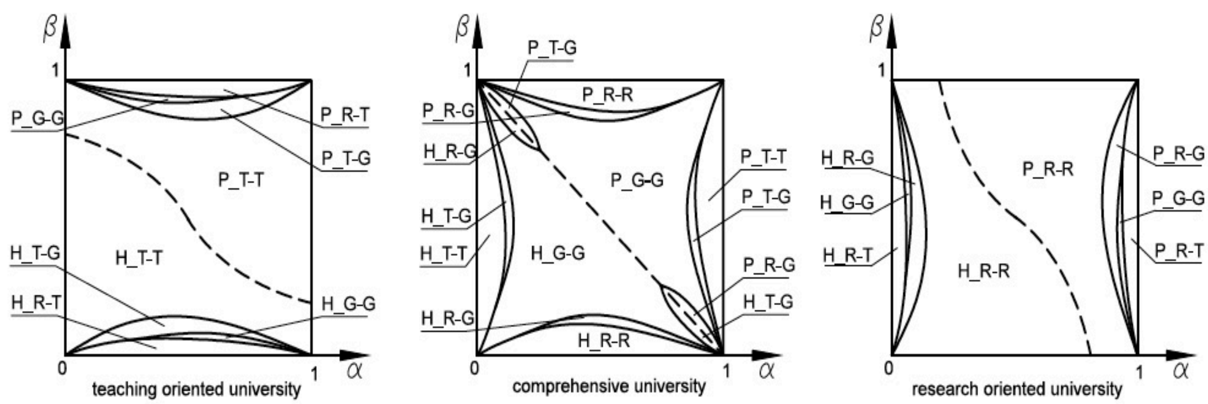

Figure 4: Optimal solutions of some discrete examples. Every point in the plane represents an environment. A notation P_R-G means a polyarchy team with a research specialist and a generalist. Notation such as P_R-G sits on where it dominates.

7 Conclusion

The interplay between decision structure and team structure translates individual decisions into collective group decisions. Various types of decision-makers interact within a decision process, formulating a composite "group-ality" influenced by individual personalities. Similar to the concept of group-intelligence (Woolley, Chabris, Pentland, Hashmi, & Malone, 2010), group decision-making can be quantified using metrics comparable to those applied to individual decision-making. This paper diverges from previous research that primarily examines these two pivotal structures independently, and instead emphasizes the *interaction* between the two. Drawing upon an illustrative example of university faculty hiring, the analysis is sequentially developed from a comparison of single evaluators, to evaluating a single generalist against a co-specialized team, and ultimately a general team against another general team. The choice of the university faculty hiring model is merely to guide and facilitate understanding for readers. The results can be applied to other contexts provided they satisfy the model's assumptions as given in Section 3.2. This section consolidates our main findings and discusses potential extensions and alternative assumptions.

7.1 Major Findings

Our findings corroborate existing literature on decision structure and team structure, underlining their fundamental roles. More significantly, our results reveal that deploying structures separately, based solely on intuition or common sense, can lead to subpar or even detrimental outcomes for organizations. It is crucial to consider both structures and their interaction in the selection of both a team and its decision structure. Key findings are summarized as follows:

In the single evaluator scenario outlined in Section 4, the decision structure does not play a role. However, determining whether to deploy a hierarchical (or polyarchical) team of specialists or a single generalist is less straightforward. In Proposition 5.1, we provide a design table as a guideline. The most influential factors to consider are the environment (quality of random applicants), relative competitiveness among evaluators, and evaluators' slackness.

Secondly, the general team comparison in Section 6 unveils various subtle phenomena not present when considering only the decision structure or the team structure. To streamline the reading experience, we present our results using the Socratic question and answer format. We begin by considering the simpler *neutral environment*, wherein a random applicant is expected to have equal proficiency in research and teaching. We sequentially pose the following questions: (1) When should a manager modify the decision structure if the team members change? (2) How should a manager adjust the decision structure? (3) Does a team always perform better if each of its members is superior? (4) When does the optimal team structure differ in a hierarchy versus a polyarchy? (5) Does a team always perform better if it has a larger total information gathering capability (defined in Table 1)?

