Speed and Search: Designing Organizations for Turbulence and Complexity

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We use an innovative technique to examine an enduring but recently neglected question: How do environmental turbulence and complexity affect the appropriate formal design of organizations? We construct an agent-based simulation in which multidepartment firms with different designs face environments whose turbulence and complexity we control. The model's results produce two sets of testable hypotheses. One set pinpoints formal designs that cope well with three different environments: turbulent settings, in which firms must improve their performance speedily; complex environments, in which firms must search broadly; and settings with both turbulence and complexity, in which firms must balance speed and search. The results shed new light on longstanding notions such as equifinality. The other set of hypotheses argues that the impact of individual design elements on speed and search often depends delicately on specific powers granted to department heads, creating effects that run contrary to conventional wisdom and intuition. Ample processing power at the bottom of a firm, for instance, can slow down the improvement and narrow the search of the firm as a whole. Differences arise between our results and conventional wisdom when conventional thinking fails to account for the powers of department heads—powers to withhold information about departmental options, to control decision-making agendas, to veto firmwide alternatives, and to take unilateral action. Our results suggest how future empirical studies of organizational design might be fruitfully coupled with rigorous agent-based modeling efforts.

Key words: organizational design; turbulence; complexity; interactions; simulation model

The past two decades have witnessed a sea change among studies of organizational design, with a wave of interest in new organizational forms sweeping aside an earlier consensus (Daft and Lewin 1993, Fenton and Pettigrew 2000). That prior consensus focused largely on formal organizational design: the allocation of tasks and decision rights, the provision of incentives, and the structuring of communication within hierarchies. In the early literature on formal design, Chandler's (1962) work on the multidivisional form was followed by a recognition that appropriate design depends on the nature of an organization's technology (Woodward 1965), its task interdependence (Thompson 1967), and its information processing requirements (Galbraith 1973), as well as on the character of change in its environment (Burns and Stalker 1961, Lawrence and Lorsch 1967). Individual elements of formal design rely on one another so strongly, it was argued, that sets of elements would arise naturally in a handful of complete configurations (Mintzberg 1979, Miller and Friesen 1984).

Shifting attention from this long line of work, careful observers of organizations in the late 1980s and 1990s began to report the emergence of new ways of organizing—organizational forms in which networks replaced hierarchies, social relations pushed aside formalized coordination, and firms were arrayed around

processes or capabilities rather than functions, products, or regions (e.g., Sabel et al. 1987, Ghoshal and Bartlett 1990, Nohria and Eccles 1992, Denison et al. 1996). Researchers shifted their focus to these new organizational forms, and work on formal organizational design began to wane despite progress in some areas (Donaldson 2001).

Authors have cited many reasons for the rise of new organizational forms, but two lines of explanation are especially prominent. First, rapid technological change, deregulation, and globalization have intensified competition and increased the turbulence that managers face, forcing them to adopt new, more responsive organizational forms (D'Aveni 1994, Hamel and Prahalad 1994, Brown and Eisenhardt 1998). Second, the complexity or interdependence of tasks within organizations has shifted in a couple of ways that require changes in form. On one hand, the rise of global organizations of unprecedented intricacy has created a need for new means of coordination (Bartlett and Goshal 1989). On the other, information technology has standardized some interfaces and has enabled managers to conduct more transactions across organizational boundaries rather than within them, leading, for instance, to more modular organizational forms (Drucker 1988, Sanchez and Mahoney 1996, Hitt 1999, Langlois 2002).

While recognizing the profound effects of turbulence and complexity, we argue that formal organizational design still deserves scholarly attention, even among students of new organizational forms. Whether or not an organization is labeled virtual (Davidow and Malone 1992, Handy 1995), learning (Senge 1990), modular (Sanchez and Mahoney 1996), cellular (Miles et al. 1997), network (Perrone 1997), or spaghetti (Gould 1999), it continues to face questions of formal design. Its managers must still allocate tasks and decision rights, provide incentives, and structure communications. Reflecting this in an extensive review of new organizational forms, Fenton and Pettigrew (2000, p. 6) note that "closer inspection of the literature reveals that many of the new forms are not entirely new but reminiscent of earlier typologies, such as Burns and Stalker's (1961) organic and mechanistic forms and Galbraith's (1973) preoccupation with lateral relations." Academically grounded books on organizational design for students and practicing managers also continue to emphasize formal mechanisms for coordination alongside discussions of innovative organization (Nadler and Tushman 1997, Burton and Obel 2004).

In this paper, we use agent-based modeling—a technique rarely employed by early students of formal organizational design—to examine the impact of turbulence and complexity on appropriate design. We place simulated firms with different designs into turbulent settings, where the mapping from firm choices to firm performance changes often into and complex settings, where firm choices interact richly in determining performance. Patterns in the performance achieved by the simulated firms allow us to develop two sets of hypotheses: one about the overall designs that fare well in different environments and one showing how the impact of individual design elements depends on other clusters of design decisions.

Building on prior literature, we find it useful to see a design as consisting of two parts: (a) an organizational archetype, and (b) more granular design elements that cut across archetypes. Prior literature has described a large number of organizational archetypes (Greenwood and Hinings 1993) that differ in how they achieve coordination across organizational units or departments. We consider a spectrum of archetypes that vary in how much power they grant to department heads. The spectrum begins with a decentralized archetype that foregoes active coordination and gives department heads full autonomy; it continues with a series of archetypes that progressively remove department heads' powers to screen departmental options, to set agendas when options are discussed, and to veto alternatives they dislike. It concludes with an archetype in which department heads are stripped of all powers and a central authority provides coordination.

Spanning the archetypes are a number of finer-grained organizational design elements. The design elements we model include the amount of information processing that occurs at each level of the firm, the richness of information flows, and the degree to which the incentive system rewards low-level managers for firmwide performance.

We deploy the model to develop hypotheses surrounding two related questions. First, how should managers design their firms for turbulent and complex environments? A first-order answer to this question can be derived from intuition alone: In turbulent settings, firms need designs that allow them to improve performance speedily to attain a decent outcome before conditions change; in complex settings, firms need designs that permit them to search a diverse array of operational configurations before locking in on a set of choices. Our results confirm this intuition, but much more importantly, the model allows us to examine what designs deliver speedy improvement and diverse search. Here we uncover considerable subtlety. In particular, many design elements have effects on speed of improvement or diversity of search that are qualitatively different in different archetypes.

The observed interdependencies between archetypes and design elements raise our second question: Are there any design elements that are appropriate in situations of great turbulence or complexity regardless of the archetype in which they are embedded? Or does everything depend on everything else so delicately that design must always come in complete configurations of design elements? We find a few, but only a few, robust relationships. For instance, rewarding low-level managers for firmwide performance consistently speeds improvement and is therefore generally appropriate in turbulent settings. The effects of most design elements are more contingent, however. Indeed, some run quite contrary to intuition and conventional wisdom. One might expect, for instance, that allowing low-level managers to consider a wider array of departmental options would lead to more diverse search. To the contrary, we find that broad search at a low level of an organization can enable parochial department heads to hide proposals they do not like from senior management, thereby restricting firm-level search. Overall, we discover few instances in which conventional wisdom about the effect of an individual design element is confirmed across the board. Far more frequently, conventional wisdom is valid in some archetypes but not in others. Differences arise between our results and conventional wisdom when conventional thinking fails to account for the powers of departmental managers—powers to screen out options from consideration, control agendas, veto alternatives, and take action on their own.

A Model of Environment and Formal Design

Studies of formal design have traditionally relied much more on careful observation of real firms than

on rigorous modeling. Recent modeling efforts by economists have focused on the generation of closed-form solutions (e.g., Aghion and Tirole 1997, Bolton and Dewatripont 1994, Garicano 2000, Harris and Raviv 2002). To preserve analytical tractability, such models rely on dramatically simplified representations of organizations. The result is a massive gap between spartan models and the rich descriptions of actual organizations in the empirically grounded literature. To narrow this gap, we follow a smaller but long tradition of computational models of organizations (e.g., Cyert and March 1963, Cohen et al. 1972, Burton and Obel 1984) that has recently sparked a burst of agent-based models (e.g., Carley and Svoboda 1996, Levinthal 1997, Anderson et al. 1999, Axelrod and Cohen 1999). This methodology enables us to incorporate more elements in a model of environment and formal design than is possible with a closed-form approach—a crucial feature if one anticipates interdependencies.

An enduring question among computational modelers is how much complexity to add to one's model in pursuit of realism. Burton and Obel (1995) argue that the realism of a model, and its attendant complexity, should be reverse-engineered from the purpose of the model: the model and the experiments conducted with it should be as complex as required to fulfill the model's fundamental purpose . . . and no more complex. The purpose of our modeling effort is to develop hypotheses about the effects of turbulence and complexity on appropriate formal design. We take two steps to ensure parsimony. First, the environment that modeled firms face is represented in a way that captures turbulence and complexity well but suppresses many other aspects of environments (Khandwalla 1977, Burton and Obel 2004). Second, rather than trying to model all of the formal design elements that one can imagine, we work through five prominent archetypes that recur in a number of prior typologies of organizational designs, and we let the archetypes themselves "speak out" about the design elements required to model them well. The model that results from this process should not be seen as a literal representation of environments and organizations, but as the simplest representation that can fulfill our intended purpose. With this approach, we strive to follow a tradition of creating simple yet insightful models (March and Simon 1958, Cohen et al. 1972, Nelson and Winter 1982, Burton and Obel 1984).

