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AN ORGANIZATIONAL LEARNING MODEL OF CONVERGENCE AND REORIENTATION*

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A critical challenge facing organizations is the dilemma of maintaining the capabilities of both efficiency and flexibility. Recent evolutionary perspectives have suggested that patterns of organizational stability and change can be characterized as punctuated equilibria (Tushman and Romanelli 1985). This paper argues that a learning model of organizational change can account for a pattern of punctuated equilibria and uses a learning framework to model the tension between organizational stability and change. A simulation methodology is used to create a population of organizations whose activities are governed by a process of experiential learning. A set of propositions is examined that predict how patterns of organizational change are affected by environmental conditions, levels of ambiguity, organizational size, search rules, and organizational performance. Implications of this learning model of convergence and reorientation for theory and research are discussed.

(ORGANIZATIONAL LEARNING; CONVERGENCE; REORIENTATION)

Introduction

A critical challenge facing organizations is the dilemma of maintaining the capabilities of both efficiency and flexibility; the observation that there exists a mix of capabilities that enable the organization both to function efficiently and to remain flexible over time is a hallmark of the organization theory literature (March and Simon 1958, Cyert and March 1963). Thompson (1967, pp. 148–150) called this the paradox of administration. Various theoretical perspectives have described the nature of this paradox, including ecological theories (Hannan and Freeman 1977, 1984), contingency theories (Lawrence and Lorsch, 1967; Galbraith 1973), and bureaucratic theories (Perrow 1986). Recently, Tushman and Romanelli (1985) observed that organizations experience long periods of convergence punctuated by fundamental reorientations. Convergence is defined as periods of equilibrium characterized by “relatively long time spans of incremental change and adaptation which elaborate structures, systems, controls, and resources toward increased coalignment” (Tushman and Romanelli 1985, p. 173). The punctuations in these equilibria are called reorientations; they are characterized by: “simultaneous and discontinuous shifts in strategy, the distribution of power, the firm’s core structure, and the nature and permissiveness of control systems” (Tushman and Romanelli, p. 179). This punctuated equilibrium perspective seeks to understand the management of both stability and change by emphasizing the role of top management in producing convergence and reorientation. Tushman and Romanelli (1985, pp. 209–215) and Tushman, Newman, and Romanelli (1986) emphasize managerial vision as the key to the successful management of this process.

The application of a learning model to the punctuated equilibrium perspective can contribute to our understanding of organizational change by offering an alternative explanation for patterns of stability, change, and organizational performance. This alternative explanation is focused on understanding organizational routines; in particular, the role of adaptive performance targets in mediating the probability of

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organizational change is stressed. This paper argues that a learning model of organizational change can account for a pattern of punctuated equilibria and uses a learning framework to model the tension between organizational stability and change. A simulation methodology is used to create a set of organizations whose activities are governed by a process of experiential learning. A set of propositions is examined that predict a pattern of organizational change characterized by punctuated equilibria. We find general support for the punctuated equilibria propositions of Tushman and Romanelli (1985) despite the fact that we have limited firm level differences, including executive leadership, to a probability distribution.

A Learning Model

Experiential Learning and Patterns of Change

According to the organizational learning perspective, organizational change can be modeled as the result of a basic learning process (March and Simon 1958; Cyert and March 1963; March and Olsen 1976; Argyris and Schon 1978); this process entails updating routines based on interpretations of experience (Levitt and March 1988). This paper proposes that a learning model can account for patterns of organizational change that have been observed in the literature (Tushman and Romanelli 1985; Tushman et al. 1986). Organizational learning models typically have three basic components (Cyert and March 1963; Levitt and March 1988). First, organizations have a target level of performance or aspiration level to which they compare their actual performance; in each period, they determine whether they have performed above or below this aspiration level. The perspective that organizations set goals, or aspiration levels, and compare their actual performance to their goals, is a common theme in learning models (Cyert and March 1963; Herriot, Levinthal, and March 1985; Lant forthcoming), the psychology of decision making (Siegel 1957; Payne, Laughhunn, and Crum 1980; Kahneman and Tversky 1979; Mezias 1988), and open-system models of organization (Buckley 1967; Cameron and Whetten 1981). Second, performance relative to aspiration levels defines the organization’s perceptions of success and failure (Cyert and March 1963; Lant and Mezias 1990; Milliken and Lant 1991), affecting the likelihood of observable organizational change. Change in behavior is more likely when performance is below aspiration level, or perceived as failure. This is a typical outcome of trial and error learning; behavior that is associated with success tends to be repeated, while behavior that is associated with failure tends not to be repeated (Levinthal and March 1981; Herriot, Levinthal, and March 1985; Levitt and March 1988). Third, unlike the typical firms of neoclassical economics which optimize in the acquisition and use of information (Varian 1978), a learning model suggests that the acquisition and processing of information about alternatives takes place in a relatively costly process of search (Cyert and March 1963; March 1978; Nelson and Winter 1982), frequently conducted under conditions of ambiguity (March and Olsen 1976). In sum, an organizational learning model suggests that the impetus for organizational change and adaptation is triggered by performance below aspiration level, and the content of change depends on the outcomes of the organizational search process.

We propose that the capabilities for both stability and change, and thus patterns of convergence and reorientation, can be described as outcomes of different types of learning. The first type of learning is called first-order learning, a routine, incremen-

1The terminology first-order and second-order is borrowed from Watzlawick, Weakland, and Fisch (1974) where these terms are applied to types of change at different logical levels. This terminology has
tal, conservative process that serves to maintain stable relations and sustain existing rules (March 1981). Bateson (1972) suggests that this type of learning reflects the organization’s ability to remain stable in a changing context. It is basically the process of gaining competence in a certain activity, routine, or technology; Tushman and Romanelli (1985) refer to this as convergence. An example of first-order learning leading to convergence is illustrated in Tushman, Newman, and Romanelli’s (1986, p. 30) description of General Radio and Company from 1915 through 1972. General Radio designed an organizational system consistent with their mission and strategy to produce innovative, high priced, high quality electronic test equipment. As the environment became more competitive, they made only incremental changes designed to improve their chosen strategy; structures and systems remained intact. Thus, even given environmental changes, their response consisted of learning how to better implement their chosen strategy while maintaining consistency in other organizational systems.

The second form of learning is called second-order learning and is characterized by the search for and exploration of alternative routines, rules, technologies, goals, and purposes, rather than merely learning how to perform current routines more efficiently. Second-order learning results from the realization that certain experiences cannot be interpreted within the current belief system, theory-in-use (Argyris and Schon 1978) or organizational paradigm (Brown 1978; Pfeffer 1981). This process of experimentation (March 1988) can lead to the recognition of new goals or means to achieve goals, new ways of assembling responses or connecting stimuli to responses (Kelley 1955), and the integration of new constructs into existing cognitive structures (Hedberg 1981); this is what Tushman and Romanelli (1985) call reorientation. Tushman, Newman, and Romanelli’s (1986, p. 30) description of General Radio in 1973 illustrates how a firm can shift from first-order learning to second-order learning. Sustained poor performance apparently led to such a degree of dissatisfaction that the current strategy and organizational systems were called into question. Beginning with a change in CEO, General Radio changed its strategy, structure, and control systems simultaneously. They even changed their name to GenRad, thereby symbolically underscoring that they had become a ‘different’ organization (Glynn and Slepian 1990). Thus, GenRad has discovered and implemented a new set of goals, purposes, routines, and rules. Rather than continuing to improve the ‘old’ way of doing things, they had learned how to create a ‘new’ way of doing things.

