Cognitive Diversity, Organizational Structure, and Exploration: Complementing Diversity with Design

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Abstract: Cognitive diversity is thought to help organizations explore because employees with differing perspectives can collectively recognize more promising new ideas. However, cognitive diversity can also prevent an organization from reaching consensus about the quality of new ideas, leaving the organization in gridlock. In this paper, I develop a mathematical model to analyze how organizational structure moderates the effect of greater cognitive diversity on the organization's propensity to pursue exploratory ideas. I find that greater cognitive diversity leads flat organizations to pursue exploratory ideas more often, but it leads hierarchical organizations to pursue exploratory ideas less often. After presenting this model, I construct a unique data set that allows me to empirically validate the model's predictions in the context of product introductions in the consumer packaged goods (CPG) sector. I find that greater cognitive diversity is positively correlated with exploration in flat organizations and negatively correlated with exploration in hierarchical organizations. Finally, I conclude with a discussion of managerial insights. My results speak to how organizational structure can play a valuable role in helping managers harness the benefits of cognitive diversity.

Key words: organizational structure, exploration and exploitation, innovation, diversity, bounded rationality, organizational decision making.

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1 Introduction

In 1998, engineers at Microsoft made an early prototype of an e-book reader. Microsoft executives did not like the prototype because it did not run on Windows. These executives had a Windows-centric approach to product development, believing that Windows should be the core of every Microsoft product. By contrast, the engineers had a more functional approach to product development, focusing on individual products instead of the link between the product and Microsoft's comparative advantage. As a result, these engineers were reluctant to make the e-book reader run on Windows. This conflict ultimately led executives to kill the project, and Amazon launched the successful Kindle e-book reader nine years later (Eichenwald 2012).

The Microsoft case is reminiscent of other business cases of innovation failure, such as Polaroid's failure to lead the market for digital cameras (Tripsas and Gavetti 2000), and Xerox's failure to commercialize the PC (Vinokurova and Kapoor 2020). In each of these cases, a prototype was introduced by engineers with a cognitive framework that differed significantly from the dominant cognitive framework among management. Furthermore, in each case, managers did not capitalize on the innovative prototypes, perhaps, because these frameworks made it difficult for managers to understand the prototype's value.

These cases pose a puzzle about the relationship between cognitive diversity and an organization's decision to pursue exploratory ideas. On one hand, having diverse cognitive frameworks may have encouraged exploration at these companies by exposing executives to a broader range of potential ideas, (i.e. e-book readers, digital cameras, PC). Indeed, management scholars often argue that cognitive diversity plays a central role in exploration (March 1991). On the other hand, having diverse cognitive frameworks may have impeded exploration by preventing executives and engineers from agreeing about the viability of specific prototypes. Relatedly, cognitively diverse organizations are sometimes stuck in gridlock because few new ideas can get the necessary support of enough stakeholders (Denis et al. 2001).

In this paper, I develop a simple analytic framework that suggests how organizations can better harness cognitive diversity to become more exploratory. More specifically, the framework makes predictions about how organizational structure moderates the effect of greater cognitive diversity on the organization's proclivity to pursue exploratory ideas. I start with a canonical economic model connecting organizational structure and organizational decision making (Sah and Stiglitz 1986). This model, with conceptual links to team theory (Marschak and Radner 1972, Garicano 2000) and the behavioral theory of the firm (Cyert and March 1963), has been recently used and extended in the management literature (Knudsen and Levinthal 2007, Christensen and Knudsen 2010, Csaszar 2013). In this model, the organization chooses whether to pursue a risky new idea or a safe (status quo) idea. I add to this classic model by introducing cognitive diversity, which causes group members to disagree about which option is best because of their differing cognitive frameworks.

My model highlights two intuitive consequences of cognitive diversity that have countervailing effects on an organization's proclivity to pursue exploratory new ideas. First a group of people with diverse perspectives are unlikely to collectively overlook a promising new idea; Microsoft considered the e-book reader only because the company employed engineers who did not have a Windows-centric view of products. Second, a group of people with diverse perspectives is unlikely to reach agreement about a new idea's quality; these Microsoft engineers often disagreed with management about product-related decisions.

The relative impact of the dual effects of cognitive diversity (more ideas recognized, less agreement about the value of specific ideas) is influenced by how the organization processes information to make decisions. Like Sah and Stiglitz's model, my model follows in the tradition of management scholars who use 'organizational structure' to describe how organizations process information (Tushman and Nadler 1978, Simon 1976, Joseph and Gaba 2020).[2] In hierarchical organizations, where taking risks requires managerial approval, cognitive diversity prevents the organization from pursuing exploratory ideas because the supervisor and supervisee cannot find common ground. By contrast, in flat organizations, where taking risks does not require (as much) managerial approval, cognitive diversity allows the organization to pursue more exploratory ideas because the organizational structure minimizes the need for finding common ground in decision making.

Empirical analysis of the interactive relationship between cognitive diversity and organizational structure has been limited by the difficulty in accessing quantitative data about individuals' cognitive frameworks. Because of this difficulty, much of the empirical analysis of the performance implications of cognitive diversity uses survey data to analyze cognitive diversity in team settings (Miller et al. 2022). This restriction is crucial because it often prevents empirical comparisons between organizations (Marchetti and Puranam

[2] Others, such as Henderson and Clark (1990), describe information-processing structure and organizational structure together, without making the potential equivalence explicit.

2022), which is essential to understanding how cognitive diversity and organizational structure interact.

To empirically validate my model's predictions, I construct a unique data set that overcomes these challenges while providing rich data about each firm's level of exploration in the context of product introductions. More specifically, the dataset tracks the level of exploration, cognitive diversity, and organizational structure for 81 large consumer packaged goods (CPG) companies between 2010-2016. Using a corpus of 176,000 online employee reviews of these CPG employers, I apply machine-learning techniques to measure a specific form of cognitive diversity in the organization: the degree to which individuals use different cognitive frameworks to make sense of an organization's culture (Marchetti 2019, Corritore et al. 2020). This approach has been praised in the cognitive-diversity literature as being exemplary of how cognitive diversity can be measured at-scale (Miller et al. 2022). Using listed job titles from the same data set, I estimate how hierarchical each organization is (Lee 2022). Finally, I use Nielsen Scanner Data to measure the commercial performance and features of new products, allowing me to construct multiple measures of exploration (Allen 2023). Suggestive of my theoretical results, I show that greater cognitive diversity is positively correlated with exploration in flat organizations and negatively correlated with exploration in hierarchical organizations.

Finally, I discuss the managerial implications of my findings. My primary result is that organizations can enable greater cognitive diversity to increase exploration by becoming less hierarchical. Doing so allows decentralized employees or groups with idiosyncratic beliefs to pursue exploratory ideas with less managerial interference. This result extends beyond literal organizational structure into considering the amount of consensus the organization requires for decision making. These results have important implications for understanding how organizations can harness the benefits of cognitive diversity.

This paper is structured as follows: (i) I give a theoretical background for my argument, (ii) I present my model, (iii) I show the analysis of my model, (iv) I present my empirical setting, (v) I show my empirical analysis, and (vi) I discuss the implications of my findings.

2 Theoretical Background

This paper combines insights from two strands of the management literature: the organizational-design literature inspired by Sah and Stiglitz (1986) and the literature analyzing how cognitive diversity affects decision-making outcomes.[3] First, the organizational-design literature inspired by Sah and Stiglitz (1986) draws on the behavioral theory of the firm by analyzing how information processing influences decision making. I contribute to this literature by incorporating another concept from the behavioral theory of the firm—namely, the firm as a political coalition—into the Sah-Stiglitz general framework. Second, the literature analyzing how cognitive diversity affects decision-making outcomes primarily argues that cognitive diversity increases exploration (Hambrick and Mason 1984). I build on conceptual frameworks more common in the organizational-design literature to explain when greater cognitive diversity does, and does not, lead to more exploration.

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[3] In both cases I focus on the broader literature considering decision-making outcomes, with my dependent variable (the organization's proclivity to choose to explore) being a specific type of decision.

In this section, I frame my paper within (i) the relevant organizational-design literature, (ii) the relevant cognitive-diversity literature, and (iii) the literature that considers how organizational design and diversity interact to affect outcomes.

2.1 Organizational Structure and Organizational Decision Making

Neoclassical economics bypassed questions of organizational decision making by assuming that decisions are made optimally, serving the organization's interests. Critiquing this approach, the behavioral theory of the firm (BToF) considers two complexities that prevent organizational decision making from being rational (Cyert and March 1963). First, the organization has imperfect information about possible choices. Second, the organization is composed of individual decision makers who have differing interests (or cognitive frameworks, as in Kaplan 2008). The BToF analyzes the organization's decision-making process to incorporate these frictions into its analysis.

Many BToF scholars considering how an organization evaluates prospective decisions have been heavily influenced by Sah and Stiglitz (1986), an economic model describing how organizations process information to make decisions. Like Sah and Stiglitz, these scholars frame 'organizational structure' as describing the process of how an organization aggregates information (Knudsen and Levinthal 2007, Christensen and Knudsen 2010, Csaszar 2013, Csaszar and Eggers 2013). This literature generally focuses on environments where employees have identical preferences and ex-ante beliefs. Many key insights from this literature relate to how organizational structure influences how effectively the firm incorporates distributed information into its final decision.

I add to this analysis by incorporating another significant concept in the BToF—organizational decision making is guided by the individual interests (in my case, cognitive frameworks) of a coalition of individuals, rather than being guided by an overarching organizational goal (March 1962).[4] To develop a model that combines these two key concepts of the BToF, I add heterogeneous cognitive frameworks to the Sah -Stiglitz model (which instead assumes that individual interests and ex-ante beliefs are completely aligned).[5] Combining these concepts allows my model to show how organizational structure influences how the diversity of cognitive frameworks relates to what types of decisions can garner the support of a sufficiently large coalition.[6]

2.2 Cognitive Diversity and Organizational Decision Making

Hambrick and Mason (1984) laid the conceptual groundwork for much of the literature on how cognitive diversity affects decision making outcomes. Building on the BToF, Hambrick and Mason emphasized the role of bounded rationality in understanding

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[4] For examples of scholars who have combined these two elements of the BTF in other families of models, see Ethiraj and Levinthal (2009) or Ganz (2018). Both these models describe the process of *searching* for information about alternatives, while my model describes the process of *evaluating* the quality of (already discovered) alternatives. For more on the distinction between search and evaluation, see Knudsen and Levinthal (2007).

[5] Csaszar and Eggers (2013) adds agent heterogeneity to the Sah-and-Stiglitz framework, but they add a different type of heterogeneity. More specifically, they allow agents to vary in the precision of the signal they receive about project quality. By contrast, I allow agents to vary in cognitive frameworks, which causes them to be biased for, or against, certain types of projects. The key difference is that my type of heterogeneity (cognitive diversity) causes systematic disagreement between agents, while the heterogeneity in Csaszar and Eggers (diversity of expertise) does not. Stated differently, while my model has politics (cognitively diverse agents are unlikely to agree about certain types of projects), the model in Csaszar and Eggers does not (any two agents are more likely than not to agree). Lee and Csaszar (2020) use a similar framing in an empirical analysis of how organizational structure interacts with the organization's decision to hire generalists and/or specialists.

[6] Relatedly, Reitzig and Sorenson (2013) show that in-group bias affects the way that organizations process information about evaluating among prospective choices.

decision making, theorizing that an individual's cognitive profile filters which facets of a complex situation she can understand. Using this framework, most scholars argue that cognitive diversity improves decision making by giving the organization access to more information (Bantel and Jackson 1989, Boeker 1997). Other scholars suggest that cognitive diversity can harm decision making by leading to dysfunctional team dynamics (Sutcliffe 1994, Miller et al. 1998). Weighing these concerns, the literature often argues that cognitive diversity increases exploration because having access to more information is especially valuable in uncertain environments (Miller et al. 2022).[7]

A common way to conceptualize these positive and negative effects of cognitive diversity involves distinguishing between two types of conflict, both of which are potential consequences of cognitive diversity (Amason 1996, Olson et al. 2007). First, cognitive diversity can cause task conflict, which is disagreement about task-related issues, such as an organization's strategy or policies. Second, cognitive diversity can cause relationship conflict, where teammates clash about relationship issues, such as social practices or political beliefs.[8] Often, task conflict is thought to help decision making, and relationship conflict is thought to harm decision making (De Wit et al. 2012).

[7] In this work, I am analyzing two specific stages of the innovation process. Though scholarly work on the innovation process varies in both the nature of the process, and the number and names of stages, Keum and See (2017) identify four specific stages: idea generation, evaluation, selection, and implementation. My analysis focuses exclusively on the organizational process of evaluating and selecting exploratory new ideas.

[8] Many scholars of cognitive diversity build on the categorization-elaboration model (CEM), proposed in Van Knippenberg et al. (2004). The CEM focuses on how diversity can harm performance through social categorization (similar to relationship conflict) and how diversity can help performance by improving the group's ability to process information (De Dreu et al. 2008). I argue that the manner in which the organization processes information (organizational structure) influences the direction of the relationship between cognitive diversity and decision-making outcomes.