We describe the modeling of environments and the modeling of organizations in turn. A qualitative discussion of each aspect is followed by computational details related to that aspect.

The Environment
Among students of organizational design, the pace and nature of external change has taken on a variety of labels, including turbulence (Ansoff 1979), dynamism (Mintzberg 1979), velocity (Eisenhardt 1989), and uncertainty (Galbraith 1973). Under different labels, these authors capture a similar notion: An environment is turbulent, dynamic, etc., if the mapping from firm actions to performance outcomes changes frequently, profoundly, and in ways that are difficult to predict. Eisenhardt and Bourgeois (1988, p. 816), for instance, write of settings, "in which there is rapid and discontinuous change in demand, competitors, technology and/or regulation, such that information is often inaccurate, unavailable, or obsolete." Note that what is relevant from a design perspective is not the source of change (customers, rivals, technology, or regulation), but its impact on the information needed to make good decisions.

While the notion of turbulence has a fairly consistent usage in prior literature, the concept of environmental "complexity" has been endowed with more diverse meanings. Drawing on Simon (1962) and Thompson (1967), we focus on the degree of interdependence among the decisions that a firm faces as a key driver of complexity. The emphasis on interdependencies among a firm's decisions as a source of complexity not only has a long tradition in the literature (Burton and Obel 2004), but also has attracted renewed attention (Levinthal 1997, Rivkin 2000, Pettigrew et al. 2003). A firm making decisions whose performance effects are independent from each other is said to operate in a simple environment, while a firm whose decisions are highly interdependent is said to operate in a complex environment. Although the interdependencies may occur within the firm, we consider this a feature of the environment in the sense that the interdependencies are dictated by the nature of the decisions themselves and, for our purposes, are not chosen by the firm. (This leaves open an avenue for future research.)

In our simulation, we first specify the characteristics of the environment in which firms operate. We then generate a set of environments that embody these characteristics, and large numbers of modeled firms with different organizational designs tackle these decision problems. In each environment, managers of a given firm must make N binary decisions about how to configure the firm's activities. N reflects the fact that a real firm must make numerous decisions. It must choose, for instance, whether to have its own sales force or to sell through third parties, whether to field a broad product line or a narrow one, whether to pursue basic R&D or not, etc. An N-digit string of zeroes and ones summarizes all the decisions a firm makes that affect its performance. We represent this "choice configuration" as $\mathbf{d} = d_1 d_2, \ldots, d_N$ with each d_i either 0 or 1. The efficacy of each decision is affected not only by the choice (0 or 1) made concerning that decision, but also by the choices regarding other decisions. Firms are, thus, conceptualized as systems of interdependent choices (Milgrom and Roberts 1995; Porter 1996; Whittington et al. 1999; Siggelkow 2001, 2002).

In the model, each decision i makes a contribution C_i to overall firm performance. C_i depends not only on d_i, but also on how K other decisions are resolved: $C_i = C_i(d_i; K$ other d_js$)$. K can lie in the range from 0 to $N - 1$. When $K = 0$, the contribution of each decision is independent of all other decisions. When $K = N - 1$, the contribution of each decision depends on how all other decisions are resolved, making it much more difficult to find the optimal combination of choices. We call an environment in which $K = 0$ a *simple* environment and an environment in which K is high a *complex* environment. After the level of K is specified, a pattern of interaction among the decisions is created by assigning to each of the N decisions K randomly selected decisions that have an effect on it. Next, a contribution C_i for each possible combination of d_i and the K other d_js is generated by a draw from a uniform $U[0, 1]$ distribution. The overall payoff associated with a choice configuration **d** is then computed as the average over the N contributions: $P(\mathbf{d}) = \sum_{i=1}^{N} C_i/N$.[1]

This procedure for generating payoff functions—stochastically, but with well-controlled patterns of interaction—is adapted from Kauffman's (1993) *NK* model, a model originally developed in the context of evolutionary biology. Numerous management scholars have used the procedure in recent years to generate payoff functions that can be employed to examine organizational search (e.g., Levinthal 1997, Marengo et al. 2000, Rivkin 2001, Rivkin and Siggelkow 2003, Siggelkow and Levinthal 2003). It is common to interpret such payoff functions in terms of high-dimensional landscapes. Each of the N decisions constitutes a "horizontal" axis in a high-dimensional space, and each decision offers different options. Resulting from each combination of choices is a payoff for the firm, which is plotted on the vertical axis. The goal of organizational search is to find and occupy a high spot on this landscape, i.e., to select a combination of choices that, together, are highly successful. Interactions among decisions, reflected in K, cause the landscape to become rugged and multipeaked, making the search for a high peak profoundly more difficult (Kauffman 1993, Rivkin 2000).

In our simulations, firms in *stable* environments operate on the same landscape for their entire life histories (200 periods). Then a new interaction pattern is created with the same level of K, new contribution values are determined, and the same set of firms is sent out onto the new landscape. This procedure is repeated several hundred times. In *turbulent* environments, the landscape undergoes "correlated" shocks in periodic intervals. In particular, once a landscape is created, every Δ periods each contribution value C_i is replaced by $\tau * C_i + (1 - \tau) * u$, where u is a new draw from a uniform distribution over the unit interval and τ is a parameter between 0 and 1. So long as $\tau > 0$, a positive correlation exists between past and future performance values of

choice configurations, but firms operating in these landscapes may have to deal with significant (low τ) and frequent (low Δ) changes. As in stable environments, after 200 periods a new interaction pattern and a new set of original contribution values C_i are created.[2] In sum, then, K parameterizes the complexity of the environment while Δ and τ meter its turbulence.

Organizations

Into each type of environment—stable or turbulent, simple or complex—we send a set of firms. Each firm in a set searches for a good configuration of choices. All firms in a particular set start with the same, randomly chosen configuration of choices. Each firm consists of two departments, each with a department head who has primary influence over a subset of the firm's decisions. One department head controls half of the decisions (decisions 1–3 if $N = 6$); the other controls the remainder (decisions 4–6 if $N = 6$). (For simplicity, we focus on firms with two equal-sized departments. A natural extension is to consider firms with more departments or departments of unequal size.)

Firms in a set differ, however, in their organizational designs. Most significantly, they may differ in how they coordinate the two department heads. As Mintzberg (1979, p. 2) notes: "The structure of an organization can be defined simply as the sum total of the ways in which it divides its labor into distinct tasks and then achieves coordination among them." The basic way a firm attempts to achieve coordination, we define as its *archetype*. Prior literature has described a large number of archetypes (Greenwood and Hinings 1993). These archetypes are distinguished from one another, as illustrated below, by their answers to the following four nested questions.

• Do department heads have full autonomy over the decisions made in their departments, or must they seek consent from others?

• If they must seek consent, do department heads privately evaluate and prescreen alternatives for their departments before discussing them with others, or do they present alternatives unfiltered?

• If department heads privately evaluate alternatives before discussing them with others, can they set the agenda for that discussion—setting out their parochially preferred alternatives first before turning to options they like less—or are they unable to control the sequence of consideration?

• When discussing options with others and considering firmwide options composed of departmental options, can a department head veto a composite option she dislikes for parochial reasons, or are composite options that benefit the firm as a whole adopted for sure?

In the rest of this section, we consider a spectrum of archetypes that vary in their answers to these questions. That is, they differ in the power granted to department heads. The spectrum ranges from an archetype in

Table 1   Summary of Archetypes

Archetype		Approach to coordination and relevant design elements	Powers of department heads			
			Complete autonomy	Screening of department alternatives	Agenda setting	Veto power
High ↑ Department head power Low ↓	Decentralized	Coordination is not attempted. Each department head implements her parochially preferred alternative. Relevant design elements: ALT and INCENT. COMP and PROP are irrelevant because department heads act unilaterally, without submitting departmental proposals for review or considering composite alternatives with others.	Yes			
	Liaison	Department heads screen alternatives, take their most preferred to a liaison session, set the agenda or order by which department alternatives are used to make composite alternatives, and exercise veto power over composite alternatives. Relevant design elements: ALT, INCENT, COMP, and PROP.	No	Yes	Yes	Yes
	Lateral communication	Department heads take unscreened alternatives to a brainstorming session in which they are chosen at random, without an agenda, to construct composite alternatives. Department heads exercise veto power over composite alternatives. Relevant design elements: INCENT, COMP, and PROP. ALT is irrelevant because department heads do not evaluate and screen alternatives before sharing them.	No	No	No	Yes
	Hierarchy	Department heads screen alternatives and send their most preferred to a CEO. Proposals are chosen at random, without an agenda, to construct composite alternatives. The CEO chooses the composite alternative that is best for the firm as a whole, without department veto. Relevant design elements: ALT, INCENT, COMP, and PROP.	No	Yes	No	No
	Centralized	Department heads are stripped of all power. The CEO herself selects alternatives with no prescreening or agenda setting by the department heads. She implements the alternative that is best for the firm as a whole, allowing no vetoes by department heads. Relevant design element: COMP. Elements ALT, INCENT, and PROP are irrelevant because department heads play no role in the decision-making process.	No	No	No	No

which department heads have full autonomy, through archetypes in which department heads lose their screening, agenda-setting, and veto powers, to an archetype in which department heads have no power whatsoever. Table 1 summarizes and compares the five archetypes we examine.