It is the central argument of this paper that routine processes of organizational learning can account for a pattern of convergence and reorientation. The key insight of a learning model of convergence and reorientation is that aspiration levels provide a basis for determining when performance is interpreted as satisfactory or unsatisfactory (March and Simon 1958; Cyert and March 1963; Mezias 1988; Glynn, Lant, and Mezias 1991; Lant forthcoming). The basic mechanisms are simple and familiar: Satisfactory performance will tend to result in reinforcement of the lessons drawn from the organization’s past experiences; the status quo will be maintained and justified, resulting in first-order learning and convergence. By contrast, this tendency toward convergence will be mitigated when unsatisfactory performance calls existing routines and practices into question. As a result, the organization is more likely to undertake major changes in an effort to raise performance above aspiration level. Thus, the equivocal experience associated with failure may produce a level of

also been used in the context of organizational learning and change by Hedberg, Nystrom, and Starbuck (1976). It bears an obvious resemblance to the single-loop and double-loop learning discussed by Argyris and Schon (1978).
organizational change consistent with reorientation. It is important to keep in mind, however, that aspiration levels adapt to performance, providing a moving target which complicates the dynamics of stability and change.

**Propositions**

This paper explores the dynamics of stability and change produced by the interaction of learning processes with different organizational and environmental conditions; our focus is on the implications of these interactions for understanding organizational convergence and reorientation. We propose that many of the patterns of change reported in the literature can be explained by the process of organizational learning in an ecology characterized by negative selection and periods of stability and change. In this section, propositions which predict how organizational and environmental conditions affect organizational change are derived from the literature.

**Environmental and Organizational Change**

The literature on organizational change has generally posited a close relationship between environmental and organizational change (Lawrence and Lorsch 1967). Tushman and Romanelli (1985, pp. 197–208) suggest several mechanisms by which environmental forces affect the probability of change to core organizational dimensions. We have argued that most organizational activity is driven by routines; organizations enact the environment in the course of routine functioning and apply routine responses to this enacted environment (March 1981). The application of routines developed in a given environmental configuration will result in decreased performance in the wake of environmental change. This leads directly to performance below aspiration level; current practices and organizational procedures are called into question (Levitt and March 1988), increasing the probability of organizational change (March and Simon 1958, p. 183). As March (1981, p. 564) has pointed out, “most change in organizations results neither from extraordinary organizational processes nor forces, nor from uncommon imagination, persistence or skill, but from relatively stable, routine processes that relate organizations to their environments.” Thus, a fundamental restructuring of environments should increase the likelihood of significant organizational change. This is the core prediction of learning models; it also corresponds to the central argument of the punctuated equilibria model (cf. Tushman and Romanelli 1985, Propositions 9, 10, and 13).

**Proposition 1.** Organizational change will increase following environmental change, and will decrease during environmental stability.

It is our intention to demonstrate that this relation results from a view of organizations as experiential learning systems, without reference to the characteristics of particular firms. In particular, the punctuated equilibria result can be derived without reference to internal consistency (Tushman and Romanelli 1985, pp. 187–189), increased structural and social complexity (Tushman and Romanelli 1985, pp. 189–191), length or stability of previous convergent period (Tushman and Romanelli 1985, pp. 192–195), the characteristics of the executive team (Tushman and Romanelli, 1985, pp. 187–189, 210–213), or the quality of executive leadership (Tushman and Romanelli 1985, pp. 209–210; Tushman, Newman, and Romanelli 1986). We posit a process of routine organizational learning in which aspiration levels mediate the interpretation of failure and success while simultaneously adapting to performance. The perspective developed here suggests that organizational change results from a process that is “routine based, history dependent, and target oriented” (Levitt and March 1988, p. 319). In the sections below, these three characteristics of
the learning process serve as the basis for a series of propositions concerning organizational change. These propositions reflect much of the literature, especially as it has been summarized in the punctuated equilibria and learning perspectives.

The Effect of Routines

Tushman and Romanelli (1985, Proposition 14) suggest that organizations can have systematically different patterns of convergence and reorientation. Further, they argue that particular patterns of convergence and reorientation will be more universally effective (Tushman and Romanelli 1985, Proposition 14A). The apparent genesis of these universally more effective patterns of convergence and reorientation is the quality of executive leadership (Tushman and Romanelli 1985, pp. 209–213), what Tushman, Newman, and Romanelli (1986) call visionary executive leadership. By contrast, a learning perspective stresses the difficulty of executive leadership: “Sometimes organizations ignore clear instructions; sometimes they pursue them more forcefully than was intended; sometimes they protect policymakers from their folly; sometimes they do not (March 1981, pp. 563–564).” A learning perspective offers an alternative explanation for why organizations will have systematically different patterns of organizational change: Differences in organizational routines affect responsiveness to environmental change. We suggest that organizations may differ systematically in the process by which they search for information about the relationship between organizational characteristics and outcomes, information about possible changes in organizational characteristics, and information about the viability of such changes. These different routines focus attention on different types of information and will have important consequences for the pattern of convergence and reorientation that characterizes the organizational life cycle.

Proposition 2. Organizations with adaptive search routines will be more responsive to environmental change than those with either imitative or garbage can routines.

We also suggest that organizations may differ systematically in the routines that determine how they respond to performance signals. Conceptually, we argue that organizations are characterized by routines which result in differential propensity to change in response to a given discrepancy between performance and aspiration level; the result is that organizations are heterogeneous with respect to the probability of change. To explore the importance of such heterogeneity of routinized change, we posit a dichotomy between firms which are more likely to change, called high change potential firms, and firms which are less likely to change, called low change potential firms.

Proposition 3. Firms with high change potential are more likely to change in response to environmental change than firms with low change potential.

History Dependence: Past Performance and Size

Tushman and Romanelli (1985, pp. 206–208) suggest that successful organizations have developed the correct balance of stability and change; these organizations will reorient when environmental conditions warrant such a change. They argue that unsuccessful organizations have not learned how to balance stability and change, and will reorient either too frequently or not at all. We argue that the posited relationships among change, success, and environmental restructuring can be generated from the assumptions of a learning model with the differences among firms reduced to a probability distribution. In this model, differential responsiveness results from the process by which aspiration levels mediate interpretations of performance as either success or failure.
PROPOSITION 4. *High-performing firms will exhibit fewer changes than low-performing firms.*

The organizations literature also has argued that large organizations are less likely to change in response to environmental changes than small organizations. Tushman and Romanelli (1985, Proposition 3) propose that increased size leads to increased complexity, increased convergence, and thus, increased inertia. A learning model, however, suggests that inertia develops as a result of a firm's performance history. Large firms tend to be successful; good performance tends to accumulate in the organization as slack (Cyert and March 1963), and the organization will grow larger with repeated success. Since success reduces the probability of change in a target-oriented organization (Cyert and March 1963), large organizations will be less likely to change.