My paper differs from this literature in both its conclusions about exploration and its proposed mechanisms through which cognitive diversity affects decision making. First, I argue that cognitive diversity has an ambiguous relationship with exploration, while the literature argues that cognitive diversity increases exploration. Second, my argument focuses exclusively on the contingent effects of task conflict, while much of the literature weighs the positives of task conflict against the negatives of relationship conflict. Like the broader literature, I view the value of task conflict to be in helping the organization recognize more promising new ideas. However, I also identify the potential of task conflict to prevent exploration by discouraging organizational consensus. [9] Consistent with my argument, some case studies demonstrate that cognitive diversity can prevent exploration by leaving an organization stuck in gridlock (Denis et al. 2001, Zuzul 2019). [10]

2.3 Complementing Diversity with Design

Recognizing that diversity has contingent effects, many organizational-behavior scholars have analyzed how organizations can augment diversity's positive consequences and diminish the impact of diversity's negative consequences (Guillame 2017). Many of the studies considering how diversity interacts with organizational structure have proposed

[9] Kaplan (2008) provides excellent insight into the process of how competing cognitive frames fight to become dominant within an organization. In my environment, there is no such competition. Rather, each individual acts according to her initial cognitive frame. While Kaplan focus on the process of different cognitive frames vying for dominance, I focus on how the presence of competing frames influences the organizations willingness to explore.

[10] In the first case of Denis et al. (2001), a hospital's attempt to make a strategic change is stymied by the inability of occupationally diverse stakeholders to agree on the best course of action. Similarly, Zuzul (2019) analyzes two case studies of interorganizational cooperation on 'smart-city' projects. In both smart-city projects, differing cognitive representations between organizations prevented some of the more innovative ideas from being incorporated into the final solution because different groups were unable to agree about the value of these ideas. Attempts to reconcile these disagreements by explaining each side's perspective backfired, causing groups to realize more ways in which they disagreed with each other.

that diversity and hierarchy are complements. The underlying intuition is that homogeneity and hierarchy are alternative means to coordinate employee's actions (Ouchi 1980, Pieterse et al. 2019, Marchetti and Puranam 2022, 2023).

As with the literature from the previous section, I differ from this literature both in my conclusions about how cognitive diversity and organizational structure interact and in the proposed mechanism through which they interact. First, while this literature argues that cognitive diversity complements a hierarchical organizational structure, I argue that, in terms of the ability to explore, cognitive diversity complements a flat organizational structure. More specifically, cognitive diversity leads to more exploration in flat organizations and to less exploration in hierarchical organizations.[11] Second, the literature often focuses on how effectively employees can coordinate their actions with each other to accomplish a task. By contrast, my focus is on how the employees' information-processing behavior influences the decision to explore.

3 Model

3.1 Model Description

The model builds on a classic model of organizational structure and decision making, Sah and Stiglitz (1986). Sah and Stiglitz considers how an organization aggregates information to decide between alternatives when employees have incomplete private

[11] Several scholars argue that diversity and a flat organizational structure are complements (Boone and Hendriks 2009, Tzabbar and Margolis 2017), but the conclusions of these papers are different than mine. More specifically, I argue not only that there is an interactive effect of organizational structure and cognitive diversity, but also that organizational structure changes the direction of the effect of cognitive diversity on exploration.

information about the quality of one alternative. More specifically, the organization must choose between a safe project of known value and a risky project of unknown value. Each employee receives a different unbiased signal of the risky project's quality and recommends which project to select. Employees usually make the same recommendation, disagreeing only because of noise in their signals of the risky project's quality. When employees make the same recommendation, the organization simply follows this recommendation. When employees make contradictory recommendations, the process of how the organization aggregates information determines the final decision, a process that Sah and Stiglitz defines as 'organizational structure'.

I add to Sah and Stiglitz (1986) by introducing a new source of disagreement between employees: cognitive frameworks.[12] Each employee's cognitive framework affects which dimensions of a project's quality she can understand (appreciate). Differing cognitive frameworks cause employees to focus on different dimensions of a project's quality, inducing disagreement between employees when a project is high-quality in some dimensions and low-quality in others.

The exposition of the model is separated into five steps: (i) features of risky projects, (ii) how employees (agents) evaluate risky projects, (iii) how I define cognitive diversity, (iv) how different organizational structures aggregate agent evaluations to make an organizational decision, and (v) how I measure exploration.

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[12] Of course, there are many sources of conflict that can cause the gridlock dynamics described in my model. For instance, employees may make contradictory recommendations because they face different incentives. In principle, this model could be used to conceptualize the consequences of other types of heterogeneity that induce conflict (including incentives).

3.2 Projects

Each risky project has n dimensions of quality. Project j's m^{th} dimension of quality is given by $q_{j,m} \in \mathbb{R}$, and project j's overall quality, $q_{j,}$ is the sum of all dimensions of quality.[13] The dimensions of quality are independent and identically distributed.

3.3 Agents

The organization has two agents, who evaluate projects. Each agent, i, has a cognitive framework, C_i, which is the set of the dimensions of project quality that she can understand (i.e., that influence her evaluation of project quality).[14] For both agents, the cardinality of C_i is fixed at some $n' < n$. An agent's perception of a project's quality is a function of dimensions of true quality that she can understand, and the error term. Mathematically, agent i's signal of project j's quality is $\tilde{q}_{i,j} = \sum_{m \in C_i} q_{j,m} + \epsilon_{i,j}$, where $\epsilon_{i,j}$ is an error term.[15] The value of the outside option, $\bar{q}$, is common knowledge. Agent i approves (positively evaluates) project j when $\tilde{q}_{i,j} > \bar{q}$.[16]

3.4 Cognitive diversity

Recall that each agent's cognitive framework, C_i, corresponds to the set of a project's quality dimensions that agent i can perceive. To mathematically define σ, I first take the set

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[13] In the Appendix, I consider a more general case where total quality is a symmetric function of all dimensions of quality. I focus on the additive case here for expositional clarity.

[14] This definition of *cognitive framework* is similar to the definition of *mental representation* used in Levinthal and Csaszar (2016). See Walsh (1995) for a broader review of how organizational cognition.

[15] I assume that the distribution of the error term is unbounded and diffuse.

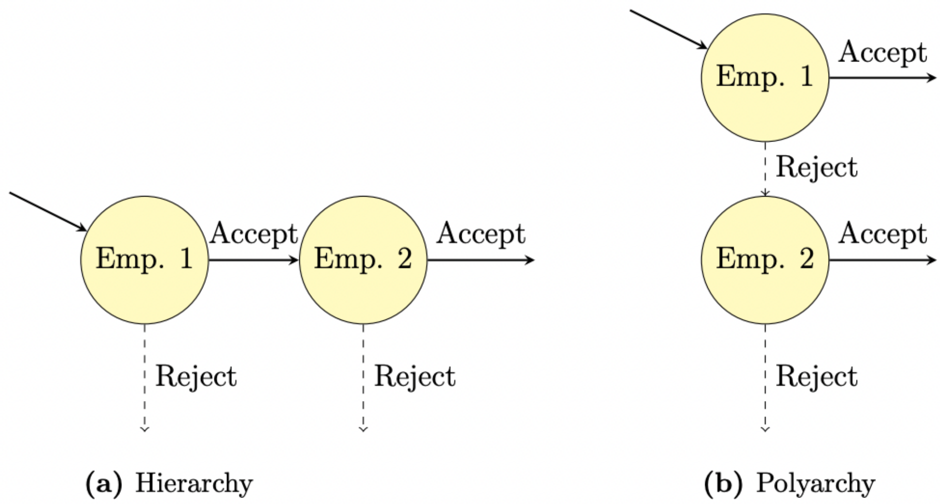
[16] Agents here are naïve in the sense that they consider neither organizational structure nor the other agent's cognitive framework when making a decision. In the extension, I consider a case with Bayesian agents who update their evaluation criteria to both organizational structure and the other agent's cognitive framework.

of quality dimensions that agent 1 can perceive and define σ to be the fraction of those dimensions that agent 2 cannot perceive (more precisely, $\sigma = \frac{|C_1/C_2|}{|C_1|}$). When cognitive diversity, σ, is equal to one, the agents have no overlap in understanding dimensions of project quality. When $\sigma = 0$, the agents have complete overlap in understanding dimensions of project quality, and The model is equivalent to Sah and Stiglitz (1986).

3.5 Organizational Structure

Like Sah and Stiglitz (1986), I model organizational structure as describing the information-aggregation process, which determines how agent evaluations affect the organization's decision. Sah and Stiglitz describe two organizational structures: hierarchy and polyarchy. Under hierarchy, first one agent (analogous to a subordinate) evaluates the project. If she does not approve the project, it is rejected. If she approves the project, then the other agent (analogous to a manager) evaluates the project and makes a final acceptance decision. Thus, under hierarchy, unanimous approval is required to accept a project. In contrast, under polyarchy, first one agent (not analogous to a subordinate or a manager) evaluates the project. If she approves the project, it is accepted. If she does not approve the project, the second agent evaluates the project and makes a final acceptance decision. Thus, under polyarchy, unanimous disapproval is required to reject a project. These processes are illustrated in Figure 2.

Figure 2: Sah and Stiglitz (1986) Representation of Hierarchy and Polyarchy



3.6 Measuring Exploration

Management scholars define exploration in many ways, and they use the term to describe phenomena ranging from organizational learning (March 1991, Levinthal and March 1993) to product innovation (He and Wong 2004, Andriopoulos and Lewis 2009) to strategic alliances (Rothaermel 2001, Rothaermel and Deeds 2004). Throughout this literature, exploration corresponds to experimentation and variation. In the context of the model, I say the organization *explores* when it chooses to implement (i.e., experiments with) the risky project. [17]

[17] Just as exploration is used to describe a variety of phenomena, it is also analyzed using several different mathematical models. For instance, March (1991) analyzed exploration in the context of a genetic algorithm, Siggelkow and Levinthal (2003) used an NK model, and Csaszar (2013) applied the Sah-Stiglitz framework. More recently, multi-armed bandit models have emerged as the management literature's predominant model of the exploration-exploitation tradeoff (Posen and Levinthal 2012, Stieglitz et al. 2016; see Levinthal 2021 for a review and a critique). Unlike the canonical Sah-Stiglitz framework, these other families of models consider repeated games that enable exploration to correspond to organizational learning. However, my model can easily be extended to become a repeated game where choosing the risky project corresponds to learning about the payoff of a new project (with the resulting information being valuable in future periods). As a result, my findings generalize to conceptualizations of exploration related to organizational learning.

4 Analysis

I now analyze the effect of cognitive diversity on exploration. The analysis is outlined as follows: (i) I show how the likelihood a specific agent approves a project varies with project quality and the agent's cognitive framework, (ii) I show my main result, connecting the likelihood that *the organization* accepts a project to organizational structure and cognitive diversity, and (iii) I discuss an extension to my model. In the Appendix, I provide both a proof of my main result,and a proof that this result also applies to the extended model.

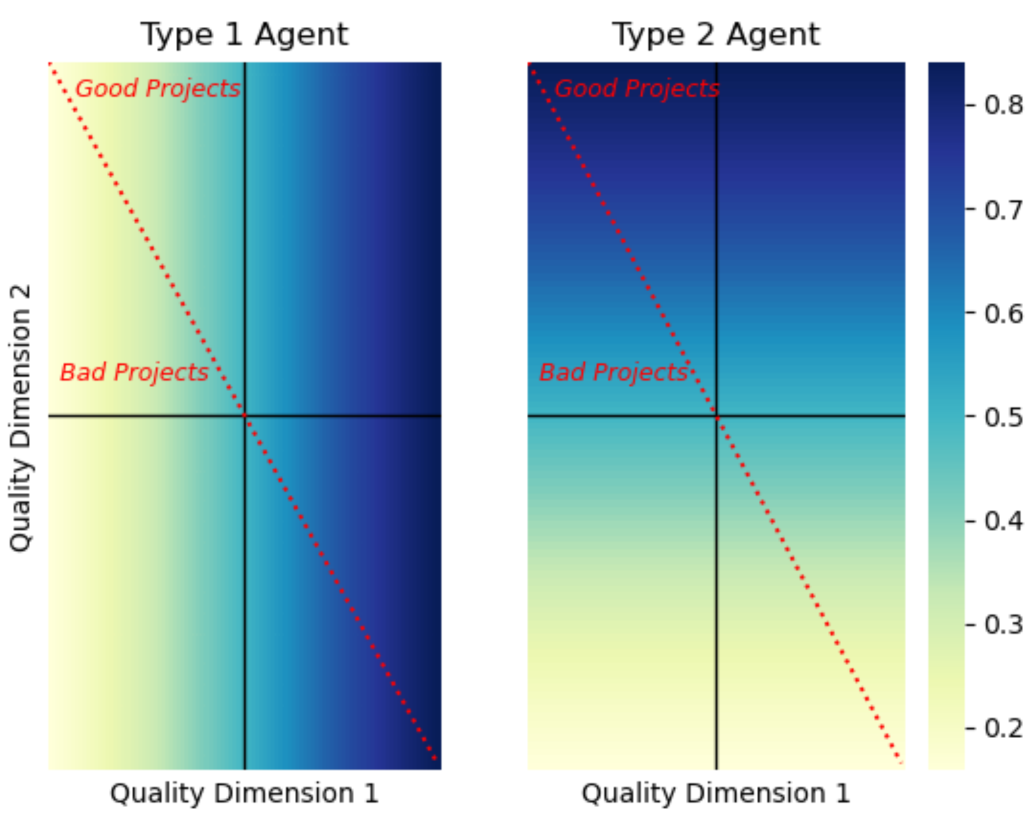
4.1 Individual Agent Recommendations

I illustrate the model's intuition in an environment with two dimensions of quality, but the results generalize to higher dimensions. Because agents have limited cognitive frameworks, in the two-dimension case, each agent's cognitive framework allows her to appreciate only one dimension of quality. As a result, there are two potential types of agents. *Type 1 agents* are influenced by only the first dimension of quality, meaning that $\tilde{q}_{i,j} = q_{j,1} + \epsilon_{i,j}$. *Type 2 agents* are influenced by only the second dimension of quality, meaning that $\tilde{q}_{i,j} = q_{j,2} + \epsilon_{i,j}$.