Decentralized Archetype. We begin with a decentralized archetype in which each department head has full authority to make decisions in her department, without being required to coordinate or to seek approval from others. This archetype contains aspects of the "professional bureaucracy" as described by Mintzberg (1979, pp. 348–379): The professional bureaucracy hires specialists "and then gives them considerable control over their own work" (p. 349), i.e., it "is a highly decentralized structure" (p. 357).

In the simulation, each department head reconsiders the configuration of choices in her department in each period. Specifically, she compares the status quo choice configuration to some number, ALT, alternative choice configurations. The alternative configurations are chosen at random from the set of local alternatives, i.e., alternatives that differ from the status quo along one decision. For instance, if $N = 6$, ALT $= 2$, and the status quo configuration in the first department is 000, then the first department head might consider alternatives 001 and 100.[3] We say that one manager has more processing power or is "more thorough" if she assesses a larger number of alternatives per period. ALT, the *processing power of department heads*, is the first of four design elements—parameters that cut across multiple archetypes. ALT captures the degree to which a department head privately evaluates departmental

options before acting on them or, in later archetypes, sharing them with colleagues. Note that Alt can be no larger than $N/2$, the total number of local alternatives in each department.

In assessing alternatives, each department head puts primary weight on the performance implications for her department, but she may also consider the effects of her changes beyond her domain. Incent, a design element that ranges from 0 to 1, captures the degree to which the manager cares about the ramifications of her actions on the other department. Incent $= 0$ implies that each manager considers only effects within her department (*parochial incentives*). Incent $= 1$ implies that each manager is equally concerned with effects outside her department and genuinely wants to maximize firmwide payoff (*firmwide incentives*). Continuing with the $N = 6$ example: In assessing any alternative **d**, the first manager will consider

$$P'(\mathbf{d}) = \{[C_1(\mathbf{d}) + C_2(\mathbf{d}) + C_3(\mathbf{d})] \\ + \text{Incent} * [C_4(\mathbf{d}) + C_5(\mathbf{d}) + C_6(\mathbf{d})]\}/6.$$

In evaluating alternatives, each department head assumes that choices in the other department will not change from their prior configuration. Each manager implements in her department the alternative she prefers without active coordination or central approval, and the resulting composite configuration is the starting point for subsequent search.

Liaison Archetype. A decentralized firm runs the risk of misaligned action. The second archetype introduces modest coordination: Before they take action, department heads meet in a coordinative session to discuss their plans. Department heads remain powerful, however. They retain their ability to screen departmental options before sharing them, to set the agenda of the joint session, and to veto alternatives that are not in their parochial interests. This archetype captures the type of firm that uses liaison devices to resolve conflict (Galbraith 1973). It echoes Mintzberg's (1979) "adhocracy," in which "integrating managers and liaison positions are established to coordinate the efforts among and between the functional units and project teams," yet individuals retain final decision power. It also reflects Miles and Snow's (1978, pp. 63–64) "prospectors," in which "control is decentralized" and "conflict must be directly confronted by the affected units and resolved through the use of coordinators or integrators who act as liaisons between independent project groups."

We simulate the liaison archetype as follows. Each department head first evaluates Alt randomly selected, local alternatives for her department in light of the incentive system Incent. She then selects her most preferred Prop departmental proposals, which may or may not include the status quo for her department, and takes

them to a liaison officer. Prop, a third design element after Alt and Incent, captures the *richness of information flow*. Note that Prop $\leq$ Alt $+ 1$; a department head cannot propose more options than she has evaluated, in addition to the status quo. The liaison officer helps the managers work through options in an order that reflects department heads' preferences—that is, department heads control the agenda. Managers start by evaluating the composite alternative consisting of each manager's most preferred proposal, and they continue evaluating composite alternatives that include progressively less preferred proposals. In total, managers discuss Comp composite alternatives.[4] Comp, the fourth and final design element, reflects the *processing power devoted to coordination*. Note that Comp $\leq$ Prop^2, the largest number of ways that Prop proposals from each of two departments can be combined. A department head agrees to a composite alternative only if, in light of her incentives, she assigns to it a payoff at least as high as that of the status quo. Otherwise, she will veto it. Among all composite alternatives acceptable to both managers, the alternative that provides the highest performance for the firm as a whole is implemented. If no evaluated composite alternative is acceptable to both department heads, the firm retains its status quo choices.

Lateral Communication Archetype. A third archetype weakens department heads further, stripping them of their power to screen alternatives and to set agendas but retaining their veto power. In this structure, department heads meet without any preconceived notions and jointly develop good solutions for the firm. The result is a free-flowing "organic" (Burns and Stalker 1961) structure with coordination achieved through lateral communication. The main coordination mechanism in such an archetype is the process of mutual adjustment: "Mutual adjustment achieves the coordination of work by the simple process of informal communication. Under mutual adjustment, control of the work rests in the hands of the doers" (Mintzberg 1979, p. 3). As Mintzberg pointed out, under mutual adjustment, the eventual decisions rest with the individual decision makers. As a result, for a new proposal to be implemented, each manager has to agree to it. Thus, in this archetype, department heads continue to have veto power.

In simulating this archetype, we assume that the two department heads meet in a brainstorming session. Reflecting the free-flowing nature of such a session, each manager brings Prop randomly selected proposals for her own department (in addition to the status quo choices) and managers use these departmental options to construct and weigh Comp randomly selected, composite alternatives for the firm as a whole. Thus managers do not prescreen proposals, nor do they insist on a particular agenda. The rest of the brainstorming session works in the same manner as a liaison session. Managers can veto composite alternatives that are less attractive to a depart-

ment than the status quo. The composite alternative that is acceptable to both department heads and that yields the highest performance for the firm as a whole is implemented. If no composite alternative is acceptable to both, the firm maintains its status quo.

Hierarchical Archetype. An alternative way to weaken the department heads is to remove their veto power but to retain their role in generating alternatives. This is the essence of one of the most commonly discussed structures, the hierarchical archetype. Department managers in a hierarchy send proposals up to a top layer of management, say the CEO, who makes final decisions. See, for instance, Burns and Stalker's (1961) "mechanistic" firms, Miles and Snow's (1978) "defenders," and Bower's (1970) classic study of resource allocation.

In our simulation of the hierarchical archetype, each department head considers ALT alternatives and the status quo in her department and ranks them in light of INCENT. Each manager then sends up to the CEO the PROP proposals she most prefers. A low level of PROP reflects a firm in which managers are expected to, or permitted to, narrow down options a great deal before turning to superiors. A high level of PROP reflects a firm in which senior managers want to review many alternatives themselves. From all possible combinations of proposals (one from each department) including the status quo choices, the CEO selects COMP composite alternatives at random, assesses them in light of the interests of the firm as a whole, compares them to the status quo, and implements the option that yields the best payoff for the firm. In this archetype, COMP reflects the cognitive power or the information processing capacity of the CEO.

Centralized Archetype. In the final archetype we consider, department heads are completely stripped of their influence and all decisions are made by a single, central individual. This organizational archetype reflects Weber's (1922) "monocratic" form or Mintzberg's (1979, p. 308) "simple structure" in which "power over all important decisions tends to be centralized in the hands of the chief executive officer." In our simulation, the CEO selects and evaluates COMP alternatives that differ from the status quo along one decision, with no prescreening, agenda-setting, or veto possibilities by lower-level managers. The CEO assesses the alternatives from the perspective of the firm as a whole, compares them to the status quo, and implements the best option.

Other Archetypes. The five archetypes described above and compared in Table 1 cover the spectrum of department-head power. By answering the four questions about department-head power in other ways, one could construct two more archetypes: a hierarchy in which department heads control the order in which the CEO considers proposals and a lateral communication

structure in which department heads prescreen proposals. We explored these variants in detail and found that they did not shed additional light. See the discussion of robustness below.

Results

We analyze appropriate design for turbulent and complex environments in two steps. First, we examine the effect of each organizational design element on the speed of improvement and the diversity of search *within* each of the five selected organizational archetypes. This allows us to answer the question, "Which design elements, if any, are appropriate in situations of great turbulence or complexity regardless of archetype?" It also enables us to compare the effect of each design element to the effect that conventional wisdom and intuition would suggest. In the second step, we compare performance *across* archetypes in different environmental settings. This analysis allows us to address the question, "Given a particular degree of turbulence and complexity, what is an appropriate organizational design?"

In all analyses, each firm makes six decisions ($N = 6$) and is observed for 200 periods on 1,500 landscapes.[5] Each firm operates in one of four stylized environments: stable and simple, stable and complex, turbulent and simple, or turbulent and complex. We designate $K = 0$ landscapes as simple environments and $K = 5$ landscapes as complex settings. In stable settings, the landscapes remain unperturbed over the 200 periods; in turbulent settings, the landscapes are perturbed every five periods ($\Delta = 5$) with a correlation between landscapes of $\tau = 0.2$. (The overall pattern of results is not very sensitive to the exact choice of these parameters. See the section on robustness.) The performance of firms is measured as a portion of the highest performance attainable on each landscape. For stable environments, we report the final performance achieved by firms at the end of the 200 periods they operate, averaged over the 1,500 landscapes. For turbulent environments, the final performance achieved is less meaningful, so we report the average performance achieved over all 200 periods, again averaged over all landscapes.[6] Each time we report that one type of firm achieves higher performance than another, the difference in mean performance is statistically significant with $p < 0.001$.