PROPOSITION 5. *Large firms will be more inert than small firms.*

*Performance Targets and Ambiguity*

Tushman and Romanelli (1985, Propositions 2 and 2A) argue that internal requirements for coordinated action and external requirements for accountability and predictability lead to increased social and structural complexity. These, in turn, lead to increased convergence upon an established strategic orientation and resistance to change in core organizational dimensions. A learning model recognizes the increased complexity of performance programs developed in response to the needs for coordinated action (March and Simon 1958; Thompson 1967). However, a learning model also suggests that given such complexity, organizations increasingly seek out clear signals about their performance by focusing on simple, objective outcomes (Cyert and March 1963; Lant forthcoming). We argue that the development of inertia may result from an organization's attempts to learn in an ambiguous world. Ambiguity complicates the relationship between firm characteristics and performance (March and Olsen 1976) and organizational attempts to seek out clear signals based on 'objective' outcomes. Under conditions of ambiguity, performance feedback can be thought of as consisting of a systematic component, relating performance to firm characteristics, and a random component. This randomness hinders the ability of the organization to determine the viability of its characteristics based on its performance. Thus, even while increased social and structural complexity focus organizations on simple, objective indicators like performance (Cyert and March 1963; Lant forthcoming), ambiguity in the signal may render its usefulness problematic. Although ambiguity makes effective change more difficult, it does not necessarily make change “essentially random with respect to future value” (Hannan and Freeman 1984, p. 151). However, in a population characterized by negative selection, costly change, and ambiguity, we expect that selection would favor organizations that are less sensitive to the ambiguous information contained in performance.

PROPOSITION 6. *As the level of ambiguity in the relationship between firm characteristics and performance increases, the average sensitivity to changes in performance will decrease.*

Finally, organizations in ambiguous worlds are more likely to remain inert in the face of performance below aspiration level. Relative to selection under unambiguous conditions, selection under ambiguous conditions favors firms that are less responsive to environmental changes. As selection pressures favor those firms that are less sensitive to changes in performance, the average firm in the population is more likely to remain inert.
PROPOSITION 7. *The greater the ambiguity in the relationship between organizational characteristics and performance, the less responsive organizations are to an environmental restructuring.*

Methodology

We have argued that organizations learn via a longitudinal process of considerable complexity. The longitudinal and evolutionary nature of the suggested theoretical framework makes deriving its implications quite complicated. It is difficult to explain how the processes develop over time in different contexts to yield various organizational outcomes. The unfolding of these processes can be observed, however, in a computer simulation. A computer simulation can take a complex set of assumptions, simulate a set of organizational processes, and represent the implications of these processes for organizational outcomes. Computer simulations have played an important role in the development of theory on organizational learning (Cyert and March 1963; Levinthal and March 1981; Herriot, Levinthal, and March 1985; March 1988; Lant and Mezias 1990; Levinthal 1990). This paper extends the application of computer simulations of organizational learning in order to derive the implications of a learning model of organizational convergence and reorientation and to test the implications of the set of propositions suggested by such a model. The basic rules which govern the behavior of these organizations are described in the following sections.²

Organizational Characteristics and Performance

The key assumption made in order to operationalize organizational characteristics and change is that organizations are completely characterized by four core dimensions (Hannan and Freeman 1984; Tushman and Romanelli 1985). For the sake of simplicity, it is assumed that firms have only two choices, e.g., 0 or 1, on each of these dimensions; thus, there are 16 distinct firm types. Contingency theory argues that organizational performance is contingent on the fit between organizational characteristics and the environment (Burns and Stalker 1961; Lawrence and Lorsch 1967; Child 1972). Thus, each of the four dimensions is assigned a performance level for each of the alternative characteristics that firms can adopt on each dimension. An example of the assignment of performance to the four dimensions of firm type and how this assignment changes during environmental restructuring is shown in Table 1. The base performance of each of the 16 types is the mean of performance assigned to each of the four dimensions of firm type rounded to nearest integer. For example, the base performance of a firm which was a type 0000, where the assignment of performance to the four dimensions was identical to that displayed in the upper panel of Table 1, is computed as follows:

\[
\frac{-11 + (-3) + 2 + (-1)}{4} = -4.25
\]

which rounds to −4. After the discontinuous change in period 20, a firm of the same type would have a base performance computed using the numbers depicted in the

² The technical details of how these rules were operationalized are described in the Appendix. Copies of programs corresponding to each proposition, which were written in Turbo Pascal, can be obtained by writing to the authors.
lower panel of Table 1 as follows:

\[
\frac{10 + (-2) + (-7) + 7}{4} = 2,
\]

which rounds to 2. An assignment of performance to dimensions is made at the beginning of each run of the simulation. Base performances for all 16 types are derived from this assignment and the firm types may be ranked on this base performance; types having better base performance are regarded as being better fit to the environmental configuration. The assignment of base performance to the types remains stable for 19 periods before changing at the time of the environmental restructuring in period 20; it then remains stable until period 50 when the simulation ends.

Performance in organizational learning models has been modelled as consisting of both a systematic and a random component (Levinthal and March 1981; Herriot, Levinthal, and March 1985; March 1988; Lant and Mezias 1990). Ambiguity is operationalized as a random component in performance. These random components come from a distribution with a mean of zero; the level of ambiguity increases with the variance of the distribution of these random components. Defined in this way, ambiguity directly and differentially affects each firm in the population in determining actual performance in each period. For propositions that do not address the effects of ambiguity directly, our baseline condition is one where the random components are all set to zero: the no ambiguity condition. However, each of these propositions is examined under conditions of no ambiguity, moderate ambiguity, and high ambiguity; results that are substantially altered as a result of different levels of ambiguity are discussed.

**Patterns of Learning: Search Behavior**

The initial search conducted by firms is founding search. During founding search, firms search among the firm types to find the highest performing type, and enter the population as this type of firm. The reasoning behind this founding search follows
from Hannan and Freeman (1987, p. 911): “Some foundings initiate an entirely new form and thus contribute qualitatively to the diversity of organizational forms in society. Most foundings replicate an existing form and contribute quantitatively to diversity.” Their description suggests two characteristics of the founding process: First, the founding process must be effective at replicating types that achieve high performance in the population when the environment is stable. Second, it must include a mechanism for introducing types that will achieve high performance in the new environmental configuration following an environmental shift. The process of organizational founding in this simulation has both of these characteristics; they emerge from a routinized founding search process that determines the type of the organization. Firms in this simulation face a liability of newness; consistent with Levinthal's (1990) arguments about refined risk sets and the liability of small size, we stress the smaller size of young firms as the cause. Following founding search, the amount of search conducted by organizations in this simulation depends on the relative wealth of the organization and a firm specific propensity to search. In addition, firms differ according to the rules governing their search behavior following founding search. It was predicted that different search rules would affect the pattern of organizational change. We examine three search rules that correspond to theoretical perspectives in the organization theory literature.

1. An adaptive perspective argues that change is designed to improve performance (Thompson 1967; Tushman and Romanelli 1985). Organizations with an adaptive strategy search for information that reveals the relationship between organizational characteristics and performance. That is, they determine which mix of organizational characteristics is associated with the highest performance and adopt these characteristics.

2. An institutional perspective argues that organizations change in order to become isomorphic with the characteristics of key firms (DiMaggio and Powell 1983). Key firms, or industry leaders, establish legitimized characteristics. Organizations with this imitative strategy monitor the behavior of industry leaders and change in order to become more like these firms, and thus, more legitimized (Mezias 1990). In this simulation, size functions as the proxy for the designation of which firm is the industry leader. Firms search for and identify the largest organization in the population and adopt the characteristics of this industry leader.

3. A garbage can perspective (Cohen, March, and Olsen 1972) explicitly recognizes the difficulty of planned change; it emphasizes the challenges faced by those who would lead organizations. Following Delacroix, Swaminathan, and Solt (1989, p. 249), we argue that organizational level change can be viewed as the result of “…probabilistic groping along the lines of the garbage can model of decision-making.” The information that these firms gather during their search will suggest the adoption of characteristics that have only a random relationship with performance.