Remember, agent i approves project j if and only if $\tilde{q}_{i,j} > \bar{q}$. Notice that this assumes agents are naïve in the sense that they do not change their recommendation in response to the other agent's recommendation; I discuss the implications of relaxing this assumption later.

In Figure 3, I show how the likelihood a project is accepted depends on each dimension of project quality for each type of agent. Recall that each agent's recommendation is influenced by only a single dimension of quality. As a result, the agent recommends too few projects that are high in the other dimension of quality, and she recommends too many that are high in her own dimension of quality. In this sense, the agent might be described as having a bias for one dimension of quality. Figure 3 shows this phenomenon with some 'good projects' (having a positive overall quality) being most likely rejected for a specific type of agent, and some bad projects being most likely accepted for a specific type of agent.

Figure 3: Probability that Agent Approves the Project



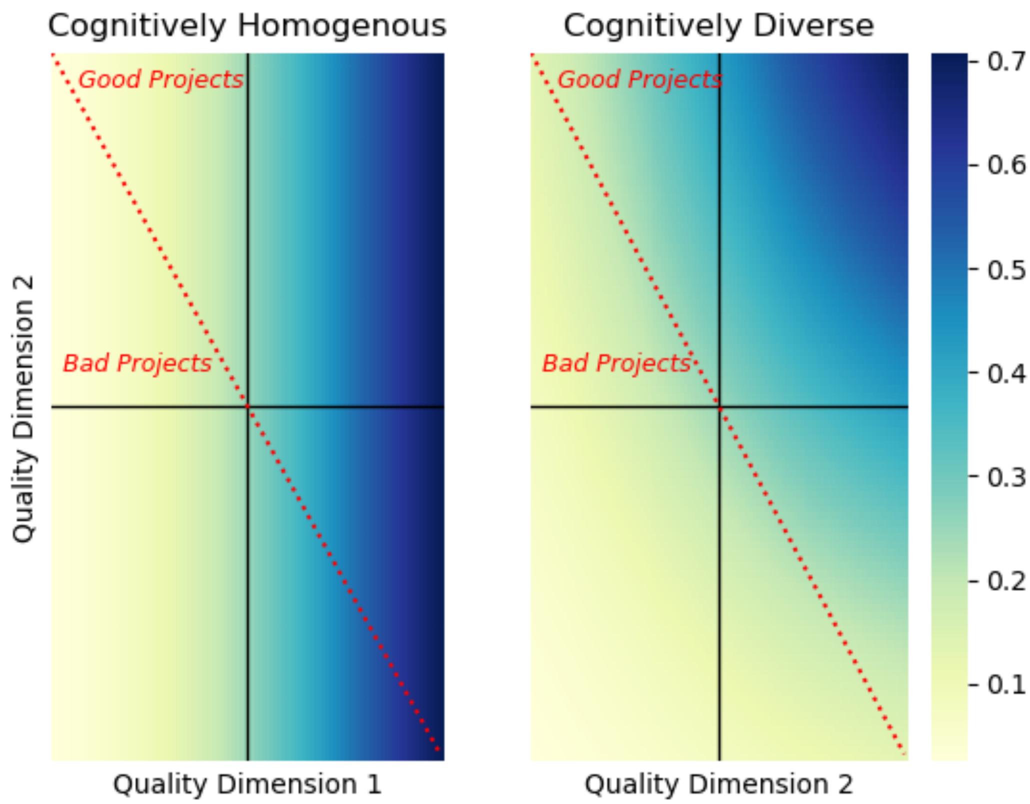
In each subfigure, the color of the heatmap corresponds to the likelihood that a specific agent will approve a project. The x-axis corresponds to the first dimension of quality, and the y-axis corresponds to the second dimension of quality. Type 1 agents appreciate only the first dimension of quality, and Type 2 agents appreciate only the second dimension of quality.

4.2 Organizational Decisions

Now I turn to how cognitive diversity influences organizational decision making, depending on whether the organization is hierarchical or flat. For each organizational structure, I compare a cognitively homogenous organization with two Type 1 agents to a cognitively diverse organization with a Type 1 agent and a Type 2 agent. First, I consider hierarchical organizations, where both agents must approve a project for it to be accepted. In Figure 4, I show how the likelihood that a project is accepted depends on project quality for cognitively diverse and cognitively homogenous hierarchical organizations. Increasing cognitive diversity increases the likelihood that some projects are accepted (when the first dimension of quality is lower than the second), and it decreases the likelihood that other projects are accepted (when the first dimension of quality is higher than the second).

In hierarchical organizations, greater cognitive diversity decreases the average probability that a random project will be accepted. In cognitively homogenous hierarchical organizations, a project is likely to be accepted if it is high-quality on the first dimension. By contrast, in cognitively diverse hierarchical organizations, a project is likely to be accepted only if it is high-quality on both dimensions. Intuitively, because hierarchical organizations require consensus to pursue a new idea, greater cognitive diversity prevents most new ideas from being pursued because it makes it harder for the organization to reach consensus.

Figure 4: Probability that the Project is Accepted under Hierarchy

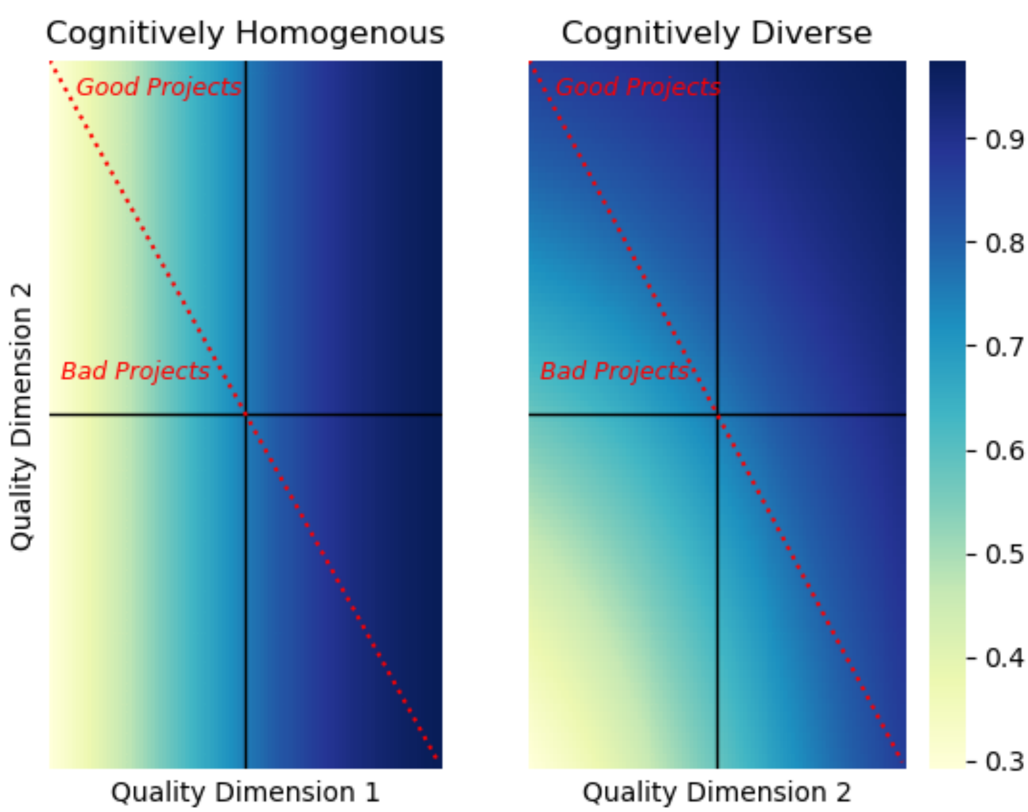


In each subfigure, the color of the heatmap corresponds to the likelihood that a specific project will be approved in a hierarchical organization. The x-axis corresponds to the first dimension of quality, and the y-axis corresponds to the second dimension of quality. A cognitively homogenous organization has two type 1 agents, and a cognitively diverse organization has one type 1 agent and one type 2 agent.

Now I turn to flat (polyarchal) organizations, where a project is accepted so long as at least one agent approves the project. In Figure 5, I show how the likelihood that a project is accepted depends on project quality for cognitively diverse and cognitively homogenous flat organizations. As with hierarchical organizations, increasing cognitive diversity increases the likelihood that some projects are accepted (when the first dimension of quality is lower than the second), and it decreases the likelihood that other projects are accepted (when the first dimension of quality is higher than the second).

In flat organizations, increasing cognitive diversity increases the average probability that a random project will be accepted. In cognitively homogenous flat organizations, as in cognitively homogenous hierarchal organizations, a project is likely to be accepted if the first dimension of quality is high (though projects are more likely to be accepted in flat organizations than in hierarchies). However, in cognitively diverse flat organizations, a project is likely to be accepted as long as it is high-quality along either dimension. The intuition is that consensus is not mandatory in a flat organization, so greater cognitive diversity encourages the organization to pursue more new ideas because it makes more new ideas appealing to at least one employee.

Figure 5: Probability that the Project is Accepted under Polyarchy



In each subfigure, the color of the heatmap corresponds to the likelihood that a specific project will be approved in a flat organization. The x-axis corresponds to the first dimension of quality, and the y-axis corresponds to the second dimension of quality. A cognitively homogenous organization has two type 1 agents, and a cognitively diverse organization has one type 1 agent and one type 2 agent.

These pieces of intuition are formalized in Theorem 1.

Theorem 1. *Increasing cognitive diversity leads to less exploration under hierarchy and more exploration under polyarchy.*

In hierarchical organizations, greater cognitive diversity prevents exploration because cognitively diverse employees struggle to find the common ground needed to pursue a specific risk. By contrast, in flat (polyarchal) organizations, greater cognitive diversity encourages exploration because the organizational structure eliminates the need for common ground in decision making.

4.3 Extension

In the main model just presented, I followed the Sah-and-Stiglitz framework in assuming that individual agents are naïve in the sense that they do not consider the organizational structure and/or approval behavior of other agents when making a recommendation. This analysis is consistent with much of the behavioral theory of the firm, which often assumes that individual decision making is best understood by analyzing relatively simple processes instead of having agents forecast distant probabilities in a utility-maximization framework (Gavetti et al. 2012). By contrast, most economic models assume that sophisticated agents update their beliefs in response to both organizational structure and the voting behavior of the other agent. In the Appendix, I present an extension of the model with Bayesian (and utility-maximizing) agents. More specifically, as in the main model, each agent believes that overall project quality is a function of only the dimensions of quality in that agent's cognitive framework, but now each agent adjusts her voting behavior in response to organizational structure and the cognitive frameworks of the other agent.

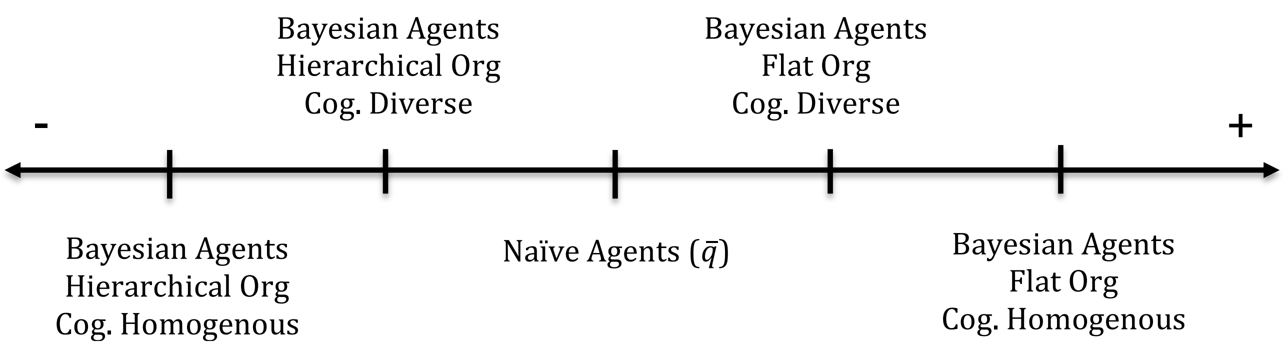
In the extended model, the result of Theorem 1 also holds. While the main model gives the intuition behind the first-order effect in the extended model, the extended model's second-order effect adds valuable insight for understanding how cognitive diversity influences exploration. More specifically, in flat organizations, increasing cognitive diversity causes agents to decrease their evaluation criteria, causing each agent to approve more projects. In hierarchical organizations, increasing cognitive diversity causes agents to increase their evaluation criteria, causing each agent to approve fewer project. To give intuition behind this result, it will first be necessary to consider how cognitively homogenous agents change their voting behavior in response to changes in organizational structure.

First, consider a flat organization. Each agent knows that her recommendation will influence the final decision only if the other agent does not approve the project. As a result, the agent's recommendation will matter only if the other agent receives a negative signal of project quality. In response to being part of a flat organization, each agent thus adjusts her evaluation criterion by adopting a more stringent standard for approving projects.

Second, consider a hierarchical organization. Each agent knows that her recommendation will influence the final decision only if the other agent does approve the project. As a result, the agent's recommendation will matter only if the other agent receives a positive signal of project quality. In response to being part of a hierarchy, each agent thus adjusts her evaluation criterion by adopting a more relaxed standard for approving projects.

Now consider how this Bayesian adjusting of evaluation criteria varies with cognitive diversity, when each agent's cognitive framework is common knowledge. As cognitive diversity increases, Agent 2's signal of project quality becomes less informative about the dimensions of quality that Agent 1 believes to be important. As a result, agents adjust their evaluation criteria less to organizational structure when cognitive diversity is higher. By implication, in flat organizations, increasing cognitive diversity decreases each employee's standard for approving projects, causing the organization to pursue more new projects. By contrast, in hierarchical organizations, increasing cognitive diversity increases each employee's standard for approving projects, causing the organization to pursue fewer new projects. Figure 6 gives a simplistic representation of how Bayesian agents' evaluation criteria depends on organizational structure and cognitive diversity.