To measure the effect of an organizational design feature in a particular archetype, we compare the performance of firms that are equal in all respects but the focal design feature. In addition, we employ two other, telling measures. In turbulent environments, it is important that firms improve their performance quickly before the environment changes. Consequently, as a measure of a firm's speed of improvement, we report the average performance improvement experienced by a firm during its first period of search.[7] Speed of improvement can

differ significantly depending on the interdependence of decisions, so we report our speed measure for both simple and complex environments.

In complex environments, it is important that firms search broadly across the landscape. As a measure of search diversity, we use the notion of "sticking points." Sticking points are choice configurations from which a firm will not move (Rivkin and Siggelkow 2002). That is, at a sticking point, there exists no alternative configuration of the N choices that the actors within the firm would consider and that meets the approval of enough actors to be adopted. Once a firm reaches a sticking point, its search has come to an end (assuming the environment does not change afterward). A firm with many sticking points will end its search quickly, before exploring much of the landscape. A firm with few sticking points will get stuck less quickly and will search more broadly for good choice configurations. As an indicator of a firm's search diversity, then, we report the fraction of all possible choice configurations on stable $K = 5$ landscapes that are *not* sticking points for the firm.[8]

With five archetypes, up to four design features within each archetype, and four stylized environments, the model permits a very large number of analyses and comparisons. Table 2 summarizes a comprehensive set of analyses that examines the effect of every design feature within every archetype. Rather than discuss all possible analyses, we focus on effects that run contrary to conventional wisdom or casual intuition. Conventional wisdom and intuition are discussed in each subsection below and are also summarized in Table 2. The results we emphasize are boldface in Table 2, which serves as a roadmap. The table shows many results that differ from conventional wisdom or intuition. In each instance—we explain below—the difference arises because conventional thinking fails to account for the powers of departmental managers: powers to take action without coordination, screen out departmental options, control agendas, and veto firm-level alternatives.

Effects of Individual Design Elements on Speed and Search

Departmental Processing Power
To understand the effects of departmental processing power (ALT) on speed of improvement and diversity of search, we investigate the six firms displayed in Table 3. For each archetype, we compare a firm in which each department head can evaluate one local alternative per period (ALT = 1) to a firm in which each can evaluate three alternatives (ALT = 3). We chose ALT = 3 because three alternatives encompass all local alternatives that a manager can evaluate given any status quo. To blend out the effects of the other design features, we set the other features to baseline values of INCENT = 0

(parochial incentives), COMP = 1 (one composite alternative is considered per period), and PROP = 1 (one proposal is brought to the liaison session or to the CEO each period).[9]

The Effect of Departmental Processing Power on the Speed of Improvement. Intuition suggests that firms with greater departmental processing power, or more thorough managers, should spot improvements faster than firms with less processing power and should therefore perform better in turbulent settings. In line with this, Bourgeois and Eisenhardt (1988, p. 828) argue that "in high velocity environments, the more comprehensive the search for strategic alternatives, the better the performance of the firm," and Child (1984, p. 219) avers that turbulence calls for "staff support for sophisticated search... activities."

Table 3 reports broad, but *not* universal, support for this conventional wisdom. In simple environments, greater departmental processing power increases the speed of improvement in all organizational archetypes. This can be seen both in the direct speed measure and in the performance of firms in simple, turbulent environments. For instance, for the decentralized archetype, firm D2 with its very thorough manager improves its performance during the first period on a typical $K = 0$ landscape by 0.187, while firm D1, with a less thorough manager, improves its performance by only 0.083. In line with the notion that improvement speed is crucial in turbulent environments, firm D2's performance in the simple, turbulent environment is much better than firm D1's: 0.990 vs. 0.937. Similar comparisons can be made for the liaison firms L1 and L2 and the hierarchical firms H1 and H2. In simple environments, then, results are in line with conventional wisdom.

In complex environments, however, we find counterintuitive results for the decentralized and liaison archetypes: More thorough managers slow down or fail to speed improvement and lead to *lower* performance in the face of turbulence. The reasons for this counterintuitive effect are different in the two archetypes. In the decentralized firm, the absence of any coordinating mechanism at the firm-level creates the possibility that changes made in either department can undermine improvement efforts in the other, slowing down the overall rate of advance. With more thorough department heads, each manager is more likely to spot an opportunity for departmental improvement, which destabilizes conditions for the other manager and raises the odds that her change will fail to yield real improvement. As a result, firm D2 with more thorough managers has slightly lower performance in the complex, turbulent environment than firm D1 with less thorough managers (0.790 vs. 0.794). The conventional wisdom fails to consider that interdependent decisions may be delegated to department heads with the power to act on their own

Table 2   Effect of Design Elements on Speed of Improvement and Diversity of Search Within Different Archetypes

	Speed of improvement						Diversity of firm-level search					
	Conventional wisdom/ intuition	Results					Conventional wisdom/ intuition	Results				
		Decentralized	Liaison	Lateral communication	Hierarchical	Centralized		Decentralized	Liaison	Lateral communication	Hierarchical	Centralized
Departmental processing power (ALT)	+	+/−	+/−		+		0	0	−	−	−	
Firmwide incentives (INCENT)	0/+	0/+	0/+	+	0/+		+	−	+	+	+	
Coordinative processing power (COMP)	+	0/+	0/+	+	+	+	0	**+**	**+**	0	0	0
Richness of information flow (PROP)	−	**0**	**0**	**0**	−		+	**0**	**0**	**0**	+	

Notes. +/− indicates an increase in a simple environment and a decrease in a turbulent environment. 0/+ indicates no effect in a simple environment and an increase in a complex environment. Results that run contrary to conventional wisdom/intuition and that are discussed in detail in the paper are boldface.

Table 3   The Effects of Departmental Processing Power

Archetype	Decentralized		Liaison		Hierarchical	
Firm	D1	D2	L1	L2	H1	H2
ALT	1	3	1	3	1	3
Speed of improvement in a…						
Simple environment	0.083	0.187	0.082	0.185	0.070	0.131
Complex environment	0.059	0.054	0.068	0.069	0.097	0.130
Diversity of firm-level search	0.937	0.937	0.618	0.258	0.796	0.762
Average performance						
Stable and…						
Simple environment	1.000	1.000	1.000	1.000	1.000	1.000
Complex environment	0.885	0.806	0.824	0.724	0.863	0.861
Turbulent and…						
Simple environment	0.937	0.990	0.937	0.990	0.929	0.977
Complex environment	0.794	0.790	0.803	0.768	0.834	0.858

Notes. Common parameters for all firms in this table: INCENT $= 0$, PROP $= 1$, COMP $= 1$. The speed-of-improvement indicator is the performance improvement of each firm in the first period of search, averaged across 10,000 landscapes. The diversity-of-firm-level-search indicator is the fraction of choice configurations that are not sticking points for each firm, an average across 500 landscapes with $K = 5$. For stable environments, the bottom panel reports for each firm the performance in period 200 averaged over 1,500 landscapes; for turbulent environments, it contains the average performance over 200 periods across 1,500 landscapes.

and that, in complex settings, this power may make extra departmental processing detrimental.

In the liaison archetype, thoroughness can lead to stubbornness: Thorough managers will tend to bring the same most preferred proposal to the negotiation table again and again. In this archetype, department heads' preferences set the agenda, or order, by which composite alternatives are evaluated. Thorough department heads consider their most preferred proposals every period and insist on discussing those proposals first, creating a stalemate. In contrast, less thorough managers may fail to evaluate their most preferred alternatives in some periods and may bring different proposals to the table, breaking out of a stalemate. As a result, the high-ALT liaison firm L2 sees no faster improvement than the low-ALT firm L1 in complex settings and performs relatively poorly in the complex, turbulent environment (0.768 vs. 0.803). This counterintuitive result hinges on the power of department heads to set the agenda for the liaison session. Where department heads do not set the higher-level agenda, as in the hierarchical archetype, extra departmental processing has the intuitive effect of speeding improvement.

In sum, while the results support conventional wisdom in simple environments, we find boundary conditions for the conventional wisdom in complex environments.

HYPOTHESIS 1. *In simple environments, more departmental processing power leads to speedier improvement. In complex environments, more departmental processing power can delay improvement if either* (a) *department heads have latitude to make decisions without firm-level coordination, or* (b) *department heads' preferences set the agenda for evaluating composite alternatives.*

The Effect of Departmental Processing Power on Diversity of Search. Intuition suggests that departmental processing power will have little if any effect on the diversity of firm-level search: Processing power increases the number of alternatives that department heads can assess each period, but it has no impact on how varied those alternatives are in the long run. Regardless of how thorough managers are, they will eventually consider the very same range of options, though more thorough managers will consider the entire range sooner. Therefore, departmental processing power should not affect a firm's ability to search broadly and to achieve high performance in (stable) complex environments, which require diverse search.

We find support for this intuition in the decentralized archetype. Decentralized firms D1 and D2 have identical portions of choice configurations that are not sticking points (Table 3) despite a difference in departmental processing power ALT.[10] In contrast, we find exceptions to the casual intuition in the liaison and hierarchical archetypes. In these archetypes, more thorough search at the department level serves to *narrow* search at the firm level. The reason for this effect is similar for both archetypes: The more thorough the department heads are, the more completely they can withhold information, screening out proposals they do not like from the other department head (in the liaison firm) or from the CEO (in the hierarchical firm). For instance, each departmental manager in the hierarchical firm H1 considers one local alternative each period (ALT $= 1$) and must submit one proposal to the CEO (PROP $= 1$). Hence, she has no choice but to reveal whatever option she considers (or send up the status quo). Each manager in H2 considers three alternatives and submits just one, enabling

her to hide parochially unattractive options. Likewise, as discussed above, thorough department heads in the liaison firm can withhold parochially unattractive options by always bringing their most preferred alternative to the negotiating table.