Aspiration Levels, Performance, and Likelihood of Change

Organizations have a target level of performance or aspiration level that adjusts over time in response to performance (March and Simon 1958; Cyert and March 1963); the aspiration levels of firms in this simulation are updated according to the formula estimated by Lant and Montgomery (1987). In each period, a firm determines whether it has performed above or below its aspiration level. The probability that a firm will change one or more characteristics is higher when performance is below aspiration level than when performance exceeds aspiration level (Cyert and March 1963). The exact decision rules governing change are probabilistic. For performance below aspiration level, the probability of change is an increasing function of the size of the discrepancy between actual performance and aspiration level. Thus, the worse
a firm performs, the more likely it is to change. Although the probability of change is highest when performance is below aspiration level, there is a small probability that firms change even when performance is above aspiration level. In these situations, the probability of change depends on serendipity in the form of a conjunction between the discovery of a good opportunity and the will to act on it even in the absence of performance below aspiration level. The likelihood of change is also affected by a randomly assigned firm specific propensity to change. Change is assumed to be costly (Hannan and Freeman 1984), and this cost is assumed to be identical for all firms in the population in all periods.

Simulating a System of Organizations

The assumptions described above are used to simulate a number of organizations over time. In each run of the program, a population of 150 organizations is created and simulated over 50 periods. At birth, organizations in the population are assigned randomly to one of the three search rules and high or low change potential. The firms engage in founding search through the 16 firm types and adopt the characteristics of the type which this search suggests will yield the highest performance. Search rule, search potential, and change potential are fixed at the firm level for the duration of the simulation. The organizations commence experiencing their performance, setting aspiration levels, searching, and changing. A firm goes bankrupt when its resources fall to zero; it is replaced by a random draw from the surviving firm types with positive performance. The new firms are assigned the search rule and propensity to change of the randomly chosen surviving firm. As a result, those values of these characteristics associated with positive performance in the current period are favored by selection pressures. Thus, the ecology created by the simulation is characterized by negative selection; this selection process results in the differential reproduction of superior firm types over time. In all other respects, the replacement firms are assigned characteristics in the same way as at the time of initialization of the population. For example, they engage in the same founding search process and are given the same initial resource allocation. The period in which a firm goes bankrupt is the last period in which it is included in the results. In all subsequent periods, the characteristics of the replacement firms are used in the compilation of population statistics; this is consistent with both theoretical and empirical studies in the ecological paradigm. There is an environmental restructuring in period 20, and the simulation ends in period 50. All results are based on 50 runs of the program, and the results reported represent the characteristics of an average firm in the population.

Results

Discussion

The results of the simulation are presented in figures with numbers that correspond to each proposition. The figures present mean levels across 50 simulated populations over time. The first five propositions do not address directly the effects of ambiguity. The figures presenting support for these propositions are for no ambiguity, our baseline condition. Where differing levels of ambiguity substantially changed the results, figures depicting the results under ambiguity are presented. The relationship between organizational change and environmental conditions is depicted in Figure 1. The figure plots the average number of changes to core dimensions over time; a discontinuous change in the environment occurs in period 20. The number of changes immediately following the initialization of the population increases briefly then declines until period 20. At period 20 the mean number of changes rises abruptly and then begins to decrease again immediately. By period 30 the number of changes has
fallen almost to pre-restructuring levels. The trend in the mean number of changes over time suggests that firms change in response to key population life cycle events: initialization of the population and environmental restructuring.

Figures 2 and 3 show the effects of two types of routines on the relationship between organizational and environmental change. Figure 2 shows the mean number of changes by three search rules: adaptive, imitative, and garbage can. Following a founding search process which allows firms to find high-performance types, only garbage can firms change prior to the environmental restructuring. The average level of change in this group decreases over time until period 20, when the restructuring occurs. Adaptive firms exhibit the highest level of change in response to the environmental restructuring; thereafter their level of change drops to about zero for the remainder of the simulation. Imitative firms do not have an immediate response to the restructuring; their number of changes does not increase until two to five periods after the restructuring before dropping off to about zero by the tenth period following the restructuring. Like the adaptive firms, garbage can firms have their highest level of response during the period of the restructuring, but this level is less than half that
of the adaptive firms in the same period. Their level of change decreases slightly, but levels off at 0.1, a higher level than that of adaptive or imitative firms.

The relationship between change potential and mean number of changes is illustrated in Figure 3. As expected, firms with high and low change potential exhibit different patterns of change. Low change potential firms exhibit fewer changes than firms with high change potential following the periods of initialization and restructuring. By nine periods after initialization and eight periods after the restructuring, the difference in average levels of change between high and low change potential firms all but disappears. This trend in the relationship over time is particularly interesting; it suggests that differences between the two groups of firms decrease with time following key population life cycle events: initialization of the population and environmental restructuring.

Figures 4 and 5 illustrate the effect of past performance on the responsiveness of organizations. The direct effect of performance on patterns of change is demonstrated in Figure 4 by comparing the number of changes made by firms performing above and below the median performance in the population. Figure 4 also reports median level of performance, the interquartile range of performance, and the overall range of performance at ten-period intervals to aid with interpretation of the figure.
Although both high and low performing organizations make the same number of changes during the periods immediately following initialization of the population and environmental restructuring, the pattern of changes is different thereafter. High performing firms exhibit a smooth decrease in number of changes following both initialization and restructuring; this number stabilizes near zero by period 3 following initialization and period 29 following the restructuring. The low performing firms exhibit less of a decline following initialization and a less smooth response following the restructuring. In the first periods after the restructuring poor performers change less than high performers. However, poor performers increase their number of changes in periods 23 through 26. After period 26, poor performers exhibit a decrease in number of changes for the remainder of the simulation, but the level of change remains higher than that of high performers.

Figure 5 compares the number of changes for firms smaller than the median size and those larger than the median; median size, the interquartile range of size, and the overall range of size at ten-period intervals are also listed to aid with interpretation of the figure. Small firms exhibit a greater number of changes than large firms after the initialization of the population. Both groups exhibit a decrease in the number of changes from periods 3 through 19; for large firms changes drop immediately to just above zero, while for small firms changes drop more gradually to about 0.1 just before the environmental restructuring. Small firms then make more changes than large firms in response to the restructuring. Immediately after restructuring, however, the number of changes for both groups is about equal and decreases to near zero by period 36. Small firms maintain a slightly higher rate of change through period 50.

The effect of ambiguity on the responsiveness of target-oriented organizations is illustrated in Figures 6 and 7. The relationship between ambiguity and sensitivity to performance signals is demonstrated in Figure 6. Sensitivity to performance is measured by the randomly assigned firm specific characteristic called change potential, distributed symmetrically around zero. Firms born with positive values of change potential are more likely to change than firms with values less than zero. Average change potential starts at about zero, as would be expected given random assignment of the variable. Under high ambiguity, change potential begins to decrease rapidly through period 15; it then decreases gradually, stabilizing at about \(-0.11\) from period 33 through 44, and increases slightly thereafter. Change potential for firms under no
ambiguity and moderate ambiguity begins to decrease in period 5, with the decrease being equal for both groups of firms. Under no ambiguity, change potential begins to increase in period 20 when the environment restructures, and shows a fairly rapid increase for the remainder of the simulation. By period 38, the mean change potential for no ambiguity firms is greater than zero. For moderate ambiguity, change potential continues to decline until about period 25, when it stabilizes at about \(-0.075\).

