Problems and Paradoxes in a Model of Punctuated Organizational Change

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A simulation model that formalizes the conventional theory of punctuated organizational change highlights a problem: under a wide range of conditions, organizations appear to fail following reorientation. I propose additions to the theory to account for punctuated transformation. The first adds a routine for monitoring organization-environment consistency; the second is a heuristic that suspends change for a trial period following a reorientation. I show the necessity of the trial period in simulations demonstrating that, while external events may set the pace of organizational change in some environments, under turbulent conditions successful change requires internal pacing, which suspends performance evaluation for a period following a reorientation.•

How do organizations undergo fundamental change? The question is important to managers in an era of globalization, intense competition, and unpredictability. The question is important to theorists, too: Perrow (1994) has argued that explaining change is—or should be—a central concern for organizational scholars today. Differing theoretical perspectives on organizations have been linked to differing predictions of whether and how organizational change takes place (Astley and Van de Ven, 1983). Despite the important theoretical and practical implications of understanding organizational change, the organizational processes involved in transformational change have not been fully explored. Critics of the existing research argue that, too often, the causal structures of the theories are not fully specified and that theoretical frameworks and empirical results are not well integrated. Recent studies surveying a large number of theories (Van de Ven and Poole, 1995) and reviewing empirical results (Barnett and Carroll, 1995) underscore the need for more work in this area.

To extend our understanding of organizational change, I take an alternative approach: I examine an existing theory in detail, formalizing it to investigate how well the theory accounts for the phenomena its authors set out to explain. My focus is Tushman and Romanelli's (1985) theory of organizational change, in which organizations undergo occasional dramatic revolutions or punctuations to overcome organizational inertia and set a new course for the organization to follow. Because it is relatively detailed and explicit, the causal argument Tushman and Romanelli present serves as an ideal foundation for a systematic exploration. My approach is designed to examine the completeness, consistency, and parsimony of the causal explanation laid out in an existing theoretical model. One precedent for such an approach is Péli and colleagues' (1994) work using first-order logic to analyze organizational theory. Although first-order logic has proved useful in identifying gaps in the logical structure of a natural-language theory, explicitly causal theories cannot easily be represented with the approach (Péli et al., 1994: 586–587). Because action is central to theories of organizational change, a causal modeling approach suitable for capturing dynamics is needed instead. I use such a method here to formalize verbal descriptions of causal relationships.

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Punctuated Change Models

Tushman and Romanelli's 1985 paper described an evolutionary process through which organizations alternate between two modes of behavior. During long, stable periods of an organization's life, labeled convergence, change is restricted to incremental adjustments that consolidate already-chosen strategic orientations. The organization experiences revolutionary shifts in relatively infrequent and short periods of dramatic changes, called reorientations or recreations. Others have identified both theoretical frameworks and empirical evidence that lend support to the proposition that organizations change strategic orientation through such rare transformative events (e.g., Miller and Friesen, 1980; Greenwood and Hinings, 1988; Gersick, 1991; Amburgey, Kelly, and Barnett, 1993). In explaining punctuated change, researchers have devised new ways to juxtapose, differentiate, and reconcile divergent models of organizations. In particular, by showing how the same organization may exhibit two different modes of behavior—adaptive and inertial—at different times, punctuated change models provide a means for integrating the strategic management and adaptationist views of organizations as readily changeable (Thompson, 1967; March, 1981) with the population ecology view, in which environmental selection is the primary mechanism for changes in organizational populations (Hannan and Freeman, 1989).

Punctuated change models have widely influenced contemporary thinking about how organizations change. For instance, over the past decade, Tushman, Romanelli, and their colleagues have developed a productive research program built on issues of technology management and executive leadership (e.g., Tushman, Virany, and Romanelli, 1985; Anderson and Tushman, 1990; Keck and Tushman, 1993; Romanelli and Tushman, 1994). Other recent work has integrated the punctuated change thesis with such perspectives as the clock-resetting process, in which organizations enjoy increased freedom in the period immediately following a revolution (Amburgey, Kelly, and Barnett, 1993), a capabilities-based view of Schumpeterian change (Levinthal, 1992), an organizational learning model in which aspiration adjustment leads to lower performance over time (Lant and Mezias, 1992), a theoretical model of organizational downsizing (Freeman and Cameron, 1993), and the coevolutionary view, in which technology and organization influence each other over time (Van de Ven and Garud, 1994).

Empirical research into the pattern of punctuated organizational change has found support for the theory in a range of industries, including airlines (Kelly and Amburgey, 1991; Miller and Chen, 1994), savings and loans (Haveman, 1992), minicomputers (Tushman, Virany, and Romanelli, 1985), cement (Anderson and Tushman, 1990), and newspapers (Amburgey, Kelly, and Barnett, 1993). Yet, as Romanelli and Tushman (1994) noted, processes within the organization that shape convergence and punctuations are relatively poorly understood. For instance, because failed attempts to undergo revolutionary change have been examined at the industry level rather than at the organizational level, and rarely at the subunit level (Romanelli and Tushman, 1994:

1160), most tests of the theory have not been able to identify how decisions or processes within the organization affect the successfulness of change efforts. Outcomes of successful change attempts—discontinuous changes in domains of organizational activity—provide evidence that revolutionary changes do take place but do not necessarily validate the causal theory put forward to explain punctuated change or delimit the conditions required for success. Romanelli and Tushman (1994: 1160) concluded that more research is needed to explore the theory systematically and "to elaborate and test the full implications of the model."

Processes, Routines, and Organizational Change

Following a rich tradition of research (e.g., Cyert and March, 1963; Nelson and Winter, 1982), I model the decision policies that shape organizational behavior. The organization is not treated as a black box, but as a collection of functions carried out by people who are influenced by organizational culture, norms, and practices and who in turn influence these organizational phenomena. Such an approach allows decision making to be represented explicitly, at least at the aggregate level. Following Tushman and Romanelli, the model I develop here focuses on top-down reorientation rather than emergent, bottom-up change. Thus, the theory assumes a managerialist view, in which transforming changes result from decisions and directions of the organization's leaders.

Decision making is represented through rules, heuristics, policies, norms, and standard procedures, which are themselves modified over time by the organization's experience. Starbuck (1965) argued that routines for change become formalized as organizations adapt over time to environmental variance. According to Nelson and Winter (1982), routines that govern organizations include predictable, stable techniques and procedures that govern day-to-day operations; policies and rules that shape decisions that effect limited change, such as ordering new capital stock; and innovation processes that change existing routines. In the course of innovation routines, people within the firm scrutinize "what the firm is doing and why it is doing it with the thought of revision or even radical change" (Nelson and Winter, 1982: 17). Levitt and March (1988) represented the change process through three routines that govern performance, search, and change. A change routine is invoked when poor performance prompts a search, the results of which appear sufficiently promising for the organization to adopt the change. Formulations of the search, performance, and change routines are derived from the tenets of the bounded rationality view developed by Simon (1957), Cyert and March (1963), and others in the behavioral decision-making tradition. Simulating the evolution and interaction of these routines allowed Levinthal and March (1981: 189–190) to investigate how organizations react to their environments while updating the rules that govern their responses. They characterized the two forms of response as first- and second-order, respectively: "First-order responses are rapid and match standard operating procedures to environmental signals. Second-order responses are slower. They involve changes in performance targets, technological opportunities, search behavior, and knowledge about opportunities.'' Both modes of search are routine-guided, although they involve different organizational routines. Mezias and Glynn (1993) identified second-order changes with Tushman and Romanelli's revolutions, suggesting that strategic reorientations and recreations are guided by routine and, presumably, relatively invariant procedures. The routines and processes that shape organizational change are thus amenable to formal modeling.