Firms whose department heads can conceal options that are unattractive to them, but that might benefit the firm as a whole, tend to get stuck quickly and explore little of the performance landscape. In this case, the high-ALT firms H2 and L2 get stuck on many more points than the low-ALT firms H1 and L1 (24% vs. 20% for hierarchical firms, and 74% vs. 32% for liaison firms) and, as a result, have lower performance in the stable, complex environment (0.861 vs. 0.863 and 0.724 vs. 0.824). Ironically, then, thorough search at the department level tends to lead to narrow search at the level of the firm as a whole when department heads can screen out alternatives.

HYPOTHESIS 2. *More departmental processing power can lead to a narrowing of search when managers evaluate alternatives privately and are allowed to screen from discussion the alternatives they do not like.*

Firmwide Incentives

To investigate the effect of firmwide incentives on the speed of improvement and the diversity of search in different organizational archetypes, we study the eight firms in Table 4. For each archetype we include the benchmark firm with parochial incentives (D1, L1, B1, H1) and a similar firm with firmwide incentives (D3, L3, B3, H3).

The Effect of Firmwide Incentives on Speed of Improvement. Conventional wisdom holds that incentive alignment is crucial for fast action in organizations. For instance, in her study of decision making in high-velocity environments, Eisenhardt (1989, p. 544) finds

that "conflict resolution is critical to decision speed." Surely firmwide incentives help to resolve conflicts. Thus we expect firms with high INCENT to improve rapidly and to fare well in turbulent environments. This should be especially true in complex environments; in simple environments, with no interactions across departments, there are no conflicts to resolve and firmwide incentives should matter little.

The results in Table 4 show robust support for this conventional wisdom. For all archetypes, firmwide incentives lead to faster improvement in complex environments and to superior performance in a turbulent, complex setting. (Effects are small or nonexistent in simple environments.) The precise means by which INCENT has its effect, however, varies substantially across archetypes. In the decentralized archetype, firmwide incentives lead to speedier improvement by ensuring that autonomous department heads never implement changes they know to be detrimental to the firm as a whole. This reduces the likelihood of the mutually destructive "improvement" efforts that we discussed earlier. In the lateral communication and liaison archetypes, firmwide incentives prevent department heads from vetoing composite alternatives that benefit the firm at the expense of one department. In the hierarchical archetype, high INCENT raises the odds that department heads will submit proposals that the CEO finds acceptable for the firm. All of these effects serve to speed improvement and to boost performance in turbulent, complex environments—in line with intuition.

HYPOTHESIS 3. *Across a wide array of archetypes, firmwide incentives promote speedy improvement in complex environments.*

The Effect of Firmwide Incentives on Diversity of Search. Intuition suggests that incentive alignment should also promote diverse search. Agreement on ends

Table 4   The Effects of Firmwide Incentives

Archetype	Decentralized		Liaison		Lateral communication		Hierarchical	
Firm	D1	D3	L1	L3	B1	B3	H1	H3
INCENT	0	1	0	1	0	1	0	1
Speed of improvement in a...								
Simple environment	0.083	0.083	0.082	0.085	0.042	0.047	0.070	0.070
Complex environment	0.059	0.085	0.068	0.097	0.061	0.087	0.097	0.104
Diversity of firm-level search	0.937	0.855	0.618	0.855	0.751	0.922	0.796	0.856
Average performance								
Stable and...								
Simple environment	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Complex environment	0.885	0.882	0.824	0.885	0.891	0.938	0.863	0.882
Turbulent and...								
Simple environment	0.937	0.937	0.937	0.937	0.880	0.892	0.929	0.929
Complex environment	0.794	0.838	0.803	0.844	0.799	0.830	0.834	0.848

Notes. Common parameters for all firms: ALT = 1, PROP = 1, COMP = 1. See note on Table 3 for further explanatory remarks.

should prevent stand-offs and vetoes that block movement and narrow search. In line with this intuition, Khandwalla (1977, p. 606) argues that "attempts to foster a collaborative organizational climate" are essential in complex environments where diverse search is especially important.

We find support for this intuition for all archetypes in which one party can block the actions of another party, i.e., in the liaison, lateral communication, and hierarchical archetypes. In each of those cases, firms with higher INCENT (L3, B3, and H3) perceive fewer choice configurations as sticky, explore the performance landscape more broadly, and hence fare better in stable, complex environments than do their low-INCENT counterparts (L1, B1, and H1). However, in the decentralized archetype, in which each manager has complete control, firmwide incentives *reduce* the portion of choice configurations that are not sticky (from 93.7% for D1 to 85.5% for D3) and *decrease* the diversity of firm-level search. The requirement that any change improve the lot of the firm as a whole, not simply the performance of a single department, increases the odds that both department heads will fail to find attractive alternatives.[11] Hence high INCENT reduces the movement of the firm on the performance landscape and limits the variety of choice configurations a firm will try out.[12] The conventional wisdom fails to realize that, when department heads have the power to act on their own, parochial incentives may make it easier for managers to employ that power and to explore a broad diversity of options.

HYPOTHESIS 4. *In archetypes in which managers can block each other's actions, firmwide incentives lead to more diverse search. In archetypes in which department heads have the power to act on their own, firmwide incentives can lead to narrower search.*

Coordinative Processing Power
In four of our archetypes—lateral communication, liaison, hierarchical, and centralized—alternatives for the firm as a whole, i.e., composite alternatives, are evaluated. The number of composite alternatives that are processed each period (COMP) reflects the intensity of lateral communication, the intensity of the liaison session, or the processing ability of the CEO and her staff. To examine how coordinative processing power affects the speed of improvement and diversity of search, we consider the eight firms in Table 5. For each archetype, we include a benchmark firm with COMP = 1 and a firm that has three times as much processing power at the top (COMP = 3).[13]

The Effect of Coordinative Processing Power on Speed of Improvement. A longstanding theme in the prior literature is that organizations in turbulent environments require a great deal of processing power at the top. Hence Eisenhardt (1989) finds that successful management teams in high-velocity environments consider more alternatives than do unsuccessful teams. Child (1984, p. 219) calls for a "high level of face-to-face participation in discussion and decision-making" when environmental conditions grow volatile. The success of Burns and Stalker's (1961) organic structures in turbulent environments depends largely on the ability of that structure to process alternatives rapidly, especially through lateral communication. Hence, conventional wisdom suggests that firms with high COMP will display speedy improvement, leading to superior performance in turbulent settings.

Table 5 reports very robust support for this proposition. With a larger number of composite alternatives, the likelihood of finding an alternative acceptable to the CEO or to both managers increases. Moreover, as more composite alternatives are evaluated, the performance of

Table 5   The Effects of Coordinative Processing Power

Archetype	Liaison		Lateral communications		Hierarchical		Centralized	
Firm	L1	L4	B1	B4	H1	H4	C1	C4
PROP	1	2	1	1	1	1		
COMP	1	3	1	3	1	3	1	3
Speed of improvement in a…								
Simple environment	0.082	0.084	0.042	0.083	0.070	0.083	0.041	0.093
Complex environment	0.068	0.121	0.061	0.129	0.097	0.124	0.087	0.159
Diversity of firm-level search	0.618	0.764	0.751	0.751	0.796	0.796	0.858	0.858
Average performance								
Stable and…								
Simple environment	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Complex environment	0.824	0.867	0.891	0.890	0.863	0.865	0.883	0.887
Turbulent and…								
Simple environment	0.937	0.937	0.880	0.937	0.929	0.938	0.887	0.953
Complex environment	0.803	0.843	0.799	0.850	0.834	0.847	0.824	0.877

Notes. Common parameters for all firms: ALT = 1, INCENT = 0. See note on Table 3 for further explanatory remarks.

the best acceptable alternative increases. Reflecting this, the speed of improvement in high-Comp L4, B4, H4, and C4 is significantly higher than in their counterparts L1, B1, H1, and C1. This greater speed translates into performance superiority in turbulent environments.[14]

HYPOTHESIS 5. *Across a wide array of archetypes, ample coordinative processing power promotes speedy improvement.*

The Effect of Coordinative Processing Power on Diversity of Search. Intuition suggests that brute coordinative processing power will do little to broaden a firm's search in the long run. A good composite alternative, if available, will eventually be discussed regardless of how many composite alternatives are evaluated per period. Greater coordinative processing power might lead to earlier adoption of a good proposal, but it does not generate a wider array of options in the long term.

The results in Table 5 confirm this intuition for the lateral communication, hierarchical, and centralized archetypes. Firms with low and high Comp (firms B1 and B4, H1 and H4, C1 and C4) get stuck on the very same choice configurations, display the very same diversity of search in the long run, and achieve comparable performance levels in stable, complex environments, where diversity of search is crucial.

The liaison archetype, however, points out a boundary condition to this intuition. In this archetype, higher Comp leads to more diverse search and correspondingly better performance in stable, complex settings (firms L1 and L4). This result arises because, in this archetype, department heads set the agenda by which composite alternatives are discussed. When managers can influence the agenda of the coordinative session, the length of this session matters. When the number of composite alternatives considered is high, department heads are forced to work far down their lists of preferred proposals

and must consider composite alternatives that otherwise would never see the light of day. Occasionally, this extra exploration yields a mutually agreeable alternative, producing more firm movement and broader search.