The effect of ambiguity on firms’ responsiveness to the environmental restructuring is also illustrated in Figure 7, which shows the effects of three levels of ambiguity on the number of changes. Firms under no ambiguity exhibit a pattern similar to that seen in Figure 1. The number of changes is high during the period of restructuring, drops quickly thereafter, shows a small second increase in period 24, and then declines throughout the simulation to a level near zero. Changes for firms under moderate and high ambiguity exhibit a pattern that is less of a function of environmental change. The level of change for these firms decreases only slightly after the restructuring, and then remains fairly stable throughout the simulation at a level higher than that of no ambiguity firms.
Unanticipated Results

The results of the simulation are generally consistent with the predictions of an evolutionary model of convergence and reorientation (Tushman and Romanelli 1985). There are, however, aspects of the results not necessarily anticipated by an evolutionary model that are worth noting. Figure 1 exhibits an unanticipated increase in mean number of changes in period 2. This increase is the result of two characteristics of the simulation. First, although firms conduct a founding search in order to enter the population as a good performing type, they are randomly assigned other fixed characteristics such as search rule and change potential. These characteristics may result in a less than perfect fit with the environment, leading to these early changes. In short, birth of the population may be as traumatic as an environmental restructuring. As more appropriate levels of these characteristics are selected for, the number of changes tends to decrease during the periods of environmental stability that follow initialization. Second, all firms in period 1 have the same initial allocation of resources and the same aspiration level. Since the impetus for change depends on aspiration level and relative wealth, firms in period 1 do not perform below their aspiration, and thus do not change. By period 2 there is variance in relative performance and aspiration level; those firms that perform below their aspiration level start changing.

It was predicted that the pattern of changes for low and high change potential firms would differ. Figure 3 indicates that these differences occur only following initialization of the population and environmental restructuring. A similar pattern in the number of changes over time is found in Figure 4, which compares the number of changes of large and small firms. Although small firms exhibit a higher level of change than large firms, the difference occurs during initialization and environmental restructuring and thereafter decreases over time. The gap narrows between initialization and restructuring and following restructuring. The pattern of change exhibited in Figures 3 and 4 can be explained by two processes that occur in this ecology. First, high change potential firms and small firms exhibit greater responsiveness to the initialization of the population and the environmental restructuring than low change potential and large firms. These firms make most of their changes soon after these events, and thus exhibit few changes for the remainder of the simulation. Second, the differential selection of firms with different search rules contributes to the decrease in the number of changes over time. Imitative and adaptive firms tend to be selected for,
while garbage can firms tend to be selected against. Garbage can firms maintain a higher level of change than imitative and adaptive firms during environmental stability. Thus, the negative selection of garbage can firms results in an overall decrease in average change in the population. Such a result suggests the importance of understanding the dynamics of the selection process with respect to a wide range of organizational characteristics in order to understand the patterns of change exhibited by a population of organizations.

In addition, the unanticipated disappearance of the difference in number of changes made by large and small firms following the environmental restructuring seems to be mediated by the level of ambiguity. Figure 5 presents the results for the baseline condition, no ambiguity; the results indicate that there is little difference in mean number of changes for firms above and below the median size in the population. Figure 8 compares the number of changes made by firms above and below the median size under conditions of moderate ambiguity; median size, the interquartile range of size, and the overall range of size at ten-period intervals are also listed to aid with interpretation of this figure. The main difference between Figures 5 and 8 is that the difference in mean number of changes made by firms above and below the median size seems to be maintained in the ambiguous condition. This suggests that part of the underlying causality for the relatively greater inertia of large firms is selection of less responsive firms under ambiguity (cf. Figure 6).

Figure 6 illustrates an unanticipated pattern with respect to the change potential of firms under no ambiguity. Mean change potential for these firms decreases until period 20, when the environmental restructuring occurs. Subsequently, change potential for these firms increases for the remainder of the simulation. This pattern indicates that sensitivity to changes in performance is selected against during periods of environmental stability, but is selected for following a period of environmental change. This suggests that the timing of environmental changes may have important effects on the ability of organizations to respond to them. If change potential is selected against during periods of environmental stability, as suggested by the first 20 periods of Figure 6, then populations of organizations that have experienced long periods of stability may find themselves ill-equipped to deal with environmental change. The rise in average change potential after the restructuring for firms under no ambiguity suggests that a higher level of responsiveness enhances survival following the environmental restructuring. This raises the intriguing possibility that selection pressures at one point in time may result in the selection of firms not well suited to future environmental configurations. Figure 6 also illustrates how ambiguity mediates the differential selection of change potential. Under conditions of ambiguity, the effect of the restructuring on the selection of change potential is moderated relative to the unambiguous condition. Instead of sloping upward, the curves for the moderate and high ambiguity conditions merely flatten out. When performance signals are noisy, the negative selection against high change potential moderates following the restructuring, but does not reverse itself.

Figure 7, which illustrates the effects of ambiguity on number of changes, had two patterns of change that were not anticipated. First, firms under moderate ambiguity stabilize at a slightly higher level of change than firms under high ambiguity. We believe that the explanation of this result lies in the increasing selection of low change potential firms as the level of ambiguity increases. Second, firms under no ambiguity exhibit a secondary rise in number of changes in period 4 after the restructuring. This effect can be explained by the mix of search rules in this group. As is seen in Figure 2, imitative firms exhibit a delayed reaction to the environmental

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3 The result is the same for the high ambiguity condition.
restructuring. This is due to the characteristics of the imitative search rule, which leads to change only when an imitative firm is not the same type as the largest firm in the population. The firm that is the largest prior to the restructuring is likely to maintain its relative size for some time after the environmental restructuring. However, the size of the original industry leader eventually declines, and a firm that is a high performing type under the new environmental configuration eventually becomes the largest firm in the population. Once a new industry leader emerges, imitative firms discover this in their search process and begin to change. Thus, the pattern of change for firms under no ambiguity illustrated in Figure 7 is a combination of the pattern exhibited by adaptive firms, which respond immediately to the restructuring, and that of imitative firms, which show a delayed response.

These unanticipated results highlight the importance of considering three factors that affect the pattern of organizational change: differential selection of organizational characteristics, environmental variability, and ambiguity. The importance of these factors as well as their interactions are illustrated clearly in Figure 6. Differential selection of firms with different propensities to change is demonstrated by varying levels of change potential in the population. The importance of longitudinal response to environmental restructuring is seen by the shift in the lines indicating mean change potential during the period of the restructuring; this shift is particularly pronounced in the no ambiguity condition, which actually begins to rise, while the others only level off. The importance of ambiguity can be seen in the differences in mean change potential for three levels of ambiguity. Average change potential under high ambiguity is lower than under moderate and no ambiguity. The interaction between selection, environmental restructuring, and ambiguity is demonstrated by the following: The slope of the line indicating average change potential in the no ambiguity condition changes direction following the restructuring. This suggests that the effect of selection pressures on high change potential firms is altered following the restructuring under no ambiguity. Conversely, the slopes of the lines under moderate and high ambiguity flatten out, indicating a somewhat different alteration of the effect of selection pressures on high change potential firms.

Conclusions

The learning model of convergence and reorientation presented in this paper has paralleled much of the literature on organizational stability and change (Cyert and March 1963; Lawrence and Lorsch 1967; Hannan and Freeman 1984; Tushman and Romanelli 1985). However, the insights of a learning model are different from much of this work in at least three areas. First, the model developed here highlighted the importance of considering longitudinal dynamics in making predictions about organizational convergence and reorientation. Unconditional statements about the universal value of particular strategies are called into question: A learning model produces many of the results predicted by the punctuated equilibria framework while avoiding claims about the universal functionality of consistency (Duncan and Weiss 1979; Tushman and Romanelli 1985), longer and less turbulent periods of convergence (Tushman and Romanelli 1985), and particular patterns of top management team demography, promotion, and succession (Allen and Panian 1982; Tushman and Romanelli 1985). Claims about effectiveness need to be couched in explicitly longitudinal terms with clear conditions for their applicability. The difficulty of making such claims is suggested by Figure 6, especially in the no ambiguity condition. The results demonstrate that selection pressures at one point in time can hinder learning in a new environmental configuration (Hedberg 1981; Lant and Mezias 1990). Such considerations speak to the applicability of a learning model of organizational
convergence and reorientation, with a particular emphasis on the ways that seemingly functional responses become competency traps (Levitt and March 1988) and the complicated dynamics that can be produced in a population of organizations characterized by a few simple routines (Lant and Mezias 1990).