Figure 6: Evaluation Criteria for Bayesian Agents



This figure shows how the evaluation criteria used by Bayesian agents depends on organizational structure. Naïve agents approve a project so long as $\tilde{q} > \bar{q}$. In hierarchical organizations, Bayesian agents adjust the criteria downwards, allowing more projects to be approved. In flat organizations, Bayesian agents adjust the criteria upwards, allowing fewer projects to be approved. Regardless of organizational structure, cognitively diverse agents adjust their evaluation criteria (relative to naïve agents) less than cognitively homogenous agents do.

More generally, management scholars and economists alike have argued that sophisticated voting behavior may cause decision-making structures to have counter-intuitive effects on decision-making outcomes (Feddersen and Pesendorfer 1998, Piezunka and Schilke 2023). The extended model implies that cognitive diversity may play a role in mitigating these effects, causing cognitive diversity to further prevent exploration in hierarchical organizations and further encourage exploration in flat organizations.

5 Empirical Setting

5.1 Overview and Hypotheses

My model implies that greater cognitive diversity increases exploration in flat (polyarchal) organization and decreases exploration in hierarchical organizations. In this section, I describe a unique data set that I use to empirically validate the main prediction of this model. Remember, one of the great challenges in analyzing the interaction between cognitive diversity and organizational structure is finding data at the appropriate scale. Most empirical measures of cognitive diversity rely on survey data (Miller et al. 2022), often preventing an organization-wide measure of cognitive diversity and comparisons of cognitive diversity across organizations (Marchetti and Puranam 2022).

In my empirical analysis, I focus on a specific type of cognitive diversity: the degree to which members of an organization use different cognitive constructs to make sense of organizational culture (Marchetti 2019, Corritore et al. 2020). I construct a measure of cognitive diversity using machine-learning techniques on a dataset of 176,000 employee reviews of these firms. I use this same dataset of employee reviews to estimate how hierarchical an organization is. I construct measures of exploration using data on more than 5,600 consumer packaged goods products introduced by 81 firms between 2010 and 2016. The primary benefit of focusing on the CPG sector is that there is rich data on new products allows me to analyze several measures of exploration.

Using this data, I empirically validate the main prediction of my model by testing two hypotheses: first, greater cognitive diversity is positively correlated with exploration in flat organization and, second, greater cognitive diversity is negatively correlated with exploration in hierarchical organizations. For both hypotheses, I test if the hypothesis holds for three different measures of exploration. First, I consider exploration defined as the rate at which firms introduce products to the market in part (a) of both hypotheses.

> **Hypothesis 1(a)**: *In flat organizations, greater cognitive diversity is correlated with introducing new products at a faster rate.*
>
> **Hypothesis 2(a)**: *In hierarchical organizations, greater cognitive diversity is correlated with introducing new products at a slower rate.*

Second, I consider exploration defined as the average novelty of introduced products in part (b) of both hypotheses.

> **Hypothesis 1(b):** *In flat organizations, greater cognitive diversity is correlated with introducing products that are more novel.*
>
> **Hypothesis 2(b)**: *In hierarchical organizations, greater cognitive diversity is correlated with introducing products that are less novel.*

Finally, I consider exploration defined as the firm producing many commercially successful new products.[18]

Hypothesis 1(c): *In flat organizations, greater cognitive diversity is correlated with introducing commercially successful products at a faster rate.*

Hypothesis 2(c): *In hierarchical organizations, greater cognitive diversity is correlated with introducing commercially successful products at a slower rate.*

5.2 Sample and Data

I test my hypotheses using data on the consumer packaged goods (CPG) sector, which includes all firms that manufacture products sold to consumers via the retail channel, spanning product categories as diverse as food, electronics, household cleaning, beauty, and over-the-counter drugs. My sample is a cross-sectional data set with measures of exploration, organizational structure, and cognitive diversity (heterogeneous cognitive framings of organizational culture) for each of 81 CPG companies (defined as having NAICS code beginning with 31, 32, or 33).

To construct measures of exploration in new-product innovation, I use Nielsen Retail Measurement Services scanner data. This data set has information about the commercial success and features of the products that each of the CPG companies sell

[18] Relatedly, Csaszar (2013) defines exploration in terms of committing few omission errors. By analogy, firms are exploratory if they do not fail to introduce prospective products that would be commercially successful. However, I cannot directly observe omission errors because I do not observe products that were not introduced. Instead, I analogize having few omission errors to introducing many commercially successful products in part (c) of both hypotheses.

between 2010-2016. The firms in my sample introduce over 5,600 new products in the relevant timeframe.

To measure both cognitive diversity and organizational structure, I use a dataset that includes all employee reviews of sufficiently large CPG employers available on glassdoor.com as of January 2023. Glassdoor is a career intelligence website that is primarily used by consumers for its jobsearch platform. Glassdoor authenticates the identity of its reviewers, but the reviewers are anonymous to other users. The reviews include a job title, a review of the company, and a description of the pros and cons of working at the company. I limit my sample to CPG companies in the Nielsen Retail Measurement Services scanner data that (i) have over 100 reviews on glassdoor.com and (ii) report relevant financial statistics to Compustat (employee count and R&D expenditures), which I use for control variables. The remaining firms in my sample are predominantly large, with over 90% having been listed on either the Fortune 1000 or Fortune Global 2000 lists.

5.3 Dependent Variable Measures

Product Introductions: I aggregate products at the UPC-bar-code level. I define a product introduction as the firm selling a product that it has never sold before. In the regression, I consider a firm's average number of annual product introductions between 2010-2016.

Product Novelty: In the Nielsen dataset, many products have a list of features. For example, a detergent might have six features: product type, form (e.g., liquid or liquid pac), container (e.g., bag or bottle), type (e.g., with bleach or stain removal), scent, and size. A product is considered novel if it introduces a new bundle of features to the market. The firm's *Average novelty* is the percentage of it's introduced products that are novel (between 2010-2016.) The results are robust to an alternative definitions of product novelty, discussed later.

Successful Product Introductions: To define a (commercially) successful product introduction, I focus on the product's gross sales during the last quarter of its two-year post-launch period. I use sales in the final quarter because earlier sales are more contingent on the initial size of the product launch, which the firm endogenously chooses (Bass 1969). I define a product introduction to be successful if its sales in the final quarter of the post-launch period exceed those of 90% of products introduced during the same quarter in the same product category. In the regression, I consider the firm's average number of annual product introductions between 2010-2016. The results are robust to alternative definitions of successful products, discussed later.

5.4 Independent Variable Measures

Cognitive Diversity: I measure a specific type of cognitive diversity: the heterogeneity of cognitive frameworks used to conceptualize organizational culture. I follow the approach outlined in Corritore et al. (2020) almost exactly, which uses machine-learning techniques on a large set of employee reviews from glassdoor.com to construct a measure this heterogeneity. This method is in the tradition of scholars who use linguistic data to measure aspects of organizational culture (Goldberg et al. 2016, Luo et al. 2016, Srivastava et al. 2018). Scholars of cognitive diversity have approvingly cited this exact measure as being exemplary of how researchers should measure cognitive diversity because it both directly measures cognitive diversity (as opposed to measuring a demographic proxy) and it can easily be applied to compare cognitive diversity across organizations (Miller et al. 2022).[19]

Like much of the textual analysis literature, I treat each sentence as a 'bag of words,' meaning I assume that a sentence's content can be identified without considering the order of the words in a sentence. Using the corpus of glassdoor.com reviews, I first limit the analysis to sentences that have a word indicating that it is describing the company's culture (e.g., culture, environment, or atmosphere). Then, I represent each of these sentences as a vector of how many times individual words appear in the sentence.

Next, I train a linguistic topical model to identify distinct dimensions of organizational culture mentioned in employees' reviews across the entirety of the Glassdoor data. To do so, I use a latent Dirichlet allocation (LDA) topic model (Blei et al. 2003). LDA identifies distinct topics across the corpus by observing words that tend to co-occur frequently within each review. LDA then outputs a matrix that assigns each review a probabilistic mixture of topics. The trained LDA model identfies a set of 500 topics that employees across organizations in the Glassdoor data collectively consider germane to organizational culture. Table 2 displays a subset of the identified topics, each with a group of selected words that correspond much more to that topic than to other topics.[20] For ease of exposition, I then propose a label for each group of words.

[19] For examples of other scholars who have used linguistic data to measure cognitive diversity, see Cho (2023) or Wilde (2023).

[20] I list six of the ten words that are most associated with the selected topic relative to all other topics.

Table 2: Most Common Words (Relatively) for Selected LDA Culture Topics

Number	Selected Words	Label
1	divers, environ, commit, nice, incl, global	Inclusive
2	network, club, boi, close, knit, frat	Exclusive
3	leadership, foster, experi, growth, integr, develop	Mentorship
4	pleasant, environ, quiet, aesthet, ambien, cozi	Cozy
6	improvea, everydai, stride, shop, serv, drive	Driven
7	leav, option, reloc, talent, price, asset	Transactional
492	Pressure, competit, change, target, lot, volume	High-pressure
497	feedback, foster, collabor, hear, innov, accomplish	Team-oriented
498	hostil, hazard, report, hr, ineffect, horrif	Toxic
500	sharehold, public, stakehold, annual, world, contribut	Shareholder-focused

After identifying these cultural topics, I fit the LDA model to the reviews in my sample. The model assigns each review a probability distribution over the set of possible topics. Cognitive diversity is measured as the degree to which a firm's employees characterize the firm's culture using dissimilar cultural topics, meaning the firm has employees who use differing cognitive constructs to make sense of which features of an organization's culture are important. For more detail on this measure, see Marchetti (2019) or Corritore et al. (2020).

Hierarchy: I measure how hierarchical a firm is in terms of the number of hierarchical levels (Burton and Obel 2004, Puranam 2018, Lee and Csaszar 2020). To construct this measure, I slightly modify the approach in Lee (2022). I categorize each employee in the glassdoor.com data set as belonging to one of 8 distinct hierarchical levels (VP, Head, Director, Senior Manager, Manager, Senior/Lead, Supervisor, and Other). The measure of an organization's hierarchy is the number of hierarchical levels present in each organization. I do not include the C-suite, owner, or president classifications because these entries were rare and nearly all firms in my sample likely have a CEO, CFO, etc.

Table 3: Measuring Hierarchical Levels

Rule	Hier. Level	If Job Title Includes Any of these Words	Examples in the Data
1	VP	"vp" or "vice president"	"vice president of sales", "vp of operations'
2	Head	"head"	"head of R&D", "head of marketing"
3	Director	"director" or "dir"	"director of operations", "brand director"
4	Senior Manager	Both (i)"senior"/'sr' and (ii)"manager"/"mgr"/"gm"	"senior brand manager", "sr IT manager"
5	Manager	"manager", "mgr", or "gm"	"logistics gm" "store manager"
6	Senior/ Lead	"senior", "sr", or "lead"	"senior engineer", "lead designer"
7	Supervisor	"supervisor" or "coordinator"	"shift supervisor", "HR coordinator"
8	Other	(includes none of the above)	"sales", "intern", "analyst"

Empirically, all sufficiently large firms have at least one employee in each hierararchical level, perhaps due to user error in entering information onto glassdoor.com. To combat this concern, I consider only the levels of the hierarchy that at least one in a thousand of reviewers occupy. I choose the cutoff of one in a thousand because the average firm in my sample has about two thousand reviewers, so the average firm would need multiple employee entries at one hierarchical level to have that level register in the measure of hierarchy. The results are robust to a wide range of alternative cutoffs.

The median firm in my sample has 7 layers of hierarchy, with 78/81 firms having between 6 and 8 layers or hierarchy. For ease of exposition, I call firms with 6 layers of hierarchy “flat”, firms with 7 layers of hierarchy “neutral”, firms with 8 layers of hierarchy “hierarchical”.

5.5 Control Variables

From Compustat, I obtain the firm’s average number of employees and R&D spending during the period. In regressions with (successful) product introduction rate as a dependent variable, I control for the scope of a firm using the firm’s average stock of preexisting (i.e., not introduced that quarter) products in the Nielsen data. Finally, in regressions considering product novelty, I control for the average number of listed features of products that the company sells because the number of features for a product class mechanically influences the measure of product novelty. Finally, I use fixed effects for NAICS codes at the 2-digit level. There are three such codes in the data, ‘31’, ‘32’, and ‘33’, with firms approximately evenly distributed across these codes.

5.6 Exploring the Data

The summary statistics of the data are outlined in Table 4. Notice that there are 81 observations for all but two of the variables. This is because 14 firms did not introduce any products with listed features, preventing a measure of product novelty. Notice that the three measures of exploration are all positively skewed. As will be discussed later, the regression method that I use (Poisson) is intended for use on skewed data, and the results are also robust to Winsorization.

Table 4: Summary Statistics

Variable	N	Mean	St. Dev.	Min	Max
product novelty	67	0.08	0.17	0.00	1.00
product intros	81	8.75	15.73	0.00	94.00
succ. product intros	81	2.35	4.77	0.00	29.00
cognitive diversity	81	0.37	0.08	0.25	0.53
hierarchy	81	7.16	0.86	5	8
employees (thous.)	81	49.99	67.08	.85	326.14
R&D exp./yr $M	81	846.12	1,504.36	3.15	5,877.66
# existing prod.	81	99.45	152.33	0.50	823.75
avg. # prod. attributes	67	3.33	1.56	0.2	6.12

The correlation matrix is presented in Table 5. The correlation between intros and successful intros is extremely high (.88). This is unsurprising because introducing a successful product requires first introducing a product. In other words, the dependent variables in Hypothesis 1(a) and Hypothesis 1(c) are highly related, and likewise for the dependent variables in Hypothesis 2(a) and Hypothesis 2(c).