RESEARCH APPROACH

A dynamic model that captures changes over time by simulating the evolving behavior of interrelated variables provides an ideal tool for analyzing organizational change. System dynamics (Forrester, 1961) provides a simulation technique well suited to representing decision-making and change processes that has already proved useful for testing macro-sociological theories (Jacobsen, Bronson, and Vekstein, 1990). While the use of simulation to examine organizational behavior is not new, system dynamics differs from other formal modeling techniques (e.g., Guetzkow, 1962) in several important ways.

First, system dynamics highlights feedback processes, or circular causal relationships in which variables influence and, in turn, respond to each other (Richardson, 1991). The open systems view and the feedback perspective in organizational theory (Richardson, 1991; Scott, 1992) emerged from research on cybernetics and control theory in the 1940s. Since then, the concept of feedback has been used to understand a large number of social processes, including racism (Myrdal, 1944), self-fulfilling prophecies (Merton, 1948), organizational adaptation (Simon, 1976), vicious circles (Masuch, 1985), organizational failure (Hall, 1976), organizational improvement programs (Sterman, Repenning, and Kofman, 1997), and other complex, dynamic organizational processes (Weick, 1979). Second, an explicit representation of behavioral decision making (Morecroft, 1983, 1985; Sterman, 1994) is central to my approach. In the simulation model, decision makers are subject to such bounds on their rationality as imperfect knowledge and expectations that take time to update. Lags inherent in collecting, assembling, and interpreting data and delays in taking action are represented explicitly. Third, system dynamics distinguishes between state variables, such as the organization's number of employees or its inertia, and variables that represent rates of change, such as the rate of hiring and laying off or the increase in inertia per unit of time. The distinction is important because state variables, which represent properties of the organization that have been accumulated over the organization's history and characterize the system, cannot be changed instantaneously. Decisions are based on information that arises from these state variables or stocks. Finally, because system dynamics models approximate continuous-time processes, rather than step-by-step discrete time processes, they capture ongoing processes and simultaneous procedures that influence each other and can be used to explore the effects of time lags likely to be at work in organizational settings.

Identifying Constructs

The first step in formalizing the theory was to identify constructs and relationships that provided the basis for the formal model. I conducted a textual analysis of Tushman and Romanelli's 1985 paper, identifying and coding statements into categories relevant for the simulation. Tushman and Romanelli provided a rich synthesis of existing research (their citation list comprises nearly two hundred references), but their dynamic theory is embedded in a mixture of assertions about causal relationships, examples, case studies, supporting evidence, accounts of related theories, detailed descriptions of organizational phenomena, and predictions of dynamics resulting from their theory. I identified statements describing constructs, collecting into categories those that appeared to refer to the same construct, and analyzed statements describing relationships between constructs. I used their qualitative descriptions of the pattern of behavior that the theory was designed to explain to make predictions against which I would test the model. Table 1 provides examples of the three types of statements used in formulating the model: definitions of variables, explications of structure or relationships between variables, and descriptions of behavior or response over time of the specified structure.

Table 1

Summary of Textual Coding Categories*

Coding category	Definition	Structure/ relationship	Dynamic behavior
Explanation	Explanation of variable.	Description of how one variable influences another.	Pattern of variables' evolution over time.
Example	"Decisions regarding products, markets served and normative postures regarding technology . . . human resources and/or competitive timing . . . define a firm's strategic orientation" (T&R: 174).	"convergent social and structural processes . . . begin to impede a firm's ability to . . . initiate a strategic reorientation" (T&R: 177).	"Organizations evolve through convergent periods punctuated by reorientations which . . . are relatively short periods of discontinuous change" (T&R: 171).
	"structural and socially anchored inertia" is identified with "webs of interdependent relationships with buyers, suppliers and financial backers" and "the extent to which commitments to internal participants and external evaluating agents are elaborated into institutionalized patterns of culture, norms, and ideologies" (T&R: 177).	"Performance pressures . . . are the most basic forces for reorientation" (T&R: 179).	"The greater the rate-of-change in environmental conditions, the greater the frequency of reorientation" (T&R: 208).

* T&R refers to Tushman and Romanelli (1985).

This early stage of model building uncovered unexpected insights into the theory. Some sections of Tushman and Romanelli's text were irrelevant to a causal explanation of punctuated change. For example, they describe strategic orientation (and its counterpart, required strategic orientation) as a multidimensional construct with components that include values, beliefs, products, markets, technologies, power relationships, control systems, and organizational structure. Yet how these dimensions interact and evolve over time is not specified in the text. Instead, the theory addresses the overall gap between the organization's strategic orientation and the strategic orientation required for good performance. I follow Tushman and Romanelli in treating the strategic orientation, required strategic orientation, and the gap between them as unidimensional constructs. I excluded other constructs that were not used in any dynamic relationships, as well as those that lay outside the model boundary.

Table 2 summarizes the four state variables—strategic orientation, inertia, perceived performance, and pressure for change—that provided the starting point for constructing the causal framework of the model. While the punctuated change theory contains many additional variables, such as the actual performance of the organization, that are central to the model, they do not represent states of the system.[1] To ensure that the variables are meaningful as well as distinct from each other, I found it useful to hypothesize how each could be measured, as shown in the table.

Representing the Causal Structure of the Theory

The next step in formalizing the model was to relate variables to each other. The result was a set of interlinked feedback loops that represent the processes of organizational change and consolidation. According to Tushman and Romanelli (1985: 197), it is these "opposing pressures of performance and inertia" that give rise to discontinuous change. In this model, change is produced by a negative, or self-correcting, loop. Convergence is the result of positive feedback, or self-reinforcing processes. Figure 1 summarizes these relationships, using the standard convention of labeling the arrow between two variables to indicate the influence of one variable on another.

Working from any variable chosen as the starting point, the polarity of a loop is established by tracing through the effects of each link until a circuit is completed. If the net effect is to reinforce an initial change in the variable chosen as the starting point, the loop is positive and is denoted by **P** in the diagram; if an initial change is counteracted, the loop is negative, denoted by **N** in the diagram. The arrows linking variables are defined formally as follows:

$$x \rightarrow^{+} y \Rightarrow \frac{\partial y}{\partial x} > 0.$$

Thus an arrow from x to y with a positive sign denotes that the partial derivative of y with respect to x is positive; an arrow with a negative sign denotes a negative partial derivative. This definition is consistent with Weick's (1979: 171) use of a positive sign to indicate that a change in one variable causes a change in the same direction in the affected variable and his use of a negative sign to indicate that an increase in one variable causes a decrease in the affected variable (and a decrease causes an increase).