Second, the learning model suggests a similarity in the internal processes which generate convergence and reorientation. This is in contrast to the evolutionary perspective: “Organizational processes are fundamentally different between convergent periods and reorientations” (Tushman and Romanelli 1985, p. 215). Specifically, models of organizational learning processes suggest a variety of ways in which mundane organizational activities sometimes lead to surprises such as reorientation (March 1981; Harrison and March 1984; Levitt and March 1988). The same processes that lead to first-order learning and convergence can provide the raw material for second-order learning and reorientation. The main impediments to second-order learning and change in this learning model are the redundancy and paucity of experience; this is similar to Tushman and Romanelli (1985), but with a focus on ‘interpretations’ of experience, especially in terms of search rules, aspiration levels, and propensity to change. However, the learning model adds the explicit recognition that normal organizational routines sometimes provide the equivocal experiences which lead to second-order learning and change. Thus, the simulation demonstrated that organizations whose behavior was guided by simple experiential learning routines that did not change over time exhibited patterns of change consistent with a punctuated equilibria perspective.

Third, the learning model of organizational convergence and reorientation de-emphasizes the role of executive leadership in comparison to much of the literature on strategic management and change (Child 1972; Miles 1982). Tushman and Romanelli (1985) maintain this emphasis on executive leadership throughout their discussion of convergence and reorientation; Tushman, Newman, and Romanelli (1986) push the importance of executive leadership even further, assigning causality for successful performance and adaptation to visionary leadership. By contrast, learning models call attention to the possibility that success has a stochastic element (March 1988); thus, it becomes important to distinguish between two possible processes that might produce the repeated success that distinguishes consistently high performing organizations. The first is having a strategy which is more effective in some ‘objective’ sense. The second is stochastic success, e.g., a lucky draw from the distribution of performance outcomes. There is an ex-post attribution problem when success resulting from the second process is interpreted to signal the efficacy implied by the first process. This ex-post attribution problem is exacerbated in a system where early success tends to become a self-fulfilling prophecy (March and March 1977) or where organizational growth is a random walk process (Levinthal 1990). In the former case, stochastic early success has a halo effect which translates into a greater probability of subsequent success. In the latter case, stochastic early failure is fatal, and those organizations that accumulate enough stochastic early successes are buffered from the effects of subsequent failure.

In the simulation presented here, choices about search rules and propensities to change were made through a random assignment. After this assignment, these characteristics were assumed to be inert. The change in core dimensions that did occur was governed by fairly simple rules about search and change. Still, with all these simplifying assumptions, the organizations in this simulation demonstrated many of the patterns suggested by Tushman and Romanelli (1985). In this way, the role of management was reduced to a probability distribution; this view follows from a logic which emphasizes that (March and March 1977, p. 377) “...there are some reasons for anticipating that careers in top management in many social systems would
tend to be nearly random events involving nearly indistinguishable managers.” It is important to make clear that our view of the role of leadership is quite distinct from the nihilistic conclusion that managers do not matter. Managers occupy well-defined social positions that require a complex bundle of skills to perform competently; as with, for example, championship skiers, the fact that luck may play a large role in determining who wins which prize on which day does not mean that an unskilled novice could descend the slope and win. However, the larger the role of luck, the more difficult it becomes to determine that success is associated with the characteristics of the particular organizations that experience it. Further, the more complex and ambiguous the context, the more problematic such assertions become.

In conclusion, a learning model directs research attention to the fact that most organizational change is produced by conventional, routine activities performed by reasonably competent organizations in ordinary ways. Thus, we would emphasize that (March 1981, p. 575) “[t]ypically, it is not possible to lead an organization in any arbitrary direction that might be desired, but it is possible to influence the course of events by managing the process of change, and particularly by stimulating or inhibiting predictable complications and anomalous dynamics. Such a view of managing organizations assumes that the effectiveness of leadership often depends on being able to time small interventions so that the force of natural organizational processes amplifies the interventions.” This first attempt at using a learning model to understand convergence and reorientation has concentrated on exploring system dynamics to discover some possible complications and anomalous dynamics. Choices about search rules and propensities to change were made through a random assignment and reproduced through differential selection. At the level of the individual organization, these characteristics were assumed to be inert. A fuller exploration of the role of management in such systems, following from the view expressed above, is a logical next step. A first pass at such an exploration of the role of management might involve relaxing the assumption of inertia with respect to these characteristics. The exploration of alternative possibilities for specifying the switching rules that organizations might employ in changing any of these parameters is a useful way to explore the possibility of successful managerial intervention. The application of simulation methodology to questions of strategic management and the use of the population as the unit of analysis serve as useful reminders that system dynamics limit the frontiers of individual efficacy and the possibilities for managerial leadership. We believe that the most useful avenues for understanding the role of leadership in organizations must stay within these bounds. More importantly, these bounds delineate a focus for the study of the role of management which can serve as a useful guide for both theory and practice.

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Appendix: Rules Governing Search, Learning, and Change

The following appendix specifies the rules governing the simulation and the choices of parameter values. To the extent possible, we have used empirical estimates to set parameter values. Where no empirical estimates were available, values were set to be consistent with prior theory. The sensitivity of the results to these values is explored at the end of the appendix. In addition to specific parameter values, we have made a number of other simplifying assumptions. For instance, firms in the simulation do not increase their
competency with activities over time. The capability of firms to move from one type to another does not depend on size. There are no barriers to entry from capital requirements or returns to scale. Although Tushman and Romanelli (1985, Proposition 12) suggest some factors that affect the probability of success with a reorientation, in this simulation the probability of successful execution of a change, once the organization has decided to undertake it, is unity. The stochastic element of change is embedded in the decision to undertake it, as discussed below in Rules Governing Change.

We have also made crucial decisions by adopting several assumptions from Hannan and Freeman (1977; 1984) and creating organizations that are relatively inert with respect to certain characteristics. Thus, we do not consider the possibility that management can choose to alter their search rules, change potential, or aspiration level adjustment parameters. These characteristics are assigned to a firm randomly at the initialization of each run of the simulation and are fixed for the life of the firm; the effect of managerial choice with respect to these characteristics is reduced to a probability distribution. Since we assume that management discretion is limited after founding, this study does not address the argument that turbulent convergent periods will lead to greater internal dissensus and less resistance to change (Tushman and Romanelli 1985, Proposition 5, p. 194), or the argument about the relationship between organizational effectiveness and characteristics of organizational demography or promotion patterns (Tushman and Romanelli 1985, Proposition 7, p. 196).