HYPOTHESIS 6. *Greater coordinative processing power leads to broader search when department heads set the agenda by which composite alternatives are discussed, but it has no effect on diversity of search in other settings.*

Richness of Information Flow

In three of our modeled archetypes—liaison, lateral communication, and hierarchical—information must flow from the departments to the locus at which composite proposals are evaluated. To examine the effect of information flow on speed of improvement and diversity of search, we study the six firms in Table 6, which differ in terms of the number of proposals that departments advance (PROP).

The Effect of Information Flow on Speed of Improvement. Prior literature tends to point to a negative relationship between richness of information flow and speed. For instance, Frederickson and Mitchell (1984) argue that communication and consideration of a comprehensive set of proposals slows down decision making. Similarly, authors such as Mintzberg (1973) contend that to make decisions quickly, managers must obtain input from few sources, consider few alternatives, and limit analysis. A rich flow of information threatens to overwhelm the limited processing abilities of managers (cf. Eisenhardt 1989).

Results for the hierarchical archetype are in line with conventional wisdom. In a hierarchical archetype, department heads pick out and send up the proposals they consider best. As a result, an increase in the number of proposals sent to the CEO dilutes the average quality

Table 6 The Effects of Richness of Information Flow

Archetype	Liaison		Lateral communications		Hierarchical	
Firm	L5	L6	B1	B5	H5	H6
PROP	1	3	1	3	1	3
Speed of improvement in a …						
Simple environment	0.140	0.140	0.042	0.040	0.106	0.051
Complex environment	0.066	0.066	0.061	0.062	0.119	0.086
Diversity of firm-level search	0.546	0.546	0.751	0.751	0.792	0.936
Average performance						
Stable and …						
Simple environment	1.000	1.000	1.000	1.000	1.000	1.000
Complex environment	0.809	0.809	0.891	0.888	0.864	0.937
Turbulent and …						
Simple environment	0.977	0.977	0.880	0.875	0.965	0.893
Complex environment	0.800	0.800	0.799	0.801	0.853	0.831

Notes. Common parameters for all firms: INCENT = 0, COMP = 1, ALT = 2. See note on Table 3 for further explanatory remarks.

of the departmental proposals, leading the CEO to reject proposals more often, which in turn slows down improvement. This effect is particularly harmful in the simple environment. In this setting, the most preferred proposals of each department head are also the most beneficial for the firm. Yet a CEO, who has to sift through less preferred proposals as well, may not have enough time in a particular period to get to the most preferred proposals. Hence, the speed indicators for firm H6 are much lower than those for firm H5, and H6 fares much worse than H5 in turbulent environments.

The results for the other two archetypes in Table 6 show boundary conditions for this conventional wisdom. In both, the number of proposals brought to the coordinative session, PROP, does not affect speed or performance, as comparisons of L5 to L6 and B1 to B5 show. In the liaison archetype, managers' preferences set the agenda for considering composite alternatives. Consequently, the most preferred alternatives of each manager are always discussed regardless of how many other proposals are brought to the session. As a result, the communication of more proposals does not slow down the speed of improvement. The power of department heads to set the higher-level agenda counteracts any tendency of more information to delay progress.

In the lateral communication archetype, the proposals that are brought to the brainstorming session are picked randomly and are not pre-evaluated (reflecting the notion that the entire creative process happens during the brainstorming session). As a result, each proposal has the same expected value, and bringing more proposals does not decrease the expected value of any composite alternative and hence does not delay improvement. The conventional wisdom assumes that department heads exercise their power to screen alternatives and promote the better ones, but this assumption is not valid in the lateral communication archetype.

HYPOTHESIS 7. *Richer information flow does not slow down a firm's improvement if* (a) *department heads set the agenda for reviewing composite proposals, or* (b) *department heads do not screen proposals before submitting them.*

The Effect of Information Flow on Diversity of Search. Intuition suggests that a richer flow of information should broaden the range of alternatives considered at the top of a firm and thereby diversify search. We find support for this intuition in Table 6 for the hierarchical archetype. Higher PROP in firm H6 forces department heads to reveal a wider range of options than their counterparts must in firm H5. Consequently, H6 sees far fewer sticking points than H5 and, thanks to its more diverse search, outperforms H5 in stable, complex environments, where search diversity matters. In contrast, a larger number of proposals does not diversify search in the liaison and lateral communication archetypes. In the liaison archetype, proposals are evaluated in a rigid order, so forcing managers to bring more to the session does not alter the set of composite alternatives that are actually considered. Intuition fails to consider that, where department heads can control higher-level agendas, enriching the flow of information to the higher level has no real effect on search diversity. In the lateral communication archetype, brainstorming proposals are chosen at random, so bringing more each period does not broaden the set considered in the long run. Casual intuition implicitly assumes that department heads are exercising the power to evaluate proposals privately and screen them out—and that enhancing the information flow will counteract this power. The intuition falls apart where department heads never exercise that power, as in the lateral communication archetype.

HYPOTHESIS 8. *Richer information flow does not broaden a firm's search if* (a) *department heads set the agenda for reviewing composite alternatives, or* (b) *department heads do not screen proposals before submitting them.*

Summary of Element-By-Element Analyses

Returning to Table 2, we see that our model makes very few predictions that are robust across archetypes. Firmwide incentives in complex settings (higher INCENT) and greater processing power at the top (higher COMP) uniformly lead to faster improvement, which is especially important in turbulent settings. Otherwise, the effects of individual elements are contingent on the archetype in which they are set. Moreover, the effects are not especially well aligned with intuition and conventional wisdom. Misalignments arise when intuition and conventional wisdom make implicit assumptions about the power of low-level managers to withhold information about department options, set high-level agendas, veto alternatives, or take independent action—assumptions that are not valid across all archetypes.

The results in Table 2 can be read in two other, related ways. First, they can be used to predict the changes in an archetype's formal structure that would productively follow a change in environmental conditions. For instance, after an increase in turbulence, we would expect to see hierarchical firms adopt design elements that promote speedy improvement: They might invest in departmental and senior processing power, shift toward firmwide incentives, and limit the upward flow of information. Second, one can use the results to prescribe design elements within an archetype. For a liaison firm facing a stable but complex environment, for example, the results would suggest a design that boosts diversity of search: An emphasis on firmwide incentives and intense liaison sessions would be in order, as might limits on departmental processing power. These prescriptions, however, are valid only within archetypes. They beg the question, "How should one choose among archetypes?"

Comparisons Across Archetypes

To address this question, we turn to direct comparisons across archetypes for different environmental settings. This forces us to address an issue: What are "fair" comparisons across archetypes? For instance, what are the specifications of a decentralized firm that can be compared fairly to a hierarchical firm? Our approach is to equalize across archetypes the total number of evaluations of alternatives. Evaluations are conducted by managers, individually or jointly, and by the CEO, if present. For instance, in a hierarchical firm with two $\text{ALT} = 1$ managers and a CEO with $\text{COMP} = 2$, four evaluations are undertaken each period (one by each manager, and two by the CEO). Corresponding firms that engage in an equal number of evaluations include a centralized firm with $\text{ALT} = 4$ and a decentralized firm with two $\text{ALT} = 2$ managers. Viewing firms as information processors (Galbraith 1973, Tushman and Nadler 1978, Radner 1993), this approach sets on par those firms that engage in the same amount of effort in evaluating alternatives.

In Table 7, we compare firms that engage in four evaluations. For each organizational archetype except the hierarchical structure, a single variant is possible. For the hierarchical archetype, two variants are possible because the level of vertical information flow can vary. We set $\text{INCENT} = 1$ for all firms, and for each environment we highlight the performance of the most successful firm in boldface. The hypotheses below draw not only from Table 7, but also from Table 2.

Stable Environments. When the environment is stable and simple, organizational design plays little role in determining the outcome of a firm's search efforts. Firms of any archetype have enough time to find a very good choice configuration. Moreover, the simplicity of the environment prevents firms from getting stuck on points other than the global peak of the landscape. In other words, the simplicity of the environment does not reward diverse search generated by sophisticated coordinating mechanisms.

HYPOTHESIS 9. *Organizational design has little impact on firm performance in stable, simple environments.*[15]

In stable yet complex environments, diversity of search plays a much more important role. In this environment, the firms with the highest performance are the hierarchy with rich information flow (firm I5) and the lateral communication archetype (firm I3). One could interpret the high performance of hierarchy as a validation of Burns and Stalker's proposition (1961, p. 5) that "mechanistic" organizational structures are "appropriate to an enterprise operating under relatively stable conditions." Yet note the importance of the detailed specifications of the hierarchical organization. Firm I4, another hierarchical firm but with less vertical information flow, is among the worst performers in this environment. Thus, whether a firm with a hierarchical arrangement is a good performer in a stable, complex environment depends crucially on the richness of the internal information flow. Unless one tightly specifies organizational details, confusion can easily arise when organizational archetypes are directly mapped to their "most appropriate" environments. Similarly, in results not reported in full here, we find that the success of firm I3, the firm with lateral communication, depends crucially on its incentive system. With parochial incentives instead of the firmwide incentives assumed in Table 7, its performance is only average compared to the other archetypes.