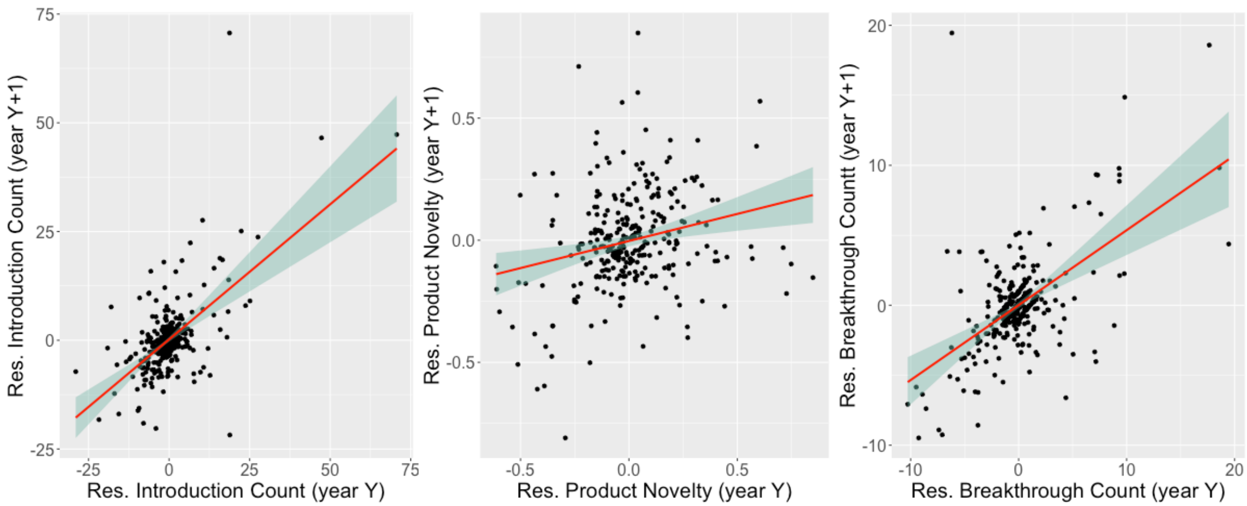
Table 5: Correlation Matrix

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1 novelty	1								
2 intros	−0.10	1							
3 suc. intros	−0.07	0.88	1						
4 diversity	0.11	0.06	0.22	1					
5 hierarchy	−0.11	0.20	0.21	0.25	1				
6 employees	−0.01	0.10	0.16	0.66	0.22	1			
7 R&D exp	−0.07	0.004	0.07	0.43	0.11	0.52	1		
8 # prod.	−0.13	0.89	0.81	0.08	0.21	0.06	0.01	1	
9 # attr.	0.15	0.13	0.26	0.15	−0.02	0.03	−0.09	0.13	1

Because my analysis focuses, in large part, on the interaction between cognitive diversity and hierarchy, it is important to consider how and why cognitive diversity and hierarchy may covary. Cognitive diversity and hierarchy are positively correlated (.25), though this correlation is not statistically significant once controlling for the number of employees in an organization. Marchetti and Puranam (2023) gives perhaps the most advanced analysis of the direction and explanation of the correlation between cultural diversity and organizational structure. In a much larger sample, Marchetti and Puranam (2023) shows that hierarchy is positively correlated with cognitive diversity, and the authors argue that this correlation is due to hierarchy and homogeneity being alternative means to coordinate employee actions. Though I do not yet have the measure of coordination used in Marchetti and Puranam (2023), I am working to obtain this measure to supplement my analysis in future drafts.

Because my analysis is cross-sectional, it relies on the notion that organizations have systematic variation in exploration, cognitive diversity, and organizational structure. Figure 7 supports the idea that there are persistent differences in exploration among seemingly similar firms by showing the relationship between exploration in year Y and exploration in year Y+1. Each subfigure corresponds to a different measure of exploration, and the displayed values are the residuals controlling for the controls in the main regression. *Product Introductions* and *Successful Product Introductions* are highly persistent over time, and *Product Novelty* is moderately persistent over time. This is consistent with the general trend that (Successful) Product Introductions are more strongly correlated with many covariates than is *Product Novelty*. In the *Product Novelty* subfigure, outliers (significant changes in *Product Novelty* between years) tend to occur for firms that introduce few products in one of the two years being compared.

Figure 7: Persistent Differences in Exploration Measures



Each subfigure shows how the residual level of exploration in year Y+1 varies with the residual level of exploration in year Y. The residuals are the difference between realized levels of exploration and the level predicted given NAICS code, employee count, capital expenditures, and R&D expenditures. The red line and shaded region correspond to a regression estimate with a (robust) 95% confidence interval.

In Figure 8, I show that there is even greater persistence in measures of cognitive diversity across time. Outliers (i.e. unusually large shifts in cognitive diversity from year to year) tend to occur in earlier years when there are fewer glassdoor.com reviews (reflecting an increase in usage of the site over time). Regressing cognitive diversity in year Y+1 on cognitive diversity in year Y has a high R-squared (.82). [21]

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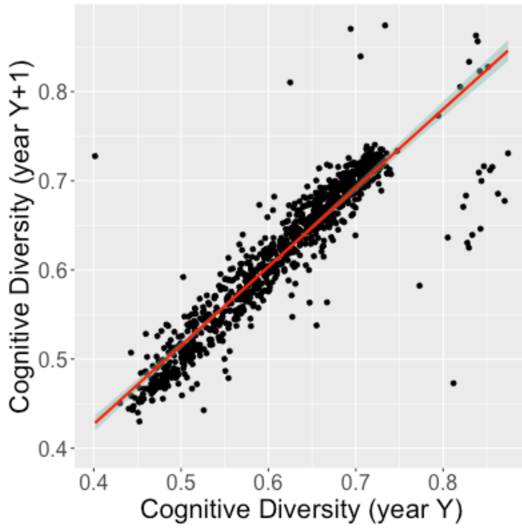
[21] I do not include a similar analysis of the measure of organizational structure because organizational structure cannot be reliably measured on annual basis. This is because variation in organizational structure often comes from variation in relatively rare job titles.

Figure 8: Persistent Differences in Measured Cognitive Diversity



This figure shows how the level of cognitive diversity in year Y+1 varies with the residual level of exploration in year Y. Cognitive diversity measured in year Y depends only on glassdoor.com reviews entered in that year. The red line and shaded region correspond to a regression estimate with a (robust) 95% confidence interval.

6 Empirical Analysis

6.1 Model Specification

I first use a Poisson regression model to estimate how the predicted expected value of each measure of exploration varies with cognitive diversity, hierarchy, the interaction between the two, and the controls. Each of the Poisson regressions has the following form:

$$\log\left(E[Exploration\ Numerator_i]\right) = \beta_0 + \beta_1 Cog.Diversity_i + \beta_2 Hierarchy_i + \beta_3 Cog.Diversity_i\ x\ Hierarchy_i + \beta_4 Controls_i + \log(Exploration\ Denominator_i)$$

In the regression for product introduction rate, *Exploration Numerator* is *Total Products Introduced,* and *Exploration Denominator* is *Total Years*. As a result, the interpretation of each coefficient is the marginal effect of increasing the relevant covariate on the log of predicted product introduction rate per year.

In the regression for product novelty, *Exploration Numerator* is *Total Novel Products Introduced* and *Exploration Denominator* is *Total Products Introduced*. As a result, the interpretation of each coefficient is the marginal effect of increasing the relevant covariate on the log of predicted likelihood that a random introduced product is novel.

In the regression for successful product introduction rate, *Exploration Numerator* is *Total Successful Products Introduced,* and *Exploration Denominator* is *Total Years*. As a result, the interpretation of each coefficient is the marginal effect of increasing the relevant covariate on the log of predicted successful product introduction rate per year.

In each of these regressions, the coefficient of the interaction between cognitive diversity and exploration is of interest. However, this coefficient does not test the hypotheses. Recall that Hypothesis 1 states that cognitive diversity and exploration are positively correlated in flat organizations, Hypothesis 2 states that cognitive diversity are negatively correlated in hierarchical organizations, and the coefficient of the interaction term is positive (negative) if cognitive diversity and exploration are more positively (negatively) correlated in relatively hierarchical organizations. While the interaction term does not directly test either hypothesis, the interaction term being negative is a necessary condition for both hypotheses to be true; if cognitive diversity and exploration are positively correlated in flat organizations and negatively correlated in hierarchical organizations, the cognitive diversity and explorations must be more negatively correlated in relatively hierarchical organizations.

To test the hypotheses, I use each of the estimated Poisson regression models to estimate the marginal effect of greater cognitive diversity on the predicted expected value of exploration conditional on (i) a flat organization (hierarchy=6), and (ii) a hierarchical organization (hierarchy=8). [22]

6.2 A Note on Identification

One potential concern with the regression is that an unobserved variable might be correlated with hierarchy, cognitive diversity, and exploration. Suppose that for this unobserved variable, θ, and some constants $\gamma_1, \gamma_2, \gamma_3,\ \mu_1, \mu_2\ and\ \mu_3$, the following statements are true:

(1) $E[Hierarchy|\theta]) = \gamma_1\theta + \mu_1$

(2) $E[\text{Cognitive Diversity}|\theta]) = \gamma_2\theta + \mu_2$

(3) $\text{Exploration} \sim Poisson\ (\beta_0 + \beta_1 Cog.Diversity\ +\ \beta_2 Hierarchy\ + \beta_3 Cog.Diversity\ x\ Hierarchy\ +\ \beta_4 Controls +\ \gamma_3\theta + \mu_3)$

Stated differently, the unobserved variable has a linear effect on hierarchy and cognitive diversity and an exponential effect on exploration. In the Appendix, I show that the Poisson regression estimate for β_3 is consistent.

Crucially, in this model, the unobserved variable both influences the level of exploration and causes correlation between cognitive diversity and hierarchy. However, the unobserved variable does not cause the estimate of β_3 to be inconsistent. The intuition behind this result is that the correlation between cognitive diversity and the unobserved

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[22] To estimate standard error, I use the delta method (Woolridge 2010)

variable's effect on log(exploration) does not depend on the level of hierarchy, so omitted variable bias may influence estimates of $\beta_1, and\ \beta_2$, but not β_3.

6.3 Regression Results

Before showing the results for each of the three Poisson regressions outlined above, I first show the results for similar Poisson regressions that omit the interaction between cognitive diversity and hierarchy. The results of these regressions are shown in Table 6. To facilitate a more natural interpretation, all regressors (besides hierarchy) are normalized to have a standard deviation of 1.

Because the Poisson regression is log-linear, the interpretation of these coefficients is in terms of percentages. For example, the 'hierarchy' coefficient of 0.097 in (1) indicates that hierarchical firms (hierarchy=8) introduce 10% more products than neutral firms (hierarchy=7), though the difference is not statistically significant. Notice that, the coefficient for cognitive diversity is not statistically significant in any of the three regressions.

Table 6: Correlation between Cognitive Diversity and Exploration

	Dependent variable:		
	intros (1)	novelty (2)	suc. intros (3)
cognitive diversity	−0.189	−0.021	-0.077
	(0.178)	(0.106)	(0.254)
hierarchy	0.097	0.045	0.146
	(0.161)	(0.086)	(0.213)
R&D expenditures	-0.174	0.073	0.067
	(0.181)	(0.076)	(0.160)
employees count	0.107	−0.039	0.059
	(0.088)	(0.057)	(0.099)
# products	0.733^{***}		0.679^{***}
	(0.072)		(0.083)
avg. # product attributes		0.302^{***}	
		(0.077)	
NAICS FE	Yes	Yes	Yes
N	81	67	81

Note: All regressions are Poisson. All variables are normalized to have a standard deviation of 1. Fixed effects are at the NAICS 2-digit level. Robust standard errors. Significance levels are as follows: *p<0.1; **p<0.05; ***p<0.01

In Table 7, I show the results for each of the three Poisson regressions including an interaction between cognitive diversity and hierarchy. Recall that a necessary condition for these hypotheses to all be validated is that the interaction between hierarchy and cognitive diversity be negative and statistically significant. To facilitate a more natural interpretation of the results, I normalize cognitive diversity to have mean zero and hierarchy to take a value of zero for neutral firms.

Table 7: Results of Main Regressions

	Dependent variable:		
	intros	novelty	suc. intros
	(1)	(2)	(3)
cognitive diversity	−0.116	0.028	0.021
	(0.086)	(0.051)	(0.123)
hierarchy	0.042	0.072	0.156
	(0.142)	(0.070)	(0.174)
diversity x hierarchy	**−0.318*****	**−0.196*****	**−0.429*****
	(0.079)	**(0.057)**	**(0.108)**
R&D expenditures	-0.016	0.148*	0.269*
	(0.164)	(0.084)	(0.160)
employees count	0.084	−0.065	0.029
	(0.078)	(0.054)	(0.076)
# products	0.772***		0.734***
	(0.064)		(0.070)
avg. # product attributes		0.379***	
		(0.078)	
NAICS FE	Yes	Yes	Yes
N	81	67	81

Note: All regressions are Poisson. Fixed effects are at the NAICS 2-digit level. All regressors are normalized to have standard deviation of one. Robust standard errors. Significance levels are as follows: *p<0.1; **p<0.05; ***p<0.01

The coefficient of the interaction between cognitive diversity and hierarchy is negative and statistically significant for all three regressions, as predicted. Recall, the interpretation of these coefficients is in terms of a percentage. Because neutral firms are normalized to have a 'hierarchy' of zero, the cognitive diversity coefficient represents the marginal effect of a standard deviation increase in cognitive diversity on exploration for neutral firms. The interaction term is added or subtracted to obtain the marginal effect of cognitive diversity on exploration in hierarchical or flat firms respectively. For example, in (1) the cognitive diversity coefficient is -0.116, and the interaction coefficient is -0.318. As a result, a marginal standard deviation increase in cognitive diversity decreases predicted product introduction rate by 12% in neutral firms, increases predicted product introduction rate by 20% in flat organizations ($-0.116 + 0.318$), and decreases predicted product introduction rate by 43% in hierarchical organizations ($-0.116 - 0.318$).