The feedback loops in Figure 1 represent the processes that Tushman and Romanelli propose to explain punctuated change. The diagram can be used heuristically to trace a path of organizational evolution that I elaborate more formally below. The story begins with a description of an organization at founding. Since the model represents general pro-

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State variables cannot be instantaneously changed but, instead, cumulate past changes: for example, the current strategic orientation equals the original strategic orientation plus all changes that have been made since the organization was born. While management cannot directly manipulate the level of organizational inertia, it can affect the current rate at which inertia is built up or drawn down. Inertia is thus modeled as a stock. Perceived performance is modeled as a state variable, since it is a combination of past perceptions of performance and current performance; current performance is continually determined anew. Similarly, pressure for change is cumulative. Other variables are directly influenced by the state variables: for instance, competence is a function of inertia and follows the same dynamics as inertia. To specify both competence and inertia as state variables would be redundant.

Table 2

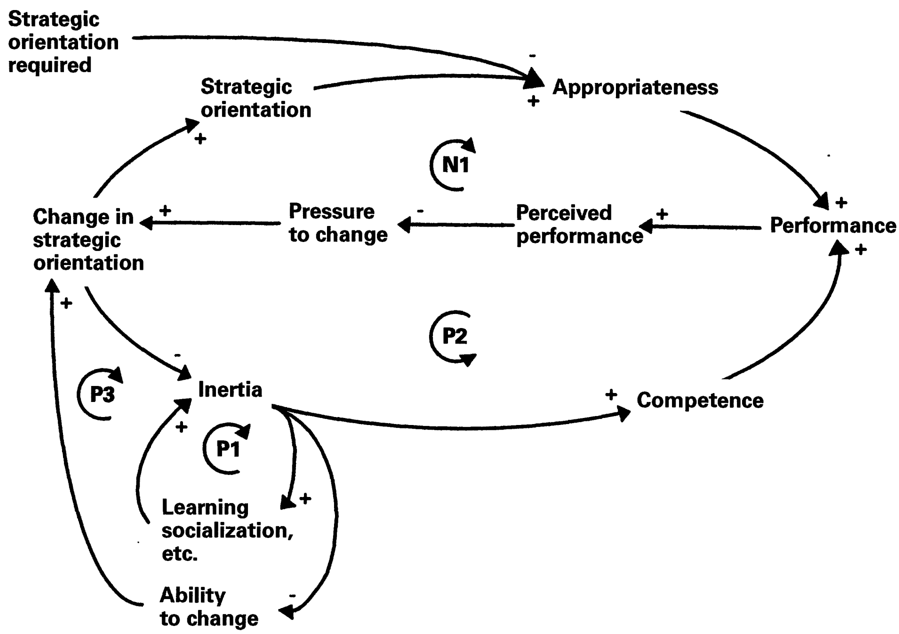
State Variables in the Punctuated Change Model*

Construct	Key elements	Description	Potential measures
Strategic orientation	Core values, beliefs. Products, markets & technologies. Power relationships. Control systems. Organizational structure.	"It answers the question: What is being converged upon?"; defines the firm "in terms of what business [it] is in and how it competes" (T&R: 176).	Identify organizational characteristics on scales: e.g., centralized vs. decentralized.
Inertia	Strength of relationships with buyers, suppliers, financial backers. Extent to which commitments by internal participants are solidified into institutionalized norms.	"a resistance to all but incremental change"; impedes "radical or discontinuous change"; determines the firm's competence (T&R: 177). Has both structural and socially anchored dimensions. High inertia impedes firm's ability to reassess its environment and to substantially change social and structural relationships (T&R: 177).	Examine relationships with related organizations; measure strength of norms and organizational culture.
Perceived performance	Perceived performance is a function of performance, which is in turn determined by appropriateness and competence.	Performance is determined by the consistency of activities, both internal and external, and by the organization's efficiency (T&R: 177). Performance is perceived and interpreted by the executive leadership (T&R: 180).	Organization's assessment of overall performance (e.g., stock performance, profits, costs).
Pressure for change	Performance pressures. Anticipated need to change (omitted in the current model).	Result of "sustained low performance due to lack of consistency among activities . . . or changes that render a prior strategic orientation no longer effective" (T&R: 197–202).	Customer complaints. Stock analysts' evaluations. Evaluations, directives issued by board.

*T&R refers to Tushman and Romanelli (1985).

cesses that affect the organization throughout its life, rather than events, founding is depicted when the model is initialized with values for the relevant variables that characterize the organization at birth. These organizational attributes include level of inertia, strategic orientation, appropriateness (which measures how well the organization's strategic orientation matches the strategic orientation required by its environment), and competence in executing the strategic orientation. When an organization is first formed, the level of inertia is necessarily low: Internal relationships, external networks, and socialization have yet to develop. The strategic orientation set by the organization's founders provides the direction in which social and structural processes coalesce. Social processes include socialization, selection of new personnel, organizational learning, and the development and dissemination of organizational culture. Structural processes include the elaboration of relationships with suppliers, customers, and other organizations, as well as networks among organizational subunits. Tushman and Romanelli argue that organizations build both socially anchored inertia and structural inertia over time. In the model, however, inertia is represented by one variable, consistent with Tushman and Romanelli's argument that the two types of inertia accumulate and dissipate in identical mechanisms. They also do not provide a causal explanation for how the two dimensions differ or interact. Processes that build up inertia are represented by a

Figure 1. Simplified causal diagram of the punctuated change theory.



single loop, denoted by **P1** in Figure 1. Once inertia begins to build, it becomes easier to increase, since more developed internal and external relationships provide a basis for their own further extension. Loop **P1** provides the self-reinforcing dynamic by which inertia builds upon itself.

As the organization develops, its ability to change decreases. Ability to change is inversely related to inertia: the higher the level of inertia, the lower the organization's ability to change. When inertia is high enough, organizational managers are less able to recognize and respond to the need for a change. Managers of a relatively young organization, with less socialized members and fluid external relationships, are able to recognize and react quickly to signals of poor performance. As inertia builds up, however, signals of poor performance must be stronger for the organization to react, as organizational members are slower to perceive discrepant signals of poor performance after a long period of convergence, and new ideas are more difficult to assimilate into an organization that has not changed in a long while. Thus, ability to change declines. When the organization fails to respond to pressure to change, this allows inertia to build up even more, further reducing the ability to change. As a result, inertia increases further and ability to change falls in a self-reinforcing feedback loop, denoted by **P2** in the figure.