HYPOTHESIS 10. *A stable, complex environment calls for an organizational design that can produce diverse search—either a hierarchical firm with limited departmental processing power and rich information flow or a lateral communication firm with firm-level incentives.*

Turbulent Environments. In turbulent and simple environments, the decentralized archetype performs best. This firm benefits from parallel decision making and does not waste effort trying to coordinate its decision makers. If decisions do not interact, sophisticated coor-

Table 7 **Performance Comparisons of Different Archetypes with Equal Total Processing Power**

Archetype	Decentralized	Liaison	Lateral communication	Hierarchical	Hierarchical	Centralized
Firm	I1	I2	I3	I4	I5	I6
ALT	2	1		1	1	
PROP		2	2	1	2	
COMP		2	4	2	2	4
Stable and…						
Simple environment	1.000	1.000	1.000	1.000	1.000	1.000
Complex environment	0.893	0.884	**0.940**	0.883	**0.939**	0.892
Turbulent and…						
Simple environment	**0.976**	0.938	0.958	0.935	0.923	0.965
Complex environment	0.835	0.858	**0.900**	0.857	0.864	**0.892**

Notes. INCENT $= 1$ for all firms. For stable environments, the table reports for each firm the performance in period 200 averaged over 500 landscapes; for turbulent environments, it contains the average performance over 200 periods across 500 landscapes.

dinating mechanisms are unnecessary, consume precious information processing resources, and can only slow down decision making, which hurts performance in turbulent environments (Lin and Carley 1997). This disadvantage is especially acute for a hierarchical firm with rich information flow (firm I5). This firm performs worst in turbulent, simple environments—a dramatic shift from its superior performance in stable, complex settings. Like the decentralized firm, the centralized firm does not "waste" its processing power on coordination. Accordingly, it fares well, though not as well as the decentralized firm because it does not benefit from parallel decision making.

HYPOTHESIS 11. *A turbulent, simple environment calls for a decentralized firm with strong departmental processing power—an organizational design that produces speedy improvement.*

When the environment is turbulent and complex, what is called for are very different organizational structures. In this environment, the pure speed of the decentralized firm backfires. The lack of coordination creates instability and little search, making the best performer in the simple environment the worst performer in the complex environment. Archetypes that work well in this environment are the lateral communication organization and the centralized organization. Each of these organizations strikes the balance of speedy improvement and diverse search that is required in this environment. As this example shows, there is no uniquely best archetype; various archetypes, configured appropriately, can achieve the required balance. Yet equifinality is not universal, as shown by the relatively poor performance of both variants of the hierarchical archetype in this environment. Hierarchical firms suffer from either narrow search (firm I4) or slow improvement (firm I5).

HYPOTHESIS 12. *A turbulent, complex environment calls for a balance of speedy improvement and diverse search that can be delivered by a lateral communication firm with firmwide incentives and strong power to process composite alternatives, or by a centralized firm with ample processing power.*

Robustness

To be clear and concise, we have presented only a small subset of all the simulations we conducted. For instance, we have illustrated the effect of each design element on speed and search within each archetype by comparing two particularly configured archetypes that differed only in the focal design element, while the other design elements were set to baseline values. Extensive simulations revealed that the effects on speed and search of each design element, as summarized in Table 2 and incorporated in Hypotheses 1–8, are robust to configuring all the nonfocal design elements in many different ways. Likewise, at the level of the environment, we

restricted our reported results to two levels of complexity ($K = 0$ and $K = 5$), and one particular form of turbulence (changes every five periods ($\Delta = 5$) with τ, the correlation between subsequent performance contributions equal to 0.2). We checked the robustness of our results by conducting simulations for all intermediate values of K and by constructing three more environmental conditions. Two conditions are "turbulent" as well, yet differ in the frequency and the magnitude of change: In one environment, $\Delta = 20$ and $\tau = 0.2$, and in the other, $\Delta = 5$ and $\tau = 0.8$. The third environmental condition introduced only mild environmental change, with $\Delta = 20$ and $\tau = 0.8$. We find that the results we report for "simple" environments tend to hold for values of K up to 2, while results we report for "complex" environments tend to hold for values of K of 3 and higher. Likewise, the results we report for stable environments are qualitatively similar to the environment with mild change, while the results we report for the turbulent environment also arise in the other two turbulent environments described above.

We also did not report results for the two additional archetypes that can be constructed given the three types of departmental power (screening, agenda setting, and veto power) because these two archetypes behave like two reported archetypes. A firm with lateral communication that allows managers to prescreen alternatives exhibits the same relationships between organizational design elements and speed and search as the hierarchical archetype. Likewise, a hierarchical firm that allows managers to set the agenda for the CEO behaves like a liaison archetype. Moreover, the two omitted archetypes never have the highest performance when included in the archetype-by-archetype comparison.

Last, in the comparison across archetypes, we set firms on equal footing by equalizing the number of evaluations that were conducted in each period. Alternatively, one could equalize across archetypes the number of *sequential* evaluations. For instance, in the hierarchical firm with ALT = 1 and a CEO with COMP = 2, three sequential evaluations are made (one by each subordinate, and two by the CEO). Corresponding firms with equal sequential evaluations would include a centralized structure with ALT = 3 or a liaison firm with ALT = 1 and COMP = 2. This alternative approach recognizes that decision making takes time, and it rewards firms that organize to permit parallel processing of decisions. Analyses with this alternative approach produced results that were qualitatively identical to the ones reported.

Discussion

Shifts in turbulence and complexity caused organizational scholars to shift their focus during the 1980s and 1990s toward the informal architecture of firms, the

boundaries between firms, and the structure of networks that link firms. Formal design within a firm attracted less attention. This balance among topics was appropriate perhaps, given how little was known about the former set of phenomena and how thoroughly studies of formal design had exhausted the techniques that were widely used at the time. Yet shifts in turbulence and complexity have implications for formal design that certainly deserve study. Indeed, in the admittedly stylized model we have constructed, formal design choices have no impact on performance in a simple, stable world and become relevant only in the face of turbulence or complexity.

Here, we have used an agent-based model to explore the implications of turbulence and complexity for formal design. The analyses produce hypotheses concerning the two questions laid out in the paper's introduction. First, how should managers design their firms for turbulent and complex environments? Comparisons across archetypes and element-by-element analyses, taken together, yield the design guidance shown in Figure 1. The figure sheds light on a longstanding debate about the impact of increasing turbulence on formal design. How should hierarchies be altered when they face rising turbulence? A tradition dating back to Weber (1922) argues that hierarchies must centralize authority in the hands of a few, capable leaders who can act rapidly and decisively. Others claim, in contrast, that decisions must be pushed out to lower-level managers who can respond to idiosyncratic, local events and who can coordinate their moves as needed through lateral devices (Burns and Stalker 1961, Mintzberg 1979). The bottom row of Figure 1 suggests that both points of view are valid. An increase in turbulence in the face of high complexity calls for a hierarchical firm to shift *either* to a centralized archetype *or* to a lateral communication archetype. The crucial matter is not that a firm centralize or decentralize per se, but that it find some archetype that permits speedier improvement without completely sacrificing diversity of search. In this case, there are two such archetypes, both equally effective.

The notion of equifinality is time-honored in organizational design (von Bertalanffy 1968, Gresov and Drazin 1997), but we hope the present model sheds some light on the underpinnings of the notion. According to Figure 1, both the lateral communication firm and the centralized firm achieve the balance of speedy improvement and diverse search required to succeed in an environment that is both turbulent and complex. What is it that grants this balance to those particular archetypes? Part of the answer may lie in Table 2. Hierarchical firms face a dilemma as they try to achieve both speedy improvement and diversity of search: An increase in ALT boosts speed but narrows search, and an increase in PROP diversifies search but slows improvement. Likewise, the decentralized firm faces an issue: firmwide incentives may speed up improvement but diminish diversity. In contrast, the centralized and lateral communication firms face no situations in which design element adjustments push improvement speed and search diversity in opposite directions. Thus, they are better able to thrive in settings that demand both speedy improvement to deal with turbulence and diverse search to cope with complexity. This is, of course, only a speculation that requires further development.

The bottom row of Figure 1 also implies that an increase in turbulence can call on an hierarchy to give department heads more power (in the change to a lateral communication archetype) or to give them less power (in the change to a centralized archetype). This illustrates a broader pattern we see in our results. The columns in Table 7 are arranged from the archetype that grants the most power to department heads on the left to the archetype that grants the least on the right. In none of the rows do we see a simple, monotonic trend in performance as we go from left to right. That is, in no environmental condition does design guidance become simply, "The more power you give to subordinates, the better (or worse) off you will be." The details and the combinations of the granted powers truly matter. In turbulent, simple settings, for instance, firms need speedy

Figure 1   Summary of Appropriate Designs

	Stable environments	Turbulent environments
Simple environments	• Goal: neither speedy improvement nor diverse search needed ⇒ Formal design has little impact	• Goal: speedy improvement ⇒ Decentralized firm with thorough department heads
Complex environments	• Goal: diverse search ⇒ Hierarchical firm with limited departmental processing power, firm-level incentives, and rich information flow OR Lateral communication firm with firm-level incentives	• Goal: balance of speedy improvement and diverse search ⇒ Lateral communication firm with firm-level incentives and ample coordinative processing power OR Centralized firm with ample processing power

improvement. This can be achieved by thorough decentralization or full centralization. Poor performance arises in the middle ground where managers waste scarce processing power on unnecessary coordination.

The second question laid out in the introduction is: Are any design elements robustly appropriate in the face of turbulence or complexity regardless of archetype? The results of our element-by-element analyses, synthesized in Table 8, suggest an affirmative answer in just two instances. Across a wide array of archetypes, firmwide incentives and ample processing power at the top of a firm promote the speedy improvement that is required in turbulent environments. Otherwise, Table 8 exhibits few simple contingencies. One cannot say, for instance, what an increase in complexity implies for the appropriate design of incentives without knowing the archetype in which the incentives are embedded.