6.4 Testing Hypotheses

Now, to test each Hypothesis, I use the point estimates above to estimate the conditional marginal effect of cognitive diversity on predicted exploration for both hierarchical and flat organizations. I use the delta method to estimate the standard errors. The results are shown in Table 8. Each entry corresponds to the conditional marginal effect of increasing cognitive diversity on the log of the predicted level of exploration. Each row corresponds to the organizational structure for which the conditional marginal effect is calculated. Each column corresponds to a specific measure of exploration.

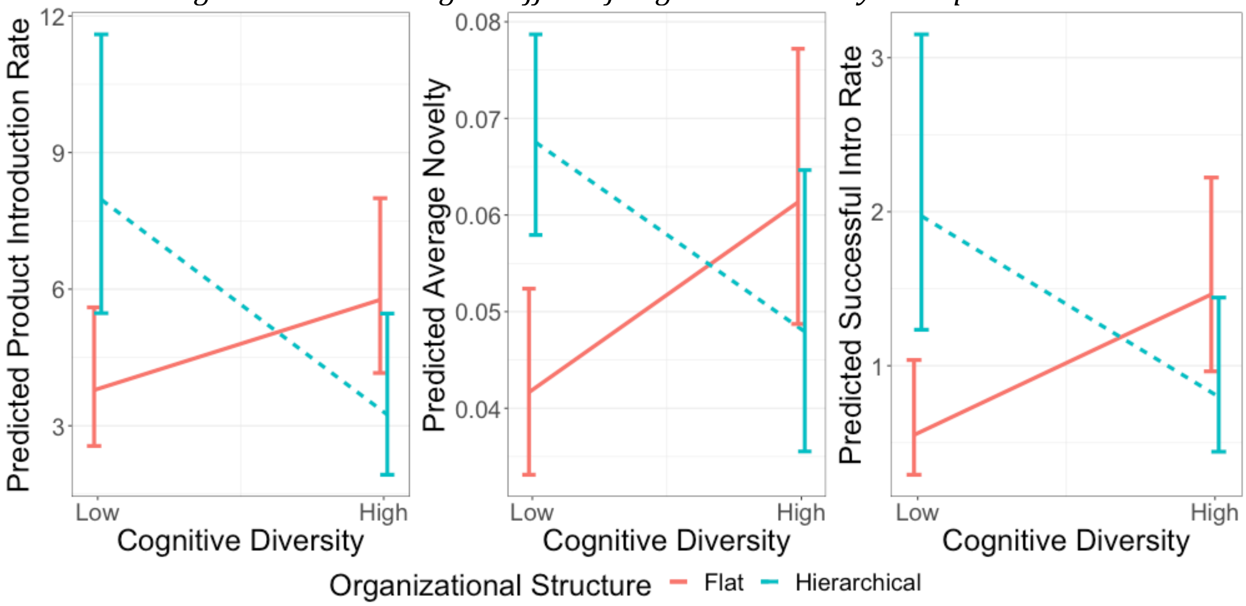
Table 8: Conditional Marginal Effect of Cognitive Diversity on log(Predicted Exploration)

Organizational Structure	*Measure of Exploration:* intros	novelty	suc. intros
flat	$\mathbf{0.202}^{**}$ **(0.080)**	$\mathbf{0.224}^{***}$ **(0.054)**	$\mathbf{0.450}^{***}$ **(0.135)**
hierarchical	$\mathbf{-0.434}^{***}$ **(0.140)**	$\mathbf{-0.169}^{*}$ **(0.093)**	$\mathbf{-0.407}^{**}$ **(0.187)**

Note: Conditional marginal effects calculated using Poisson regressions. The row corresponds to the relevant organizational structure, and the column corresponds to the relevant measure of exploration. Each entry corresponds to the conditional marginal effect of increasing cognitive diversity on log(predicted exploration). Robust standard errors. Significance levels are as follows: $^{*}p<0.1$; $^{**}p<0.05$; $^{***}p<0.01$

These estimates indicate that, in flat organizations, a marginal increase in cognitive diversity is correlated with a predicted marginal *increase* of 20% in product introduction rate (statistically significant at the .05 level), 22% in average product novelty (statistically significant at the .01 level), and 45% in successful product introduction rate (statistically significant at the .01 level). These results are as predicted in Hypotheses 1(a), 1(b), and 1(c). Similarly, these estimates indicate that, in hierarchical organizations, a marginal increase in cognitive diversity is associated with a predicted marginal *decrease* of 43% in product introduction rate (significant at the .01 level), 17% in product novelty (significant at the .1 level) and 41% in successful product introduction rate (significant at the .05 level). These estimates are as predicted in 2(a), 2(b) and 2(c). These results are visualized in Figure 9, which shows how the relationship between cognitive diversity and the predicted value of each measure of exploration depends on organizational structure.

Figure 9: The Contingent Effect of Cognitive Diversity on Exploration



Note: In each subfigure, I use the results of regression (1), (2), or (3) to show how the predicted level of one measure of exploration varies with cognitive diversity. `Low' and 'High' corresponds to cognitive diversity measures one standard deviation below and above the mean respectively. The orange 'flat' and blue 'hierarchy' lines corresponds to hierarchy measures of 6 and 8, respectively. In each sub-figure, the 95% confidence intervals are log-symmetric.

6.4 Robustness

In the Appendix, I consider a variety of robustness checks, which I outline here. First, I consider the empirical results for alternative definitions of the dependent variables (measures of exploration). For example, my primary definition of *product novelty* measures the percentage of new products that introduce a novel bundle of features to the market. The results are qualitatively unchanged if I use alternative measures of novelty that consider the percentage of a product's features that are novel to the market and/or define novelty relative to the firm's existing products rather than relative to the market's existing products. Likewise, to measure *successful product introduction rate*, I define a product as being commercially successful if, two years after being launched, it is more commercially successful than 90% of products launched in the same product category and quarter. In the

Appendix, I show that the results are generally invariant to a variety of different cutoffs of commercial success and different time horizons for measuring that success. Most of the results also remain statistically significant when the data is winsorized (at the 90% or 98% levels) or when including additional controls (more compustat variables and the number of reviews for a company on glassdoor.com).

7 Discussion

In this paper, I show how the effect of cognitive diversity on the organization's proclivity to pursue exploratory ideas depends on organizational structure. To perform this analysis, I present a formal model of how organizations evaluate and select potential courses of action. I argue that organizational structure influences the relationship between cognitive diversity and exploration. More specifically, cognitive diversity leads flat organizations to pursue more exploratory ideas, but it leads hierarchical organizations to pursue less exploratory ideas. After presenting my model and theoretical results, I empirically validate the model's predictions. Using a novel data set that combines organization-wide measures of cognitive diversity with rich measures of exploration, I show that cognitive diversity and exploration are positively correlated in flat organizations and negatively correlated in hierarchical organizations.

Before concluding, I discuss (i) the managerial implications of my results and (ii) the limitations and future direction of my research.

7.1 Managerial Implications

My results suggest that organizations can harness the benefits of greater cognitive diversity to pursue exploratory ideas by becoming less hierarchical. By limiting the number of employees with explicit or implicit veto power, the organization prevents greater cognitive diversity from causing gridlock.

Importantly, the result about organizational structure is less about literal organizational structure than about decision-making processes. More specifically, organizations can enable cognitive diversity to increase exploration by not requiring as much consensus to pursue a new course of action. For example, consider a cognitively diverse hiring committee where each member values different traits in candidates. If the hiring committee requires unanimous approval to hire a candidate, the organization will hire candidates who are omnicompetent at the expense of those who are outliers in a few skills. In this vein, in 2017, Facebook recruiters criticized the company's hiring practices for harming diversification efforts. More specifically, they argued that because the hiring process had too many veto points, the only candidates who could receive the necessary support were well-connected traditional candidates from elite universities (Huet 2017).

These results also have important implications for venture capital, an industry that often values the ability to perceive opportunities that others cannot. Indeed, many venture capitalists believe that a potential investment may be most valuable when only a small minority of individuals recognize its value. Furthermore, venture capitalists believe the ability to select investments to be more valuable than the ability to source investments or add value to investments after they have been made (Gompers et al. 2020). In such a context, creating an environment where people with diverse perspectives can pursue controversial ideas is vital.

7.2 Limitations and Future Direction

The empirical results in this paper serve two functions. First, they establish an important empirical fact about how the correlation between cognitive diversity and exploration depends on organizational structure. To strengthen this finding, I plan to augment this analysis with richer measures of cognitive diversity, as in Cho (2023). Second this analysis empirically validates the main predictions of my model. Second, these results empirically validate the main predictions from my model. Ideally, the empirical tests should ideally test the mechanisms described in the model instead of testing correlations predicted by the model. An experimental approach is best suited for this type of test. Another concern is that my sample is small (81 observations). To consider a larger observational test of my model's predictions, I am in the process of scraping glassdoor.com data for all Fortune 500 companies. I can the measure how exploratory these firms are using publicly available patent data.

This paper studies how organizational structure interacts with an important topic in management scholarship (cognitive diversity) to affect strategy. In ongoing work, a coauthor and I perform a similar analysis that empirically tests a theoretical framework about how organizational structure changes employees' incentives to use quantitative vs. qualitative analysis when advocating for a specific decision. Similar analyses could be conducted on questions such as how well different organizational structures handle communication errors, which has important implications for multinational enterprises.

7.3 Conclusion

Many organizations recognize the significant potential of cognitive diversity in helping organizations better explore. Naturally, trying out new ideas requires having employees that recognize the value of those new ideas. However, examples abound of cognitively diverse companies that passed over innovative ideas because only a small fraction of employees recognized the innovative ideas' promise. In this paper, I suggest how organizational design can play a valuable role in helping organizations harness the benefits of cognitive diversity to pursue more exploratory initiatives. An organization can complement a cognitively diverse workforce with a flat organizational structure and by reducing the need for organizational consensus in decision making.

References

Amabile TM, Conti R, Coon H, Lazenby J, Herron M (1996) Assessing the work environment for creativity. Academy of management journal 39(5):1154–1184.

Amason AC (1996) Distinguishing the effects of functional and dysfunctional conflict on strategic decision making: Resolving a paradox for top management teams. Academy of management journal 39(1):123–148.

Andriopoulos C, Lewis MW (2009) Exploitation-exploration tensions and organizational ambidexterity: Managing paradoxes of innovation. Organization science 20(4):696–717.

Bantel KA, Jackson SE (1989) Top management and innovations in banking: Does the composition of the top team make a difference? Strategic management journal 10(S1):107–124.

Bass FM (1969) A new product growth for model consumer durables. Management science 15(5):215–227.

Blei DM, Ng AY, Jordan MI (2003) Latent dirichlet allocation. Journal of machine Learning research 3(Jan):993–1022.

Boeker W (1997) Strategic change: The influence of managerial characteristics and organizational growth. Academy of management journal 40(1):152–170.

Boone C, Hendriks W (2009) Top management team diversity and firm performance: Moderators of functional-background and locus-of-control diversity. Management science 55(2):165–180.

Burt RS (2004) Structural holes and good ideas. American journal of sociology 110(2):349–399.

Burton RM, Obel B (2004) Strategic organizational diagnosis and design: The dynamics of fit, volume 4 (Springer Science & Business Media).

Cameron, A. C., & Trivedi, P. K. (1990). Regression-based tests for overdispersion in the Poisson model. *Journal of econometrics*, *46*(3), 347-364.

Chi NW, Huang YM, Lin SC (2009) A double-edged sword? exploring the curvilinear relationship between organizational tenure diversity and team innovation: The moderating role of teamoriented hr practices. Group & Organization Management 34(6):698–726.

Cho S (2023) The Effects of the Diversity of Emotional and Cognitive Culture on Strategic Choices in Entrepreneurial Ventures. Manuscript.

Choi B, Kumar MS, Zambuto F (2016) Capital structure and innovation trajectory: The role of debt in balancing exploration and exploitation. Organization Science 27(5):1183–1201.

Christensen M, Knudsen T (2010) Design of decision-making organizations. Management Science 56(1):71–89.

Corritore M, Goldberg A, Srivastava SB (2020) Duality in diversity: How intrapersonal and interpersonal cultural heterogeneity relate to firm performance. Administrative Science Quarterly 65(2):359–394.

Csaszar FA (2013) An efficient frontier in organization design: Organizational structure as a determinant of exploration and exploitation. Organization Science 24(4):1083–1101.

Csaszar FA, Eggers J (2013) Organizational decision making: An information aggregation view. Management Science 59(10):2257–2277.

Lee, S., & Csaszar, F. A. (2020). Cognitive and structural antecedents of innovation: A large-sample study. *Strategy Science*, *5*(2), 71-97.

Cyert RM, March JG (1963) A behavioral theory of the firm, volume 2 (Englewood Cliffs, NJ).

De Dreu, C. K., Nijstad, B. A., & Van Knippenberg, D. (2008). Motivated information processing in group judgment and decision making. *Personality and social psychology review*, *12*(1), 22-49.