The remaining loops relate performance and organizational change through the key processes of convergence and reorientation. Early in the organization's life, performance may be low. The initial level of low inertia is associated with low competence, as the organization's members have had little opportunity to learn by doing, and the structural and social dimensions of the organization are not yet developed. Depending on the organization, appropriateness, or the fit between the organization and its environment, may be high or low. If it is low—the organization comes into being with a strategic orientation that is not well-suited to its environment—the organization will perform poorly. Pressure to change may be generated as a result, in turn leading to organizational change. If this change is in the wrong direction or dimension, the organization's performance will remain low. Such an extended period of low performance may explain the liability of newness (Stinchcombe, 1965).

If, by contrast, at its founding the organization's strategic orientation is well matched to environmental requirements, then overall performance, a function of both appropriateness and competence, would reach a moderate level. If the level of performance is high enough to avoid pressure to change, there is no impetus for change, and, without a reorientation, strategic orientation remains at its (well-matched) initially chosen value. In the absence of change, the reinforcing loop **P3** operates to generate convergence: as the organization continues doing what it has been doing with increased competence, organizational members learn to perform their tasks more efficiently, and improvements in technology and work processes follow from experience. Higher levels of competence result in increased performance, which reduces (or at least fails to increase) pressure for change. As a result, the organization does not change its strategic orientation, and inertia-building processes continue, boosting competence and validating members' beliefs that they are on the right course. Performance increases, as a result of higher competence, and pressure to change is further reduced.

As a result of shifts in the external environment that are exogenous to the model, the required strategic orientation—defined as the orientation best suited to the environment—may change over time.[2] Once the environment shifts, ever-increasing competence in an inappropriate strategic orientation no longer benefits the organization. High levels of inertia both delay and increase the difficulty of change processes. When pressure for change has built up to a level high enough to overcome the effects of inertia, management relieves the pressure by changing the organization's strategic orientation. The negative loop **N1** thus ensures that a reduction in appropriateness, which causes a drop in performance, is eventually addressed by a change in strategic orientation. This change may or may not improve performance, depending on the appropriateness of the new strategic orientation. When the shift is deleterious, change in strategic orientation no longer positively affects appropriateness, and the relationship switches to a negative one. The balancing loop **N1** turns into a reinforcing loop, as a result.

Because Tushman and Romanelli's theory does not define organizational failure, the model also does not explicitly represent failure as an event. Instead, I interpret organizational failure as an extended period of low performance. Exactly how low and for how long performance must decline for failure to result would depend on the organization's environment, its resources, and its relationship with stakeholders. Some simulations show performance falling to zero and staying there. In such cases, it seems clear that organizational failure has resulted.

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Endogenous changes in the required strategic orientation may also be at work. For instance, the organization may have grown too large for the initial strategic orientation to continue to be appropriate. Although I tested several versions of the model in which required strategic orientation had both exogenous and endogenous components, I saw similar behavior in all cases and therefore used the simplest version of the model here and excluded endogenously driven changes in the required strategic orientation.

The interlinking of positive and negative feedback loops depicts the fundamental tension between competence and appropriateness that lies at the heart of Tushman and Romanelli's theory: "To disrupt stable patterns of activities and processes, even in the face of organization-environment inconsistencies, is to disrupt the pattern of competence" (p. 206). While the diagram is useful in telling the story of how these interrelationships evolve, a formal model is essential to explore the dynamic implications of this tradeoff. The model of the punctuated change theory is fairly simple, containing only four state variables. It is difficult to simulate mentally, however, since it contains feedback and nonlinear relationships. The use of a computer ensures that the dynamics resulting from the simultaneous interaction of all the assumptions are correctly inferred (Sterman, 1994). Thus, the modeling technique removes uncertainty about the dynamic implications of a set of assumptions, leaving the challenge of specifying the model to capture the elements of the original theory accurately. This was the next goal.

Guidelines for Formalizing the Model

In moving from the causal diagram to a more formal description of the theory, the question is how the model's formulations and output are to be evaluated. A number of criteria provide guidelines for specifying the model and standards against which it can be judged. Where the theory provides endogenous explanations, the model should, too. Because decisions are represented explicitly, formulations should reflect our existing understanding of behavioral decision making. To ensure that variables are measurable and relationships observable, real-world observations, such as the examples Tushman and Romanelli present, should inform the modeling as much as possible.

To validate the model, prior predictions of behavior are compared with model output. Descriptions of behavior over time from Tushman and Romanelli's paper are, in effect, predictions of the dynamics generated by the theoretical model, providing hypotheses against which the model's performance can be judged. The dynamic behavior they predict is as follows:

> Organizations evolve through convergent periods punctuated by reorientations (or recreations) which demark and set bearings for the next convergent period. Convergent periods refer to relatively long time spans of incremental change and adaptation. Convergent periods may or may not be associated with effective performance. Reorientations are relatively short periods of discontinuous change where strategy, power, structure and controls are fundamentally transformed towards a new coalignment. (Tushman and Romanelli, 1985: 171)

The model does not have such behavior built into it, for instance, by requiring change to be either of the incremental or revolutionary type or by setting a switch in the model to a mode of change. Instead, the same variables and relationships that generate convergent change should also generate reorientations. To test the model, I will compare the behavior over time of the model's output with the hypothesized behavior (i.e., statements coded "dynamic behavior" in the textual analysis).

Several principles of simulation modeling are important for obtaining interpretable results. Units of measurement, even for such soft variables as inertia, must be included in the model. This helps to enforce dimensional consistency, or equivalence of units on each side of the equation. Variables must relate to real-world phenomena that can be perceived and measured, and state variables representing quantities that accumulate over time must be distinguished from other variables that may change instantaneously.

Finally, because all models necessarily omit many aspects of the real world, it is important to recognize which phenomena lie outside the model boundary. For the present model, I selected aspects of Tushman and Romanelli's arguments by focusing on the theoretical explanation of the punctuated change pattern, excluding material not relevant to the revolutionary dynamic. For instance, Tushman and Romanelli also address the role of executive leadership as another level of explanation for the success or failure of the change effort. The present model, however, does not represent explicitly the organization's executives; rather, it depicts the broad outcomes of their decision making within the organization. Below, however, I will show that executive leadership can be explored indirectly through existing variables in the simple model developed here.

FORMALIZING THE MODEL

The model is divided into four general sectors that represent strategic orientation, inertia, performance, and pressure to change. Each sector includes several equations that govern the behavior of the state variable. Standard continuous-time notation represents differential equations that describe this behavior. I developed formulations to yield operating points in the zero-unit interval when possible. I chose this scaling for convenience, since the original paper does not provide numerical data suitable for calibrating the model, but does provide detailed qualitative descriptions that can be represented formally, as this section shows.

Inertia. As long as the organization does not change its strategic orientation, inertia builds up over time through ongoing social and structural processes, "as webs of interdependent relationships with buyers, suppliers, and financial backers strengthen, and as commitments to internal participants and external evaluating agents are elaborated into institutionalized patterns of culture, norms, and ideologies, the organization develops inertia" (Tushman and Romanelli, 1985: 177).