Firm Types and Base Performance

Firms are characterized completely by four dimensions; on each of these dimensions, the firm has a value of one or zero. The result is 16 distinct combinations of zeros and ones, each of which represents a distinct firm type. Each type can be depicted as a unique four-digit combination of zeros and ones. Each of the four dimensions is assigned a performance level for both of the alternative characteristics which firms can adopt on that characteristic. In order to avoid the possibility that performance could be negative for all alternatives on all dimensions, the rule that at least one of the alternatives on all dimensions had to offer the possibility of nonnegative performance was imposed. The randomly assigned performance level assigned to characteristics on each dimension is an integer between −20 and 20 which reflects the degree of fit between the environment and organizations which have the given alternative for the given dimension. The base performance of each of the 16 types is the mean of the performance assigned to each of the characteristics on the four dimensions. This assignment is fixed until period 20, when the discontinuous change in the environment takes place. At this time, all 16 firm types are assigned a new base performance by the process described above. This relationship then remains fixed for the remaining periods of the simulation. The calculation of base performance, \(BP_{k,t}, k = 1, \ldots, 16, t = 1, \ldots, 50\), from a combination of 4 dimensions can be seen in Table 1. For instance, Type 1 carries a score of 1 on each of the 4 dimensions, and thus is a 1111. Base performance is calculated by taking the mean of performance assignments for a firm which is a 1 on each dimension and rounding that mean to the nearest integer. Assuming that \(t = 1\), then the expression to compute the performance of a Type 1 is given by: \(BP_{1,1} = (0 + 6 + (-7) + 8)/4 = 4\). The reassignment of base performance after an environmental restructuring can be seen by comparing the Upper and Lower Panels of Table 1. For example, using the numbers in Table 1, Upper Panel, \(BP_{1,1} = 4\), \(BP_{2,1} = 2\), and \(BP_{16,1} = -3\). While the environment is stable, the relationship between each firm type and its performance does not change. However, when the environmental restructuring occurs, the relationship between performance and firm type is likely to change due to the new random reassignment of firm types to performance. This is shown in Table 1, Lower Panel. Beginning in the period following the restructuring, \(BP_{1,20}\) is 2, \(BP_{2,20}\) is 6, and \(BP_{16,20}\) is 2.

Performance and Resources

\(P_{it}\), the performance of firm \(i\) at time \(t\), consists of a systematic component, related to its firm type, and a random component which is different for each firm in each period. This is summarized by the following expression: \(P_{it} = BP_{kt} + \mu_{it}\). As defined above, \(BP_{kt}\) is the base performance of type \(k\) at time \(t\), the value of \(k\) depends on the type of firm \(i\). In the unambiguous condition, \(\mu_{it}\) is zero; in the moderate ambiguity condition, \(\mu_{it}\) is a draw from the uniform distribution of integers between −10 and 10 for firm \(i\) at time \(t\); in the high ambiguity condition \(\mu_{it}\) is a draw from the uniform distribution of integers between −20 and 20. Performance, whether negative or positive, is added to total resources in each period. The following expression describes this process: \(R_{it} = R_{it-1} + P_{it}\), where \(R_{it}\) denotes the resources of firm \(i\) at time \(t\), and \(P_{it}\) is defined as above. Firms receive an initial resource allocation of 35 units. This value is chosen so that a firm which experienced the median worst possible performance could survive for 5 periods. This initial resource allocation produces a liability of newness due to small size, but allows firms some time to adjust to the environment before they are selected out of the population. When a firm’s resources go to zero or below, it is eliminated from the population and is no longer included in the computation of population statistics to compile the results. That firm is then replaced by a random draw from the surviving firms with positive performance at time \(t\); the new firm inherits the firm type, search rule, search potential, and change potential of the random firm which is selected. The results reported here are most likely quite
sensitive to this treatment of births and deaths; it is justified by its consistency with both theoretical and empirical work in the ecological perspective.

**Aspiration Level Updating**

Aspiration level formation is based on performance, \(P_{it}\). In the initial period, aspiration level \(AL_{it}\) is set to 0.5. In each subsequent period, aspiration levels adjust to the current performance by a weighted average formula as estimated from the data of Lant and Montgomery (1987):\(^4\)

\[
AL_{it} = 0.15736 + 1.0987(AL_{it-1}) + 1.2571(AD_{it-1})
\]

where \(AL_{it}\) is the current aspired level of performance for firm \(i\) at time \(t\). \(AD_{it-1} = P_{it-1} - AL_{it-1}\) is defined to be the attainment discrepancy in the last period, that is, last period aspiration level minus the last period performance.

**Rules Governing Search**

The initial search conducted by firms is founding search, which takes place at the beginning of the organizational lifecycle to determine the characteristics of the organization to be founded. In keeping with the population ecology literature, founding search is modeled as an attempt to discover the relationship between firm type and performance. In this way, new firm types can be introduced to the population and existing types can be replicated. We have assumed that this occurs without ambiguity. All firms in the population search at founding through some subset of the \(K\) firm types choosing the type that satisfies the following relation: \(\text{Max}_i F_{Pi}^{ik}\). The decision rule is that firm \(i\) founded at time \(t\) becomes the type that founding search has revealed to have the highest base performance.

Subsequent to founding search, firms may search the environment for information about the relationship between the characteristics of firms and survival, size, or performance. In any period, a firm may choose to expend resources on search. The amount of resources dedicated to search by a firm depends on the amount of resources available\(^5\) and a firm specific propensity to search, \(SP_{it}\), called search potential. \(SP_i\) is a random draw from the integers \(-1\) and \(1\). The maximum number of searches a firm will conduct in a given period is binomial with \(n = 4\) and the probability of a search given by \(\pi_{it}\). \(\pi_{it}\) is defined to be equal to \((RR_{it} + SP_i)/2\), with \(SP_i\), the search potential of firm \(i\) defined as above. \(RR_{it}\), defined to be the relative resources of firm \(i\) at time \(t\), is a measure of relative wealth; the resources of firm \(i\) are stated as a proportion of the resources of the largest firm in the population at time \(t\). This quantity is denoted \(RR_{it} = R_{it}/\text{Max}_i(R_{it})\), where \(R_{it}\), as above, measures the resources of firm \(i\) at time \(t\) and \(\text{Max}_iR_{it}\) denotes the resources of the largest firm at time \(t\). Each search uses 1.75 units of resources; this is the cost of search associated with each search a firm makes in each period, regardless of the type of search. The cost of each search is equal to 5% of the initial resource allocation. This means that a firm that does all possible searches in every period would die after 5 periods given the initial resource allocation.

We impose the rule that search starts from the neighborhood of current firm type (Cyert and March 1963). Four types of searches may take place. The first type of search involves examination of the types of firms that the searching firm would become by changing only one dimension of its structure. For example, a firm characterized by 1111 would look at types 1110, 1101, 1011, and 0111. The second type of search involves examination of all the changes of two dimensions. The third type of search involves examination of all the changes of three dimensions. Finally, the fourth type of search involves examination of the type that the firm would become if it changed all dimensions simultaneously. Firms follow different rules for making these 4 types of searches depending on the search rules elaborated below. The purpose of search is to collect information to guide organizational change; in the absence of guidance from search, changes do not occur.

**Adaptive Search Rule.** The adaptive search rule tries to discover the true underlying relationship between firm type and performance, as given, for example, in Table 1. These firms try to determine which changes to the firm’s type will improve performance. For a given number of changes, adaptive firms determine which of these changes will yield the highest base performance. For example, if a firm is a 1111, the base performance of 1111 is compared with that of 1110, 1101, 1011, and 0111, to determine which change to a single dimension will enhance performance the most. Analogous processes take place for changes of two, three, and four dimensions. Firms store this information; when the decision is made to

\(^4\)The constant term used here restates the actual estimate of the constant as a percentage of the average initial allocation of dollars to firms in the Lant and Montgomery (1987) sample.