De Wit, F. R., Greer, L. L., & Jehn, K. A. (2012). The paradox of intragroup conflict: a meta-analysis. *Journal of applied psychology*, *97*(2), 360.

Denis JL, Lamothe L, Langley A (2001) The dynamics of collective leadership and strategic change in pluralistic organizations. Academy of Management journal 44(4):809–837.

Ethiraj SK, Levinthal D (2009) Hoping for a to z while rewarding only a: Complex organizations and multiple goals. Organization Science 20(1):4–21.

Feddersen, T., & Pesendorfer, W. (1998). Convicting the innocent: The inferiority of unanimous jury verdicts under strategic voting. *American Political science review*, *92*(1), 23-35.

Ganz SC (2018) Ignorant decision making and educated inertia: Some political pathologies of organizational learning. Organization Science 29(1):39–57.

Garicano L (2000) Hierarchies and the organization of knowledge in production. Journal of political economy 108(5):874–904.

Gavetti, G., Greve, H. R., Levinthal, D. A., & Ocasio, W. (2012). The behavioral theory of the firm: Assessment and prospects. *Academy of Management Annals*, *6*(1), 1-40.

Goldberg A, Hannan MT, Kov´acs B (2016) What does it mean to span cultural boundaries? variety and atypicality in cultural consumption. American Sociological Review 81(2):215–241.

Gompers, P. A., Gornall, W., Kaplan, S. N., & Strebulaev, I. A. (2020). How do venture capitalists make decisions? *Journal of Financial Economics*, *135*(1), 169-190.

Greve HR (2007) Exploration and exploitation in product innovation. Industrial and corporate change 16(5):945–975.

Guillaume YR, Dawson JF, Otaye-Ebede L, Woods SA, West MA (2017) Harnessing demographic differences in organizations: What moderates the effects of workplace diversity? Journal of Organizational Behavior 38(2):276–303.

Hambrick DC, Mason PA (1984) Upper echelons: The organization as a reflection of its top managers. Academy of management review 9(2):193–206.

Harris SG (1994) Organizational culture and individual sensemaking: A schema-based perspective. Organization science 5(3):309–321.

Harvey S, Kou CY (2013) Collective engagement in creative tasks: The role of evaluation in the creative process in groups. Administrative science quarterly 58(3):346–386.

He ZL, Wong PK (2004) Exploration vs. exploitation: An empirical test of the ambidexterity hypothesis. Organization science 15(4):481–494.

Helfat CE, Peteraf MA (2015) Managerial cognitive capabilities and the microfoundations of dynamic capabilities. Strategic management journal 36(6):831–850.

Henderson, R. M., & Clark, K. B. (1990). Architectural innovation: The reconfiguration of existing product technologies and the failure of established firms. *Administrative science quarterly*, 9-30.

Homan AC, Van Knippenberg D, Van Kleef GA, De Dreu CK (2007) Bridging faultlines by valuing diversity: diversity beliefs, information elaboration, and performance in diverse work groups. Journal of applied psychology 92(5):1189.

House, Chuck. (2013). Permission Denied: Odyssey of an Intrapreneur.

Huet, E. (2017). *Facebook's Hiring Process Hinders Its Effort to Create a Diverse Workforce*. Bloomberg.com. https://www.bloomberg.com/news/articles/2017-01-09/facebook-s-hiring-process-hinders-its-effort-to-create-a-diverse-workforce?in_source=embedded-checkout-banner

Jansen JJ, Van Den Bosch FA, Volberda HW (2006) Exploratory innovation, exploitative innovation, and performance: Effects of organizational antecedents and environmental moderators. Management science 52(11):1661–1674.

Jones, J. (2023, April 5). *Sonny Vaccaro's belief in Michael Jordan, changing Nike, shown in New film "air."* The Athletic. https://theathletic.com/4378839/2023/04/05/air-movie-sonny-vaccaro/

Joseph J, Gaba V (2020) Organizational structure, information processing, and decision-making: A retrospective and road map for research. Academy of Management Annals 14(1):267–302.

Kaplan, S. (2008). Framing contests: Strategy making under uncertainty. *Organization science*, *19*(5), 729-752.

Kearney E, Gebert D (2009) Managing diversity and enhancing team outcomes: the promise of transformational leadership. Journal of applied psychology 94(1):77.

Keum DD, See KE (2017) The influence of hierarchy on idea generation and selection in the innovation process. Organization Science 28(4):653–669.

Knight D, Pearce CL, Smith KG, Olian JD, Sims HP, Smith KA, Flood P (1999) Top management team diversity, group process, and strategic consensus. Strategic management journal 20(5):445–465.

Knudsen T, Levinthal DA (2007) Two faces of search: Alternative generation and alternative evaluation. Organization Science 18(1):39–54.

Lahiri, A., Pahnke, E. C., Howard, M. D., & Boeker, W. (2019). Collaboration and informal hierarchy in innovation teams: Product introductions in entrepreneurial ventures. *Strategic Entrepreneurship Journal*, *13*(3), 326-358.

Lavie D, Stettner U, Tushman ML (2010) Exploration and exploitation within and across organizations. Academy of Management annals 4(1):109–155.

Lee J, Lee J, Lee H (2003) Exploration and exploitation in the presence of network externalities. Management Science 49(4):553–570.

Lee S (2022) The myth of the flat start-up: Reconsidering the organizational structure of start-ups. Strategic Management Journal 43(1):58–92.

Lee S, Csaszar FA (2020) Cognitive and structural antecedents of innovation: A large-sample study. Strategy Science 5(2):71–97.

Levinthal DA (2021) From arms to trees: opportunity costs and path dependence and the exploration-exploitation tradeoff. Strategy Science 6(4):331–337.

Levinthal DA, March JG (1993) The myopia of learning. Strategic management journal 14(S2):95– 112.

Luo N, Zhou Y, Shon J (2016) Employee satisfaction and corporate performance: Mining employee reviews on glassdoor.com.

March JG (1962). The business firm as a political coalition. *The Journal of politics*, *24*(4), 662-678.

March JG (1991). Exploration and exploitation in organizational learning. Organization science 2(1):71–87.

Marchetti A (2019) Firms of a feather merge together: The coordination benefits of compatible cultures. Available at SSRN 3712838 .

Marchetti A, Puranam P (2022) Organizational cultural strength as the negative cross-entropy of mindshare: a measure based on descriptive text. Humanities and Social Sciences Communications 9(1):1–14.

Marchetti A, Puranam P (2023). Are less hierarchical firms organized around stronger cultures? Evidence from big data.

Marschak J, Radner R (1972) Economic Theory of Teams. (Yale University Press).

Martins LL, Schilpzand MC, Kirkman BL, Ivanaj S, Ivanaj V (2013) A contingency view of the effects of cognitive diversity on team performance: The moderating roles of team psychological safety and relationship conflict. Small Group Research 44(2):96–126.

Miller CC, Burke LM, Glick WH (1998) Cognitive diversity among upper-echelon executives: implications for strategic decision processes. Strategic management journal 19(1):39–58.

Miller CC, Chiu S, Wesley II CL, Vera D, Avery DR (2022) Cognitive diversity at the strategic apex: Assessing evidence on the value of different perspectives and ideas among senior leaders. Academy of Management Annals 16(2):806–852.

Olson BJ, Parayitam S, Bao Y (2007) Strategic decision making: The effects of cognitive diversity, conflict, and trust on decision outcomes. Journal of management 33(2):196–222.

Oren SS, Rothkopf MH, Smallwood RD (1980) Evaluating a new market: A forecasting system for nonimpact computer printers. Interfaces 10(6):76–87.

Ouchi WG (1980) Markets, bureaucracies, and clans. Administrative science quarterly 129–141.

Pelled LH, Eisenhardt KM, Xin KR (1999) Exploring the black box: An analysis of work group diversity, conflict and performance. Administrative science quarterly 44(1):1–28.

Piezunka, H., & Schilke, O. (2023). The dual function of organizational structure: aggregating and shaping individuals' votes. *Organization Science*.

Pieterse AN, Hollenbeck JR, van Knippenberg D, Spitzm¨uller M, Dimotakis N, Karam EP, Sleesman DJ (2019) Hierarchical leadership versus self-management in teams: Goal orientation diversity as moderator of their relative effectiveness. The Leadership Quarterly 30(6):101343.

Posen HE, Levinthal DA (2012) Chasing a moving target: Exploitation and exploration in dynamic environments. Management science 58(3):587–601.

Puranam P (2018) The microstructure of organizations (Oxford University Press).

Qian C, Cao Q, Takeuchi R (2013) Top management team functional diversity and organizational innovation in china: The moderating effects of environment. Strategic Management Journal 34(1):110–120.

Reitzig, Markus, and Olav Sorenson. "Biases in the selection stage of bottom-up strategy formulation." *Strategic Management Journal* 34.7 (2013): 782-799.

Rivkin JW, Siggelkow N (2003) Balancing search and stability: Interdependencies among elements of organizational design. Management science 49(3):290–311.

Rothaermel FT (2001) Incumbent's advantage through exploiting complementary assets via interfirm cooperation. Strategic management journal 22(6-7):687–699.

Rothaermel FT, Deeds DL (2004) Exploration and exploitation alliances in biotechnology: A system of new product development. Strategic management journal 25(3):201–221.

Sah R, Stiglitz J (1986) The architecture of economic systems: Hierarchies and polyarchies. Technical Report 4.

Samba C, Van Knippenberg D, Miller CC (2018) The impact of strategic dissent on organizational outcomes: A meta-analytic integration. Strategic Management Journal 39(2):379–402.

Schilling MA, Fang C (2014) When hubs forget, lie, and play favorites: Interpersonal network structure, information distortion, and organizational learning. Strategic Management Journal 35(7):974–994.

Siggelkow N, Levinthal DA (2003) Temporarily divide to conquer: Centralized, decentralized, and reintegrated organizational approaches to exploration and adaptation. Organization Science 14(6):650–669.

Siggelkow N, Rivkin JW (2005) Speed and search: Designing organizations for turbulence and complexity. Organization Science 16(2):101–122.

Simon, H. A. (1976). *Administrative behavior* (3rd ed.). New York: Macmillan.

Smith DK, Alexander RC (1999) Fumbling the future: How Xerox invented, then ignored, the first personal computer (toExcel).

Srivastava SB, Goldberg A, Manian VG, Potts C (2018) Enculturation trajectories: Language, cultural adaptation, and individual outcomes in organizations. Management Science 64(3):1348– 1364.

Stieglitz N, Knudsen T, Becker MC (2016) Adaptation and inertia in dynamic environments. Strategic Management Journal 37(9):1854–1864.

Strassman P (2008) The computers nobody wanted: My years with Xerox (The Information Economics Press).

Sutcliffe KM (1994) What executives notice: Accurate perceptions in top management teams. Academy of management Journal 37(5):1360–1378.

Tripsas, M., & Gavetti, G. (2000). Capabilities, Cognition, and Inertia: Evidence from Digital Imaging. *Strategic Management Journal*, 1147-1161.

Tushman ML, Nadler DA (1978) Information processing as an integrating concept in organizational design. Academy of management review 3(3):613–624.

Tzabbar D, Margolis J (2017) Beyond the startup stage: The founding team's human capital, new venture's stage of life, founder–ceo duality, and breakthrough innovation. Organization Science 28(5):857–872.

Van den Steen E (2010) Culture clash: The costs and benefits of homogeneity. Management Science 56(10):1718–1738.

Van Knippenberg, D., De Dreu, C. K., & Homan, A. C. (2004). Work group diversity and group performance: an integrative model and research agenda. *Journal of applied psychology*, *89*(6), 1008.

Vinokurova N, Kapoor R (2020) Converting inventions into innovations in large firms: How inventors at xerox navigated the innovation process to commercialize their ideas. Strategic Management Journal 41(13):2372–2399.

Walsh, J. P. (1995). Managerial and organizational cognition: Notes from a trip down memory lane. *Organization science*, *6*(3), 280-321.

Wilde D (2023). Driving Intra-firm Cognitive Variation and Strategy within the Automotive Industry. Manuscript.

Wooldridge, J. M. (2010). *Econometric analysis of cross section and panel data*. MIT press.

Zuzul TW (2019) "matter battles": Cognitive representations, boundary objects, and the failure of collaboration in two smart cities. Academy of Management Journal 62(3):739–764.

Appendix

Theoretical Results

I prove the result for a more generalized version of the main model. Let f $:\mathbb{R}^n \to \mathbb{R}$ be a symmetric function that is increasing along each dimension. The total quality of project j is given by: $q_j = f(q_{j,1}, q_{j,2}, \dots, q_{j,n})$. Agent i's signal of project j's quality is given by $\tilde{q}_{i,j} = f(x_{i,j,1}, x_{i,j,2}, \dots, x_{i,j,n}) + \epsilon_{i,j}$, where $x_{i,j,m} = q_{j,m}$ if $m \in C_i$, and $x_{i,j,m} = E[q_{j,m}]$ otherwise. Agent i approves a project iff $\tilde{q}_{i,j} > \bar{q}$.

Notice that this more general model is equivalent to the main model in the main paper when f is the sum of its elements and some term to correct for the mean of each dimension of quality. The more general version accounts for the fact that quality might not be additive.