In the model, inertia, I, is a stock representing the degree to which these networks and relationships are solidified and the extent to which organizational culture is developed. Like other stocks, at time t, inertia is simply the integral of all previous changes in inertia, plus its initial value:

$$I = \int_{t_0}^{t} \dot{I} + I_0. \qquad (1)$$

The rate of change of inertia, $\dot{I}$, has two components, allowing processes that increase inertia to be differentiated from those that draw it down. Thus, the net rate of change of inertia equals the rate of inertia increase, i_i, less the rate at which inertia is decreasing, i_d (as I show below, while i_d can exceed i_i, the stock of inertia is constrained from becoming negative):

$$\dot{I} = i_i - i_d. \quad (2)$$

Equation 3 decomposes the increase in inertia i_i itself into two elements. First, basic socialization processes always take place, regardless of the level of inertia. A small fixed increment i_0 represents this by means of a minimum addition to the inertia stock. When inertia is at very low levels, this constant increment dominates the growth of inertia. The second component is a function of the existing level of inertia. When inertia is low, the rate of inertia increase is directly proportional to the level of inertia. As I increases, however, the fractional rate of increase in inertia, $f_i(I)$, gradually diminishes. The rate of increase falls to zero when I reaches its maximum value. In the model, this maximum is set at a value of one. Finally, an additional factor α_i scales the growth rate of inertia, allowing the strength of the inertia-building processes to be varied.

$$i_i = \alpha_i[i_0 + I \cdot f_i(I)] \quad i_0 > 0; \alpha_i > 0; \quad (3)$$
$$f_i'(\cdot) \leq 0; f_i(0) = 1; f_i(1) = f_i(I_{max}) = 0.$$

To explain why the rate of growth of inertia depends on the level of inertia itself, I interpret equations 2 and 3 (assuming $i_d = 0$) as follows: When inertia is low, socialization, culture, and relationships with organizational stakeholders are weak, and so it is relatively difficult for these dimensions of inertia to be reinforced. At this point, inertia grows by only a small increment, although the fractional rate of increase, f_i, is high. As inertia increases, however, culture and internal and external relationships become more defined and elaborated. It becomes easier to transmit the organization's culture to newcomers, to select new members who fit the mold, and to build on existing relationships with suppliers and buyers. Thus, at low and mid-range levels of inertia, inertia's absolute growth rate increases over time, resulting in exponential growth produced by the positive feedback mechanism described by loop **P1.**

Eventually, these processes reach a point of diminishing growth: Once organizational members are homogenous, adding another similar member does little to further increase the level of homogeneity; once internal and external relationships are solidified, they cannot be elaborated much more. Thus, the function $f_i(I)$ is at first constant and then decreasing in I so that the self-reinforcing, exponential growth in inertia slows down at high levels of I. As a result, when left unchecked, inertia eventually reaches a maximum value.

Inertia decreases only when the organization changes its strategic orientation. Since reorientation is a "change in the organization which fundamentally alters its character and fabric" (Tushman and Romanelli, 1985: 179), the decrease in inertia is determined by the change in strategic orientation. The organization's strategic orientation is denoted S and its rate of change is therefore $\dot{S}$:

$$i_d = I \cdot f_d(|\dot{S}|) \qquad f_d(0) = 0; f_d'(\cdot) \geq 0. \quad (4)$$

When there is no change in strategic orientation, the fractional decrease in inertia is zero and inertia continues to grow as described above. Changes in strategic orientation destroy some of the organization's inertia by disrupting existing networks, injecting new themes into the organizational culture, and bringing in new organizational members. The larger the absolute value of the rate of change in strategic orientation, the larger the rate of decrease of inertia. In the extreme case, a very large change in the organization destroys its inertia. Because the amount of inertia destroyed in the change effort is also a function of the level of inertia, larger reorientations are needed to destroy inertia in older, more experienced organizations. Inertia cannot become negative, however, because the rate of decrease is a fraction of the existing stock of inertia.

Inertia has two direct consequences for the organization. The first, competence, is a result of "emergent social and structural processes [that] facilitate convergence on a strategic orientation" (Tushman and Romanelli, 1985: 177). Convergence, in turn, leads to a high degree of competence by increasing standardization and reducing ambiguity within the firm. Competence, defined as the firm's ability to execute a strategic orientation, increases over time as inertia grows: "holding the external environment constant, the longer and less turbulent the convergent period, the more effective the organization" (Tushman and Romanelli, 1985: 195). In the model, inertia determines the organization's level of competence, *C:*

$$C = \alpha_c I \qquad \alpha_c > 0, \tag{5}$$

where α_c is a factor that scales or assigns a weight to competence.

But inertia has a second important effect, which influences the organization's ability to change: It leads to "a resistance to all but incremental change" (Tushman and Romanelli, 1985: 177). Processes that build convergence "begin to impede (although *not* preclude) a firm's ability: (1) to reassess environmental opportunities and constraints, and thus to initiate a strategic re-orientation; and (2) even given such a reassessment, to substantially disrupt the networks of interdependent resource relationships and value commitments toward implementing a new strategic orientation" (p. 177). Thus the ability to change strategic orientation, *B,* is determined by the level of inertia:

$$B = f_B(I) \qquad f'_B(\cdot) \leq 0; f_B(1) = f_B^{min} > 0; f_B(0) = f_B^{max} = 1. \tag{6}$$

As equation 6 shows, when inertia is low, ability to change is at its maximum value. At high levels of inertia, *B* falls to close to zero, but it does not reach zero, because high inertia "impedes" but does "not preclude" change. Thus, f_B is a decreasing function of inertia, *I.*

Strategic orientation. Strategic orientation, *S,* is a state variable that is changed by decisions made in the organization. Change in strategic orientation is determined by two factors. First, the impetus to change results from pressures due to poor performance, which are "the most basic forces for reorientation" (Tushman and Romanelli, 1985: 179). Second, the effect of this pressure is counteracted by the resistance to change resulting from inertia: "ever more coupled and interdependent structural and social decisions . . . reduce the probability of perceiving the need for or implementing fundamental change" (Tushman and Romanelli, 1985: 190).

These factors are captured here in the form of a continuous expression that represents management's policy of responding to pressures to change. In the model, strategic orientation is changed by an increment determined by *R,* the current level of pressure to change, *B,* the organization's current ability to change, and α_S, a parameter representing the organization's responsiveness to change pressures:

$$\dot{S} = \alpha_S R \cdot B \qquad \alpha_S > 0. \tag{7}$$

The parameter α_s allows organizational responsiveness to be varied explicitly. *R* and *B* are multiplied because both are requirements for organizational change. The formulation ensures that when pressure to change is zero, organizational change will not be undertaken, even if the organization's ability to change is high. Low levels of either pressure to change or ability to change result in relatively small changes in strategic orientation; for a large change to take place, relatively high levels of both determinants of change are required.