This lack of simple contingencies throws in sharp relief the difficulties of empirical work on organizational design. Tests of the appropriateness of individual design elements that do not take into account the archetypes in which design elements are embedded, as well as tests of archetypes that do not take into account finer design details of these archetypes, are likely to yield confounding results. The hypotheses derived from our model suggest subtle effects at times, depending on environmental conditions and organizational archetype. A research strategy for testing these hypotheses would involve studying firms in four different environmental conditions (simple versus complex, stable versus turbulent) and characterizing firms' organizational designs along the types of power available to department heads (screening of proposals, agenda setting, and veto powers). Within each archetype-environmental condition cell, regressions of firm performance on finer-grained design elements, such as the degree of decision support for department managers or the incentive system, would help test Hypotheses 1–8. Pooling observations across archetypes, one could test Hypotheses 9–12 by regressing performance within each environmental condition cell on archetype dummy variables, design element variables, and interactions between archetype and design element variables.

More broadly, we hope that the hypotheses derived from our analyses make a case for using agent-based models to study organizational design in a rigorous way. Such models offer precise hypotheses as fodder for empirical studies, and they force researchers to articulate their assumptions and logic with a clarity that verbal theorizing may lack. Moreover, agent-based simulations allow researchers to consider far more variables and more interactions among variables than one could manage in closed-form models.

The particular model we build here is not complete by any means. It overlooks an array of environmental conditions other than turbulence and complexity as well as organizational characteristics that prior scholars have argued are important (Khandwalla 1977, Burton

Table 8   Overview of Design Element Effects

Conventional wisdom/intuition	Results
Effects on speed of improvement	
• Greater departmental processing power allows firms to spot improvements faster and boost performance more quickly.	• General support in simple environments • In complex environments, greater departmental processing power can lead to slower improvement due to increased likelihood of mutually destructive changes and greater ability of department managers to insist on parochial agendas

• Firmwide incentives are important for fast action	• General support due to several mechanisms:
	  —Firmwide incentives reduce the likelihood of vetoes
	  —Firmwide incentives reduce the likelihood of detrimental changes

• More coordinative processing power leads to faster improvement	• General support across archetypes
• Rich information flow slows down improvement	• Rich information flow slows down improvement only if department managers cannot insist on their agendas
Effects on diversity of search	
• Greater departmental processing power has little effect on diversity of search because it does not affect eventual diversity of alternatives considered	• *Negative* effect when greater departmental processing power enables managers to hide proposals they do not like
• Firmwide incentives enables broader search because they avert stand-offs	• General support, except for decentralized archetype in which firmwide incentives make it harder to find new alternatives
• More coordinative processing power does not affect the eventual diversity of alternatives that are considered	• If department managers can control agendas, more processing power at the top increases diversity of search
• Richer information flow leads to broader search	• Richer information flow leads to broader search only if managers can prescreen departmental options and cannot veto composite alternatives

and Obel 2004). It ignores important realities of organizational life like miscommunications, mistakes, and misperceptions, and it does not couple formal design with informal structure. It also does not permit firms to change their designs over time. All of these are important gaps in the model. Yet all can be fruitfully addressed using the kinds of techniques we employ in this paper.

Conclusion

The problem of finding appropriate organizational designs for different environmental conditions remains a steep challenge for practicing managers. What makes the choice of appropriate organizational design difficult is, in part, the interdependencies among the various aspects of design. Interdependencies can create surprising and subtle effects that, without systematic analysis, can lead intuition astray. We believe that agent-based simulations like the one used here can equip scholars to better understand and anticipate interdependencies among aspects of design.

In sum, our analysis makes three contributions. First, as summarized in Table 8, our model allows us to identify a number of boundary conditions to conventional wisdom about appropriate organizational design for different environmental conditions. The same design element can have very different performance effects depending on the archetype in which it is embedded.

Second, when conventional wisdom fails to hold across all archetypes, it generally fails because conventional wisdom makes implicit assumptions about the power of department heads to take unilateral action, screen out departmental options, control agendas, and veto firm-level alternatives—assumptions that are not valid across all archetypes. Moreover, a characterization of archetypes along dimensions of department head power makes it possible to describe, in a systematic manner, a wide range of archetypes that have been discussed in the prior literature.

Third, we show that the challenging task of formal design becomes more manageable if one can identify constructs that mediate between environmental conditions and design choices. Improvement speed and search diversity serve as intermediate constructs in our context. In thinking through environmental complexity and incentives, for instance, it is helpful to realize first that a rise in complexity calls for an increase in search diversity. One can then ask, "In a given archetype, what change in incentives is required to boost search diversity?" Intermediate constructs help scholars and managers to break design problems into manageable parts. We believe firmly that speed and search are important constructs that shed light on design for turbulence and complexity, but there is little reason to believe that our stylized model has pinpointed the *only* constructs relevant to organizational design. A worthy priority for future research is to seek other similar constructs—for turbulence, for complexity, and for other aspects of organizations' environments.

Endnotes

[1] This set-up presumes that two firms that arrive at the same configuration of choices achieve the same level of performance even if different organizational structures guided them to this common set of choices. Put differently, in our model, organizational arrangements have no direct costs or benefits (see also Endnote 15). They influence performance only through the operational choices they evoke.

[2] This model is agnostic concerning the source of the environmental turbulence, taking it as an exogenous factor. An avenue for future research is to allow firms' actions to influence the degree of turbulence.

[3] We conducted simulations in which we not only varied the number of alternatives considered by each manager per period (ALT), but also allowed each manager to consider alternatives involving a change in more than one decision. Results, available from the authors, are consistent with the findings reported in this paper.

[4] In more detail, let i be the rank of a proposal of manager A, and j be the rank of a proposal of manager B. Then managers will successively evaluate composite alternatives with higher sums of ranks $s = i + j$: They start out with the composite alternative with the lowest s ($i + j = 1 + 1 = 2$), then pick in random sequence the composite alternatives with the next higher s ($i + j = 1 + 2 = 3$ or $i + j = 2 + 1 = 3$), etc., until they have evaluated COMP composite alternatives.

[5] A problem space with six decisions is large enough to allow adequate range for the parameters in the model. Larger problem spaces increase the computational burden but do not qualitatively change the reported results.

[6] We chose 200 periods because in stable environments no modeled firm improves its performance after 200 periods. In turbulent environments, a firm's performance pattern through each environmental cycle is fairly similar across cycles. With 200 periods we capture enough cycles to detect inherent performance differences across designs.

[7] Focusing on the first period yields the purest speed measure. Performance improvements over longer intervals would commingle speed and search effects.

[8]We do not report a similar measure for stable $K = 0$ landscapes because, in such settings, every firm experiences only a single sticking point—the global optimum—regardless of organizational design. We do not report a similar measure for turbulent environments because, there, firms do not settle down into static configurations of choices.

[9]Because ALT does not play a role in the lateral communication or centralized archetype, this analysis examines only three of the five archetypes.

[10]The performance of the decentralized archetype is, however, also affected by the mutually destructive "improvement" efforts by the independent managers. This can lead to performance-degrading instability: Firms may never settle down on a choice configuration but may continue to cycle back and forth among a small number of configurations. More thorough managers are more likely to create instability because they are less likely to overlook seeming improvements. This effect explains the performance difference between firms D1 and D2 in stable, complex environments. In more than 38% of all landscapes firm D2 ends up cycling, in contrast to 4% for firm D1. If we consider only firms that reach sticking points, we find that firms D1 and D2 have similar performance, as one would expect given that they have the same sticking points.

[11]With firmwide incentives, both managers consider the same benchmark (current overall firm performance) when deciding whether an alternative should be implemented. If firm performance is high, both managers will find it difficult to find attractive alternatives and the firm remains stuck. With parochial incentives, both managers use less correlated benchmarks (the performance of their own departments). As a result, if one manager cannot find an attractive alternative, the likelihood that the other manager finds an attractive alternative is not affected.

[12]While D1, with parochial incentives, has the advantage of broader search relative to D3, which has firmwide incentives, D1 suffers from increased instability. In this case, the two effects cancel out and D1's performance is not significantly different from D3's performance in the stable, complex environment.

[13]To create a long enough stack of composite alternatives for the liaison archetype when COMP $= 3$, it is necessary to set PROP $= 2$ for firm L4.

[14]In the simple, turbulent environment, the liaison archetype forms an interesting exception in that COMP has no effect on performance. With no interdependencies, each department heads' most preferred alternative is also the most preferred for the firm as a whole. Because the composite alternative composed of the department heads' most preferred alternatives is always the first to be discussed in the liaison archetype, digging further down into the stack of composite alternatives (via a higher COMP) does not affect performance in this circumstance.

[15]Given the lack of an effect of organizational design on search outcomes in this environment, cost considerations are likely to play an important role in determining the optimal organizational structure. The costs associated with each archetype are, however, not straightforward. For instance, the decentralized firm employs two managers, while the hierarchical structure employs three. At the same time, the department heads in the decentralized firm are working harder (they evaluate two alternatives in every period) than the department heads in the hierarchical structure who evaluate only one alternative in every period. Consequently, the department heads in the decentralized firm may require a higher wage. Due to the large number of assumptions that would have to be made to model the cost side explicitly, we decided in this paper to focus exclusively on the search-related benefits of different organizational structures.

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