Let C_1 be the first agent's fixed cognitive framework. Let $C_{2,A}$ and $C_{2,B}$ be two candidate cognitive frameworks for the second agent such that $|C_1/C_{2,A}| + 1 = |C_1/C_{2,B}|$, and $|C_{2,A}/C_{2,B}|$ =1. Switching from cognitive framework $C_{2,A}$ to cognitive framework $C_{2,B}$ is a marginal increase in cognitive diversity. Let $\tilde{q}_{2,j,A} = \tilde{q}_{i,j}$ under cognitive framework $C_{2,A}$, and let $\tilde{q}_{2,j,B} = \tilde{q}_{i,j}$ under cognitive framework $C_{2,B}$

Lemma 1. *The probability that agent 2 approves a project conditional on agent 1 approving that project decreases in cognitive diversity. Mathematically the statement is as follows:*

$\mathbb{P}(\tilde{q}_{2,j,A} > \bar{q} | \tilde{q}_{1,j} > \bar{q}) > \mathbb{P}(\tilde{q}_{2,j,B} > \bar{q} | \tilde{q}_{1,j} > \bar{q})$

Let $x \in C_{2,A}/C_{2,B}$ and $y \in C_{2,B}/C_{2,A}$. Notice that $x \in C_1$ and $y \notin C_1$. For an arbitrary $q^* \in \mathbb{R}$, by Bayes rule

$$\mathbb{P}(q_{j,x} > q^* | \tilde{q}_{1,j} > \bar{q}) = \frac{\mathbb{P}(\tilde{q}_{1,j} > \bar{q} | q_{j,x} > q^*)}{\mathbb{P}(\tilde{q}_{1,j} > \bar{q})} \mathbb{P}(q_{j,x} > q^*)$$

Because $\tilde{q}_{1,j}$ is increasing in $q_{j,x}$, we know that $\frac{\mathbb{P}(\tilde{q}_{1,j} > \bar{q} | q_{j,x} > q^*)}{\mathbb{P}(\tilde{q}_{1,j} > \bar{q})} > 1$. Because of the independence of the distributions of different dimensions of quality, we have:

$$\mathbb{P}(q_{j,x} > q^* | \tilde{q}_{1,j} > \bar{q}) > \mathbb{P}(q_{j,x} > q^*) = \mathbb{P}(q_{j,y} > q^* | \tilde{q}_{1,j} > \bar{q})$$

Because $\tilde{q}_{2,j,A} - \tilde{q}_{2,j,B} = q_{j,x} - q_{j,y}$, we have that $\tilde{q}_{2,j,A} | \tilde{q}_{1,j} > \bar{q}$ strictly first order stochastic dominates $\tilde{q}_{2,j,B} | \tilde{q}_{1,j} > \bar{q}$ As a result, we get

$$\mathbb{P}(\tilde{q}_{2,j,A} > \bar{q} | \tilde{q}_{1,j} > \bar{q}) > \mathbb{P}(\tilde{q}_{2,j,B} > \bar{q} | \tilde{q}_{1,j} > \bar{q})$$

QED.

Theorem 1. *In a flat organization, the expected probability that a random project is accepted increases in cognitive diversity. In a hierarchical organization, the expected probability that a random project is accepted decreases in cognitive diversity.*

The expected probability that a random project is accepted by an agent is independent of the agent's cognitive framework. Because the probability that agent 2 accepts an idea conditional on agent 1 accepting the idea decreases in cognitive diversity, the following two statements are a simple application of set theory:

- The likelihood that both agents accept a project decreases in cognitive diversity.
- The likelihood that at least one agent accepts a project increases in cognitive diversity.

QED.

Extension

Here, I sketch a proof that the main results also apply in the extension. Suppose agent i's utility is total project quality, if the project is accepted, and $\bar{q}$ otherwise. Agent i incorrectly believes that $q_{i,j} = f(x_{i,j,1}, x_{i,j,2}, \dots, x_{i,j,n})$, where $x_{i,j,m} = q_{j,m}$ if $m \in C_i$, and $x_{i,j,m} = E[q_{j,m}]$ otherwise. Stated differently, each agent believes that only the dimensions of quality that she can understand actually affect total quality.

Now suppose that agents set evaluation criteria to maximize expected utility given an organizational structure, and the other agent's cognitive framework. More specifically, under hierarchy, there is an evaluation criterion $\bar{q}_h$, such that each agent's utility-maximizing strategy is to approve a project if and only if $\tilde{q}_{i,j} \geq \bar{q}_h$. In theory, the agents could choose different criteria, but that is an off-path strategy. Notice that the following must be true for the equilibrium level of $\bar{q}_h$:

$$E[f(x_{1,j,1}, x_{1,j,2}, \dots, x_{1,j,n}) | \tilde{q}_{1,j} = \bar{q}_h, \tilde{q}_{2,j} \geq \bar{q}_h] = \bar{q}$$

Now I again adopt the notation of $C_{2,A}$, and $C_{2,B}$. Let $\bar{q}_{h,A}$ be $\bar{q}_h$ when the cognitive frameworks are C_1 and $C_{2,A}$. Let $\bar{q}_{h,B}$ be $\bar{q}_h$ when the cognitive frameworks are C_1 and $C_{2,B}$.

Lemma 9. *Under hierarchy, the evaluation criteria increase with cognitive diversity ($\bar{q}_{h,B} > \bar{q}_{h,A}$)*

Define

$$g_A(q) = E[f(x_{1,j,1}, x_{1,j,2}, \dots, x_{1,j,n}) | \tilde{q}_{1,j} = q, \tilde{q}_{2,j,A} \geq q]$$

and

$$g_B(q) = E[f(x_{1,j,1}, x_{1,j,2}, \dots, x_{1,j,n})|\tilde{q}_{1,j} = q, \tilde{q}_{2,j,B} \geq q]$$

Intuitively, $g_A(q)$ is the expected value of the marginal acceptance to agent 1 with evaluation criteria q if the second agent's cognitive framework is $C_{2,A}$, and $g_B(q)$ is the expected value of the marginal acceptance to agent 1 with evaluation criteria q if the second agent's cognitive framework is $C_{2,B}$. Notice that g is increasing in q.

Applying logic from the previous proof, we know that for all m, q, the posterior distribution of $x_{1,j,m}|\tilde{q}_{2,j,A} > q$ first-order stochastic dominates the posterior distribution of $x_{1,j,m}|\tilde{q}_{2,j,B} > q$. As a result, it must be the case that $g_A(q) > g_B(q)$. Thus we have that $g_B(\bar{q}_{h,B}) = \bar{q} = g_a(\bar{q}_{h,A}) > g_B(\bar{q}_{h,A})$. Because, g is increasing, we have that $\bar{q}_{h,B} > \bar{q}_{h,A}$.

QED

Without loss of generality, under a flat organization, the evaluation criterion decreases in cognitive diversity.

Theorem 2. *Assuming Bayesian agents, in a flat organization, the expected probability that a random project is accepted increases in cognitive diversity. In a hierarchical organization, the expected probability that a random project is accepted decreases in cognitive diversity.*

Using the results above,

$$\mathbb{P}(\tilde{q}_{2,j,A} > \bar{q}_{h,A} \bigcup \tilde{q}_{1,j} > \bar{q}_{h,A}) > \mathbb{P}(\tilde{q}_{2,j,B} > \bar{q}_{h,A} \bigcup \tilde{q}_{1,j} > \bar{q}_{h,A}) >$$
$$\mathbb{P}(\tilde{q}_{2,j,B} > \bar{q}_{h,B} \bigcup \tilde{q}_{1,j} > \bar{q}_{h,B})$$

Meaning that, in a hierarchical organization, the expected probability that a random project is accepted decreases in cognitive diversity. Without loss of generality, in a flat organization, the expected probability that a random project is accepted increases in cognitive diversity.

QED.

More generally, changing cognitive diversity influences the likelihood that a random project will be accepted through two mechanisms. First, altering cognitive diversity changes the likelihood a project will be accepted for fixed evaluation criteria. Second, altering cognitive diversity changes the likelihood a project will be accepted by altering the evaluation criteria. The results of the main model gives us that, only considering the first force, greater cognitive diversity increases exploration in flat organizations and decreases exploration in hierarchical organizations. The results above give us that, only considering the second force, the same results hold. Therefore, the results from Theorem 1 hold with Bayesian agents.

Omitted Variable Assumption

Here, I include the sketch of a proof of the statement made in the paper about omitted variables. Suppose that θ is an omitted variable such that:

(1) $E[Hierarchy|\theta]) = \gamma_1\theta + \mu_1$

(2) $E[\text{Cognitive Diversity}|\theta]) = \gamma_2\theta + \mu_2$

(3) $\text{Exploration} \sim Poisson\ (\beta_0 + \beta_1 Cog.Diversity\ +\ \beta_2 Hierarchy\ +\ \beta_3 Cog.Diversity\ x\ Hierarchy\ +\ \beta_4 Controls +\ \gamma_3\theta + \mu_3) + \epsilon$

Assume that (γ_3, μ_3) is in the span of (γ_2, μ_2). There must then exist a δ_1, δ_2 such that

$$\text{Exploration} \sim Poisson(\beta_0 + [\beta_1 + \delta_1]Cog.Diversity + [\beta_2 + \delta_2]Hierarchy + \beta_3 Cog.Diversity\ x\ Hierarchy\ +\ \beta_4 Controls)$$

Furthermore, adjusting the estimate of β_3 violates this formula because of the θ^2 $term$. The Poisson regression estimate of β_3 is thus consistent.

Empirical Robustness Checks

First, I consider alternative measures of each of the outcome variables. I display the results in Table A1. I define a product as being successful if it sells more than 90% of products introduced in the same product category/quarter in the final quarter of its second year. There is potential concern about both the timing of when success is measured, and of the cutoff for success. In Table A3 I replicate the test of Hypothesis 3, considering alternative definitions of a successful product. Alt S1 corresponds to measuring sales in the final year of its two-year post-launch period. Alt S2 corresponds to measuring sales in the entire two-year post-launch period. Alt S3 corresponds to a product being successful if it sells more than 95% of products introduced in the same product category/quarter in the final quarter of its two-year post-launch period. Alt S4 corresponds to success being defined as more sales than the median product in the same product category/quarter in the final quarter of its two-year post-launch period. Notice that 7/8 of the results are statistically significant with the other result (hierarchy for Alt S3) having a p-value of .24.

Table A1: Conditional Marginal Effect of Cognitive Diversity on Alternative Measures of Successful Product Intrductions

Org Structure	Measure of Exploration: Alt S1	Alt S2	Alt S3	Alt S4
flat	$\mathbf{0.555}^{***}$ **(0.132)**	$\mathbf{0.519}^{***}$ **(0.132)**	$\mathbf{0.465}^{***}$ **(0.169)**	$\mathbf{0.265}^{***}$ **(0.088)**
hierarchical	$\mathbf{-0.406}^{**}$ **(0.193)**	$\mathbf{-0.424}^{**}$ **(0.184)**	−0.266 (0.229)	$\mathbf{-0.440}^{***}$ **(0.147)**

In the paper, I define product novelty to be the average number of features a product introduces to the market. In Alt N1, I define product novelty to be the percentage of listed products features that new products introduce to the market. In Alt N2, I define product novelty to be the percentage of introduced products that contain a new bundle of feature *for the firm*. In Alt N3, I define product novelty to be the percentage of listed products features that new products introduce to the *firm*. Five out of six results are as predicted in the paper.

Table A2: Conditional Marginal Effect of Cognitive Diversity on Alternative Measures of Exploration

Org Structure	Measure of Exploration: Alt N1	Alt N2	Alt N3
flat	$\mathbf{0.240}^{***}$ **(0.074)**	$\mathbf{0.107}^{***}$ **(0.041)**	0.029 (0.054)
hierarchical	$\mathbf{-0.210}^{**}$ **(0.095)**	$\mathbf{-0.162}^{**}$ **(0.062)**	$\mathbf{-0.217}^{***}$ **(0.040)**

Next, I consider the results when the outcome variables are Winsorized at the 10% level in Table A3. Five out of six results are as in the body of the paper.

Table A3: Conditional Marginal Effect of Cognitive Diversity on Exploration (Winsorized)

Organizational Structure	*Measure of Exploration:* intros	novelty	suc. intros
flat	0.068 (0.088)	$\mathbf{0.210}^{***}$ **(0.052)**	$\mathbf{0.253}^{**}$ **(0.140)**
hierarchical	$\mathbf{-0.390}^{***}$ **(0.130)**	$\mathbf{-0.168}^{*}$ **(0.097)**	$\mathbf{-0.344}^{***}$ **(0.140)**

Note: Conditional marginal effects calculated using Poisson regressions. The row corresponds to the relevant organizational structure, and the column corresponds to the relevant measure of exploration. Each entry corresponds to the conditional marginal effect of increasing cognitive diversity on log(predicted exploration). Winsoration at the 10% level. Robust standard errors. Significance levels are as follows: $^{*}p<0.1$; $^{**}p<0.05$; $^{***}p<0.01$

In Table A4, I consider the results adding additional controls: average total assets, average common equity, and the number of total reviews. Five of the six results are as in the paper.

Table A4: Conditional Marginal Effect of Cognitive Diversity on Exploration (Additional Controls)

Organizational Structure	*Measure of Exploration:* intros	novelty	suc. intros
flat	$\mathbf{0.235}^{**}$ **(0.092)**	$\mathbf{0.321}^{***}$ **(0.061)**	$\mathbf{0.516}^{***}$ **(0.146)**
hierarchical	$\mathbf{-0.385}^{*}$ **(0.200)**	-0.097 (0.141)	$\mathbf{-0.406}^{*}$ **(0.241)**

Note: Conditional marginal effects calculated using Poisson regressions that also include regressors of average total assets, average common equity, and the number of glassdoor reviews.. The row corresponds to the relevant organizational structure, and the column corresponds to the relevant measure of exploration. Each entry corresponds to the conditional marginal effect of increasing cognitive diversity on log(predicted exploration). Robust standard errors. Significance levels are as follows: $^{*}p<0.1$; $^{**}p<0.05$; $^{***}p<0.01$