Strategic orientation, in turn, determines the organization's appropriateness. Internal and external consistency with respect to political and economic domains is required for good performance: "In addition to successfully addressing requirements of political and economic domains independently, activities must be consistent or coupled with each other to achieve high performance" (Tushman and Romanelli, 1985: 177). In the model, the consistency between the organization's strategic orientation (*S*) and that required for high performance (*S**) is measured by the strategic orientation gap (*G*), the difference between required and actual orientation:

$$G = S^* - S. \tag{8}$$

G determines *A,* the appropriateness of the organization's strategic orientation:

$$A = f_a(|G|) \qquad f_a'(\cdot) \le 0;\ f_a(0) = f_a^{max}(\cdot);\ f_a(\infty) = f_a^{min}(\cdot) = 0, \tag{9}$$

where f_a is a decreasing function of the absolute value of *G,* since a small gap means high appropriateness and a large gap means low appropriateness. Its maximum occurs when the organization's strategic orientation is matched to that required by the environment; at this point *G* is zero. Appropriateness falls as *G* increases.

Performance. Both appropriateness and competence determine performance. High levels of performance require "appropriate activities with respect to political and economic requirements" as well as "consistencies in and among activities" (Tushman and Romanelli, 1985: 177). High performance also requires high levels of competence: the authors explain that as the organization converges on a strategic orientation, the "emergent social and structural processes" that they identify with convergence can increase the organization's competence in executing its strategic orientation (p. 177).

While Tushman and Romanelli do not describe exactly how these dimensions of performance combine, a multiplicative relationship is consistent with their discussion, because it ensures that low levels of either variable result in low performance. Thus high levels of both appropriateness and competence are required for performance to be high:

$$P = f_P(A \cdot C) \qquad f'_P(\cdot) \geq 0; \qquad (10)$$
$$f_P(A \cdot C_{max}) = f_P^{max}(\cdot);\ f_P(A \cdot C_{min}) = f_P^{min}(\cdot),$$

where f_P is proportional to the product of the two dimensions of performance for most of its range. Because very high levels of one component may offset lower levels of the other, the function flattens to a maximum at large values of $A \cdot C$. Such a formulation increases model stability by allowing maximum performance when one (but not both) of the performance dimensions is slightly below its maximum value. Both appropriateness and competence have finite limits, so the function f_P also has a maximum value.

Managers cannot measure performance instantly, so decision makers are modeled as reacting to perceived performance, rather than to actual performance. Tushman and Romanelli (1985: 180) discuss the importance of perceiving and interpreting dimensions of performance; this, they argue, is the role of executive leadership: "whatever the nature of the opportunity or crises, recognition of an actual or potential organization-environment inconsistency . . . is required for a reorientation to occur."

In the initial model, such inconsistencies are not measured directly; instead, in keeping with Tushman and Romanelli's (1985: 179) argument that "performance pressures . . . are the most basic forces for reorientation," performance pressure determines management's actions. Perceived performance is tracked by a process in which existing perceptions of performance are updated adaptively. Perceived performance is denoted by P^p and actual performance is denoted by P. The adaptive updating process is a weighted average of recent performance and perceived performance. The weighting is determined by the time constant τ_p, which governs the rate at which performance is updated:

$$\frac{dP^P}{dt} = \dot{P}^P = (P - P^P)/\tau_p \qquad \tau_p > 0. \qquad (11)$$

Following the mathematics of exponential adjustment, given a one-time drop in performance, say from 1 to 0, at the end of a period τ_p, perceived performance P^p will have fallen by 62 percent of the gap, in this case to a value of 0.38. While Tushman and Romanelli (1985) do not explicitly describe an updating process, I chose the present formulation to match their general description of the role of executive leadership in tracking performance, and it is consistent with empirical research on updating (Lant, 1992).

The time constant governing this adjustment process is itself a function of the state of the organization. As inertia increases, the time required to perceive anomalous or new information increases: "increased structural elaboration and social complexity . . . reduce the probability of perceiving . . . the need for change" (Tushman and Romanelli, 1985: 190).

This reduction in perceptiveness could be caused by a number of factors associated with high levels of inertia: increased socialization of organizational members, "institutional factors [that] are a homogenizing and constraining force," and "increased coupling and specificity of social and technical systems" that reduce organizational flexibility (p. 190). The perception time that governs the rate at which perceptions are adjusted is:

$$\tau_p = f_\tau(I) \qquad f'_\tau(\cdot) \geq 0;\ f_\tau(I_{max}) = f_\tau^{max}(\cdot);\ f_\tau(I_{min}) = f_\tau^{min}(\cdot), \tag{12}$$

where $f_\tau(I)$ is an increasing function of inertia I.

Finally, perceived performance P^P is judged against desired performance P^* to generate the performance shortfall P^g:

$$P^g = P^* = P^P. \tag{13}$$

Pressure for change. When performance is low for sustained periods, pressure for change accumulates:

> To the extent that incremental modifications to values, strategies, power systems, structure, and controls fail to maintain consistencies (or to establish them in the first place), the organization will fail to achieve a sustainable level of performance, and be forced to a fundamental reordering of activities. . . . two basic forces for change [are]: (1) sustained low performance resulting from a lack of consistency among activities in the four political-economy domains, regardless of the appropriateness of overall strategic orientation; and (2) major changes in competitive, technological, social, and legal conditions of the environment that render a prior strategic orientation, regardless of its success, no longer effective. (Tushman and Romanelli, 1985: 178)

Pressure for change, R, is a stock representing the accumulation over time of performance pressures. The rate of change of R is the rate of increase in pressure to change r_i less the decrease in pressure to change r_d:

$$\dot{R} = r_i - r_d. \tag{14}$$

The increase in pressure for change is simply the performance shortfall:

$$r_i = \alpha_R P^g \qquad \alpha_R > 0. \tag{15}$$

Thus, as long as perceived performance is below desired performance, pressure for change builds up. Its increase is proportional to the performance shortfall. When P^g is negative, however, perceived performance exceeds desired performance and pressure to change decreases. The parameter α_r determines the size of the effect of performance shortfall on the buildup of pressure for change.

When the organization's strategic orientation changes, pressure for change falls. The fractional decrease in pressure for change is determined by the magnitude of the change in strategic orientation $\dot{S}$:

$$r_d = R \cdot f_r(|\dot{S}|) \qquad f'_r(\cdot) \geq 0;\ f_r(0) = f_r^{min}(\cdot) \geq 0;\ f_r(|\dot{S}|_{max}) = f_r^{max}(\cdot). \tag{16}$$

When $\dot{S}$ is zero, r_d is its minimum value, and as $\dot{S}$ increases, r_d increases, too. Thus f_r is an increasing function.

The final component of the model is the only exogenous input: the environment, which is represented by the required strategic orientation, denoted S^*. This input can take any form, constant or changing over time. For example, I examined change by steps, gradual change, accelerating change, random variation, and cyclical patterns. As noted, S^*, like S, is univariate, since the original theory offers no explanation for causal relationships between multivariate dimensions of either variable.