\(^5\)Thus, search depends indirectly on whether performance is above or below aspiration level. However, no distinction is made here between problemistic search, normally thought of as occurring when performance is below aspiration level, and slack search, normally thought of as occurring when performance is above aspiration level (Cyert and March 1963; Levinthal and March 1981).
make a certain number of changes to the characteristics of the firm, the results of search are used to choose from among change possibilities. Thus, adaptive firms tend to adopt the characteristics of firm types with high base performance. The process of comparing two firm types proceeds as follows. The firm measures the effect of changing from type $k$, its current type, to type $l$, some different firm type, by examining the following expression: $D_l = BP_{l,t} - BP_{k,t} + \mu_{ijkl}, l \neq k$. In the unambiguous condition, $\mu_{ijkl}$ is zero; in the moderate ambiguity condition, $\mu_{ijkl}$ is a draw from the uniform distribution of integers between $-10$ and $10$ for firm $i$ at time $t$ and each type $l$ with which it compares itself; in the high ambiguity condition, $\mu_{ijkl}$ is a draw from the uniform distribution of integers between $-20$ and $20$. If $D_l$ is positive, then the number of changes, $NC$, required to change from type $k$ to type $l$ is counted. If $BP_{l,t} - BP_{k,t}$ is the largest positive value among all changes which require the same number of changes as the transition from $k$ to $l$, then the result of search, $S_{NC}$, $NC = 1, \ldots, 4$, is the retention of the largest change in performance that will result from a change to NC dimensions. For example, a Type 1, denoted 1111, operating in an ecology without ambiguity and with the relationship between performance and type depicted in the Upper Panel of Table 1 would have a value of 3 for $S_3$. This is true because the change of one dimension that would result in the biggest increase in performance would be to change to Type 3 with a base performance of 6.

Imitative Search Rule. Firms using an imitative search rule determine the largest firm in the population, and focus their search process on this firm. They determine whether this firm is of a type that would require 1, 2, 3, or 4 changes to core dimensions. The result of search for a given number of changes, $S_{NC}$, is zero unless that is the number of changes required to move to the firm type of the largest firm in the population. In this case, $S_{NC*}$, is the number of the firm type containing the largest firm in the population. For example, assume that a firm of Type 1 from Table 1, Upper Panel, is doing an imitative search. If the largest firm were a Type 16, four changes would be required. Thus, $S_1$, $S_2$, and $S_3$ would be set equal to zero, and $S_4$ would equal 16.

Garbage Can Firms. For garbage can firms search results in random noise. Their search provides no real information about firm types or corresponding performance. For example, consider two firm types: $k$ is the current type of the firm, and $l$ is a different firm type. When garbage can firms compare the type which they are currently with another type, the procedure is as follows. The firm measures the effect of changing from type $k$ to type $l$ by examining the following expression: $D_l = p_{jl}, l \neq k$. $p_{jl}$ is a draw from the uniform distribution of real numbers between $-1$ and $1$. If $D_l$ is positive, then the number of changes, $NC$, required to change from type $k$ to type $l$ is counted. $D_l$ is compared for all changes requiring the same number of changes as the transition from $k$ to $l$. The largest nonnegative value of $D_l$ for this number of changes is determined, and $S_{NC}$, $NC = 1, \ldots, 4$, is set equal to the corresponding firm type. If there are no positive draws for that number of changes, $S_{NC}$ is set equal to zero. Despite the fact that this information is not related to performance, the firms use it as the basis for making changes to firm structure.

Rules Governing Change

Failure-Induced Change. The likelihood that a firm will change one or more core dimensions depends on its performance relative to aspiration level and a firm specific propensity to change, $CP$, called change potential. $CP$ is a random draw from the integers $-1$ and $1$. In response to performance below aspiration level, firms increase their likelihood of changing some aspect of their type. Each change to one of the core dimensions uses 10% of the firm's resources. The maximum number of changes that a firm will make in a given period, denoted $C_{it}$, is distributed binomial ($4, \pi$). The determination of $\pi$ depends on whether performance is above or below the aspiration level. Failure induced change occurs when performance falls below aspiration level; thus, these rules apply only if $AD_{it} < 0$. The number of changes they will consider is related to the size of the attainment discrepancy. For $\pi = 4$ and

$$\pi = \frac{-AD_{it}}{2\max(\{-AD_{it}\}) + CP_{it}^2}.$$  

$AD_{it}$, the attainment discrepancy of firm $i$ at time $t$, and $CP_{it}$, the change potential of firm $i$, are as defined above. $\max(\{-AD_{it}\})$ denotes the largest negative attainment discrepancy in the population at time $t$. Thus, the probability of a change in the firm's structure is equal to the negative of the attainment discrepancy as a percentage of the magnitude of the largest negative attainment discrepancy in the population at time $t$ plus one-half times its change potential. Provided the $C_{it}$ observation from this distribution is greater than zero, firms make changes in accordance with the results of search. Adaptive and garbage can firms will make $NC \leq C_{it}$ changes according to a comparison of the best change in performance which search suggests will result from making no more than $C_{it}$ changes. The imitative firms change if and only if
$C_{it} \geq NC^*$, where $NC^*$ is defined to be the number of changes required for the firm to become the type that its search has revealed to be that of the largest firm in the population.

**Slack Change.** A firm with performance above aspiration level will change under limited circumstances. Specifically, a random real number between 0 and 1 is generated. If that number exceeds 0.95 and the results of at least one search are greater than zero, then the firm will change. Results of search are held indefinitely, but are eliminated each time the firm changes its type. In the absence of guidance from search, changes do not occur.

**Levels of Ambiguity**

Ambiguity is defined as variance in the relationship between firm types and performance; this is true both for the computation of firm performance and adaptive search. In the unambiguous condition, the variance of the random components $\mu_{ij}$ and $\mu_{jit}$ is zero for all comparisons. Thus, the variance in the relationship between performance and firm type is zero, and firm type predicts performance perfectly. In the moderate and high ambiguity conditions, the variance in the relationship between performance and firm type, $\sigma_p$, is equal to the variance of the uniform distributions of $\mu_{ij}$ and $\mu_{jit}$ described above. The variance of a uniform distribution is equal to the range of the distribution squared divided by twelve.

**Sensitivity Analysis**

The sensitivity of our results to different parameter values has been explored. A range of performance draws from −10 to 10 is tested along with the range of −20 to 20 used in the reported results. Three levels of ambiguity are tested: under no ambiguity $\mu_{ij} = 0$; under moderate ambiguity $\mu_{ij}$ ranges from −10 to 10; under high ambiguity $\mu_{ij}$ ranges from −20 to 20. Three slack change parameters are tested, 0.90, 0.95, and 0.975. The impact of the various levels of these three parameters is examined with an ANOVA analysis with mean number of changes in the population as the dependent variable. The results of the ANOVA suggest that the range of performance draws, either 10 or 20, is significant. We have examined all of the plots in the paper using the range of 10 rather than 20; there is no qualitative change to the results. The ANOVA also suggests that the three levels of ambiguity make a difference; where this changed our results we have incorporated the differences into our discussion. The impact of levels of ambiguity can be seen directly in Figures 6, 7, and 8. The levels of the slack change parameter, chosen to approximate what we believe to be a sensible range, make no difference. The interactions of range of performance and level of ambiguity are also significant; again, this made no qualitative difference to the results we report. The two-way interactions with level of slack change and the three-way interaction were not significant. Finally, an earlier version of this paper tested the same propositions and argument using random assignment of performance to the 16 types rather than random assignment of performance to dimensions which then determines the performance of types. Again, the qualitative thrust of the conclusions we draw here is unchanged by this difference.

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