Significant managerial insights are garnered from exploring these questions. In a neutral environment characterized by high project uncertainty, one intriguing observation is that the team structure does not always influence the optimal decision structure, and vice versa. However, in most cases, these two structures interact with each other, which is the crux of our investigation. Our results and examples reveal the intricacies in selecting the best decision structure given a team structure, and the nuances of this selection when the decision structure is predetermined. For instance, it may seem logical that a greater total team information gathering ability would enhance overall utility. However, Section 6.1.2 demonstrates this is not always the case: the type of team members and their respective decision functions can significantly impact the outcome.

The non-neutral general environment (e.g., an applicant is expected to excel in research but not teaching) is explored in Section 6.2. New phenomena are uncovered by addressing questions such as: (6) In a general environment, is it still true that a manager need not adjust the decision structure as long as the evaluators have similar slackness? (7) How should a manager adapt the decision structure of a team to a changing environment and a changing team? (8) In a general environment, should a manager always prefer slack evaluators when a random applicant is good? Should a manager always prefer strict evaluators when a random applicant is bad? (9) In a general environment, given one evaluator has been selected, is it better if the other evaluator possesses a higher information gathering capability?

An illustrative insight from these questions is that a team with unbalanced knowledge (in research versus teaching) can impact the effectiveness of the decision structure. For instance, even if the research environment is not conducive for a polyarchy to outperform a hierarchy, a team with more research knowledge can compensate for polyarchy's shortcomings in making commission errors, warranting the consideration of adopting polyarchy for that team. Our model also reveals that choosing decision functions and types of evaluators cannot be achieved solely by intuition, as they can exhibit counterintuitive behavior under certain conditions. For example, increasing the knowledge of one evaluator does not always improve the team's decision-making performance. In some instances, knowing less is better. More detailed analyses of these phenomena are provided in the respective sections.

7.2 Discussion

Our analysis is grounded in a specific model, and in the following section, we will discuss its various assumptions, advantages, potential limitations, and possible extensions.

Firstly, we have chosen to conceptualize the decision-making process as a combination of information gathering and processing. Consequently, decision errors can be traced back to either a deficit in information or a lack in processing ability. This nuanced modeling choice is crucial as it unveils the subtle and unexpected phenomena detailed in Section 6. If one were to simplify the decision process by merging information gathering and processing into a single action, these phenomena would likely remain hidden. Realistic decision-making situations often involve multiple features, requiring an individual to first gather all relevant information before proceeding with processing (e.g., analysis, inference) and decision-making. However, it's important to note that many real-world decision-making problems diverge from the university faculty hiring process presented in this paper. For instance, judgment may not necessitate information gathering, decision-making could be based on common sense or experience, or decision-making could be supplanted by instructions where information itself becomes the decision. Nevertheless, the general model presented in Section 3 offers flexibility for a wider range of applications, as it allows tuning the relative importance between information gathering and processing, and is not confined to certain forms of information aggregation (equation (3.3)) and screening functions (equation (3.4)).

Secondly, in (3.2), we have designated the *average* value of the projects from the portfolio as the base of zero knowledge. This choice was made as the average value can often be estimated using experience or historical records. A more general form of (3.2) could be $y_i = Z + \epsilon_i(x_i - Z) + err$. For instance, $Z = \mathbb{E}[X_i|\text{experience}]$ reflects our assumption. However, the basis could be set to *random* guessing, making Z a random variable in itself. Additionally, the general formulation includes a random error, which was omitted in our analysis. We propose future work to investigate erroneous information-propagation in the system.

Thirdly, we have assumed that the decision functions take a linear form $av_E + b$. Although this may appear simplistic, it is a choice that was utilized in the seminal work of (Sah & Stiglitz, 1986) and many subsequent studies. This choice provides several distinct advantages: it facilitates analysis, and the parameters a and b carry significant meanings. Naturally, a real decision function in a given scenario may deviate considerably from this form, so our results should be interpreted with this choice in mind.

The findings of this article are also constrained to the dynamics of project screening processes. We have stipulated that evaluators are to accept applicants deemed valuable. An alternative dynamic—where only the top K applicants get approved—would render our model outcomes inapplicable. A direct extension to such a scenario is feasible, but would necessitate a fresh analysis. Lastly, we have assumed that the two features of the environment are independent from each other. However, in reality, correlation among different information channels is often observed. It would be beneficial to adjust our model to examine such scenarios.

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