When all equations are combined with parameter values for the constants, initial conditions for the state variables, and formulations for the functions described above, the model is completely specified. Appendix A contains a model listing with fully specified equations and functions, and Appendix B provides a table of parameter values and initial conditions used in each simulation run discussed here. The computer model was constructed using the ithink software program (High Performance Systems, 1994).

SIMULATING THE FORMAL MODEL

A systematic approach guided model testing. I began with a standard first step in validating simulation models, equilibrium tests. I then examined more complex scenarios in which the environment changed over time. For every scenario, I tested many combinations of model parameters to understand how assumptions built into the model affected simulation results and to pinpoint problems with the model. Selected model output is reproduced here; complete sets of graphs, as well as results from additional tests, are available from the author.

Results indicated that the theory could generate pathological cases of ongoing failure and continuing reorientation. To show how these pathologies arise, as well as how they can be prevented, I investigated simulations that yielded surprising results.

Initial equilibrium tests. The first set of simulations examined whether the model behavior followed the predicted pattern when the environment was unchanging, i.e., S^* was constant. I expected the organization to reach and maintain equilibrium, since no pressure to change would arise. Under unchanging conditions, organizations that are appropriately aligned to their environments should continue to build competence and refrain from changing.

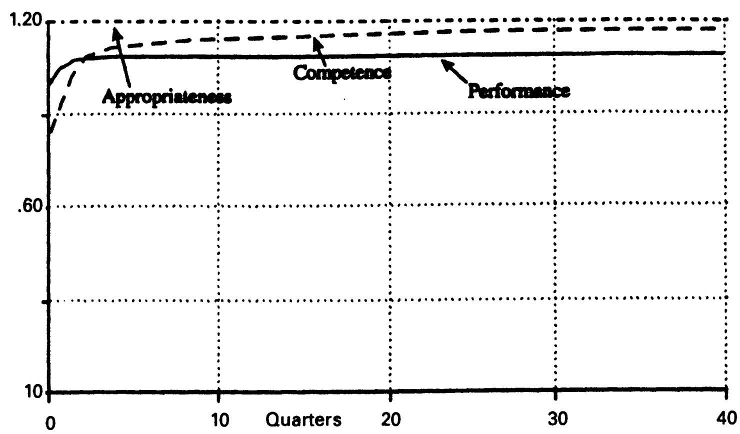
I began with an organization that had existed for some time without experiencing a reorientation, represented in the model by setting the initial value of inertia at a high level. High inertia also meant that competence was well established. Here, the model was initiated in benign conditions—the environment was stable, and performance relatively high because appropriateness was maximal and competence moderately high. As a result, no pressure for change was generated. Figure 2a shows the resulting evolution over time of the performance variable and its two components, appropriateness and competence. Because performance was high enough, the loop **N1** (in Figure 1) was not active, and there was no change in strategic orientation. The negative loop was dominated by the convergence-generating reinforcing loops **P1, P2,** and **P3,** which increased inertia and competence over time.

Although performance did not start at its maximum value, because competence was initially suboptimal, it was high enough to prevent pressure to change from mounting. Since there was no change in strategic orientation, inertia accumulated, as shown in Figure 2b, and competence rose in concert. Over time, a stable equilibrium was reached at the maximum value of performance.

The second equilibrium test changed just one aspect of the initial conditions, the level of inertia. With a lower value of initial inertia, the simulation represents a younger organization or one that has undergone a reorientation more recently than in the previous instance. As in the first test, the organization operated in an unchanging environment (S^* was constant), and I began the simulation with appropriateness at its maximum value.

Figures 3a and 3b depict the results. While the first simulation showed an unchanging organization, this time the orga-

Figure 2a. Performance under benign conditions (high level of initial inertia).*



*As I have combined graphs of multiple variables and used arbitrary units that are scaled to be consistent with each other, the units for each variable should be interpreted only in relation to other simulations. More information about units for each variable appears in Appendix A.

Figure 2b. Inertia under benign conditions (high level of initial inertia).

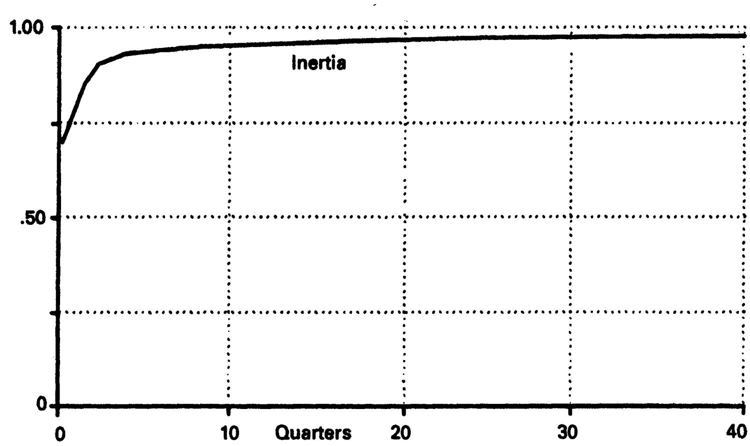


Figure 3a. Performance over time with low initial level of inertia.

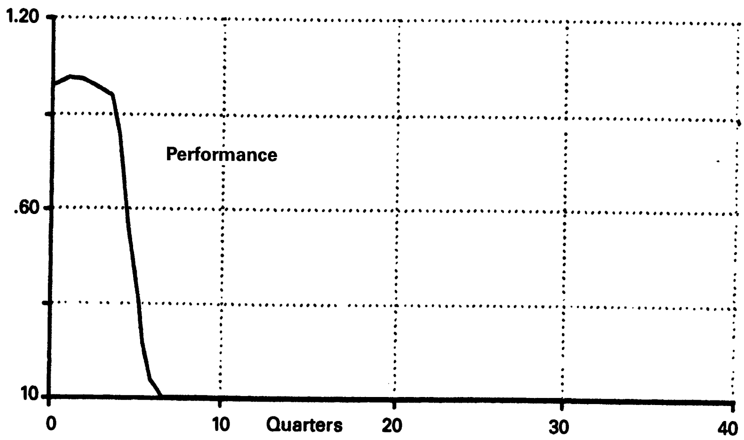
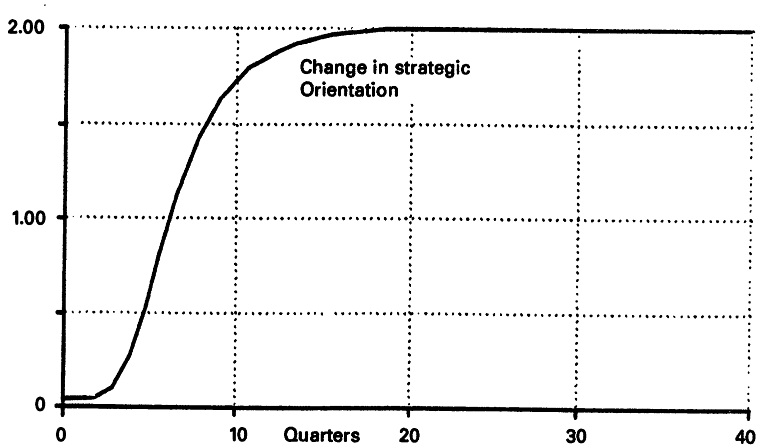


Figure 3b. Change in strategic orientation with low initial level of inertia.



nization began to change right away and continued to change its strategic orientation for the remainder of the simulation. As a result, performance plummeted and did not recover; as Figure 3b shows, the organization failed (assuming that failure has occurred when performance fell to zero and remained there). This pattern of behavior—an inappropriate, ongoing reorientation leading to organizational demise—was surprising.

Given the invariant conditions in this simulation test and the initialization of the model in equilibrium, I did not expect to see reorientation: As in the first case I tested, an organization ideally oriented toward an unchanging environment should not change but should build inertia and competence. Instead, I found ongoing change. The causal loop diagram in Figure 1 is useful in explaining why. Initially, competence was low enough to result in low performance, so pressure for change immediately began to accumulate. Low inertia also resulted in low resistance to change, making the reinforcing loops **P1** and **P2** relatively weaker. Pressure for change quickly built up to a level high enough to overcome the effects of inertia, initiating the balancing process of **N1**, by which the organization reoriented in response to sustained poor performance.

Although reorientation was the *wrong* response—the organization was already ideally matched to its environment—it was an *inevitable* result of performance pressures, given the way the model was formulated: ongoing performance shortfalls generated pressure to change. Once undertaken, reorientation put the organization into a vicious cycle of ongoing change. When the organization first changed, it moved away from the optimal strategic orientation, and its appropriateness fell. Loop **P3** ensured that the lower inertia and competence resulting from the reorientation further reduced performance and hence further increased pressure for change, leading to even more reorientation. As the organization continued to change its strategic orientation in the same direction, this change would lead the organization even further from the required strategic orientation. At this point, **P3** acted in concert with **N1** to reduce both dimensions of performance. These processes dominated the reinforcing loops **P1** and **P2,** and the organization continued to turn, inappropriately, to reorientation as a means of improving its performance. This response further reduced performance.

Could the simulated organization move toward the optimal strategic orientation—in this case, return to its initial strategic orientation—to correct such a downward spiral? It is possible that once change is initiated, the direction and magnitude of the organization's course of change is altered over time in such a way as to counteract the effects of the recently undertaken maladaptive change. If, for instance, the organization randomly changes direction at random rates of speed, it might happen to hit on the optimal strategic orientation. But without feedback on the difference between the organization's strategic orientation and that required by the environment—i.e., without some method of sensing how close the organization is to its goal—the organization will overshoot or wander away from this optimum, unless, of course, the organization happens not only to reach the optimal strategic orientation by chance but also happens to stop changing at that moment; in the many tests I conducted, I could not make this happen.

The pattern of ongoing, maladaptive change was pervasive in my early results. In a range of additional cases I tested, including those with shifts in the required strategic orientation as well as others with unchanging environments, I found that, once change was initiated, organizations continued to reorient inappropriately beyond the optimal point, eventually resulting in the same type of organizational collapse seen above. Although in several of these tests some measure of change was adaptive, organizations would overshoot the strategic orientation required for maximum appropriateness.

Inappropriate change takes place in the model because there is no feedback that allows organizational decision makers to learn the cause of poor performance or to deduce in what direction—or how much—the organization should change to maximize appropriateness. Reorientation is undertaken whenever performance is low enough—regardless of whether low competence or low appropriateness is to blame. To avoid this problem, the organization should reorient only when appropriateness is the problem; if poor competence is the cause, the organization should avoid reorientation and instead build competence. As the model is presently formulated, however, every change in strategic orientation large enough to reduce competence leads to ongoing reorientation.

Explaining inappropriate reorientations. Does such apparently inappropriate behavior make sense? There are three potential explanations. First, the problem could lie in my interpretation of Tushman and Romanelli's text or in the present formulation of the simulation model; however, careful textual analysis and extensive model tests were designed to minimize these risks. Second, the simulations could be depicting a real-world phenomenon already explored in the research on organizational change.[3] The model's dynamics match the self-reinforcing "death spirals" seen in organizations engaging in increasingly radical transformations (Hambrick and D'Aveni, 1988). Similar protracted decline processes have been noted in a range of organizations (Meyer and Zucker, 1989; McKinley, 1993). In addition, recent research has found an increased hazard of organizational demise following transformation (Singh, House, and Tucker, 1986; Haveman, 1992; Amburgey, Kelly, and Barnett, 1993). While the empirical data show that organizational death is by no means a certain outcome of reorientation, the simulations depict failure as inevitably following transformation—once the change process is initiated, it does not stop. Thus, the current version of the model fails to represent adaptive or benign organizational transformation.

We are therefore left with a third alternative explanation of the problem: the discrepant behavior is the result of a gap in the original theory described by Tushman and Romanelli (1985). While the original theory appears to explain how pressure to change builds up, leading to the initiation of a change attempt, it does not account for procedures necessary to conclude the reorganization. I experimented with the model to take into account the fact that both beneficial and deleterious transformations take place and discovered additional assumptions necessary to explain fully observed data on punctuated change. I propose an addition to the theory that corrects the collapse dynamic shown in Figure 3a.

Adding a measure of organization-environment consistency. In the initial version of the model, change in strategic orientation depended on the organization's responsiveness, resistance to change, and pressure to change. The formulation kept with Tushman and Romanelli's (1985: 179) assertion that "performance pressures . . . are the most basic forces for reorientation." To avoid inappropriate change, however, I found that decision makers must also measure and respond to organization-environment fit.

Knowledge of fit implies knowledge of the strategic orientation required for performance to be high. How likely is it that organizational leaders know the required strategic orientation? Tracking the match between organization and environment is a challenging task. While IBM's leadership probably recognized that the organization's performance was declining in the 1980s, did managers recognize right away that the mainframe business was eroding and the PC market grow-

3
Inconsistencies between empirical research on organizational change and the simulation results suggest several points to consider. While some studies show that organizational change does not always increase performance, little research has explored whether real-world organizations choose inappropriate behavior by reorienting in stable environments. Such inappropriate reorientation may explain the liability of newness as well as organizational failures that are not related to change in the environment. In environments with one-time jolts, the literature suggests that failures result when organizations do not match changes in the environment fast enough. In contrast, the model suggests that failures may result from too much change, rather than too little. Finally, the literature emphasizes the role of low appropriateness or poor fit in organizational failure, whereas the simulations suggest that low competence plays an equally important role. One explanation for differences between model results and empirical findings is that these two phenomena—reorientations in unchanging environments and the role of low competence in explaining post-reorientation failure—are simply overlooked in the existing research, perhaps as a result of the situations chosen for empirical study.

ing? Over time, IBM's leaders have learned that this is the case, but at the time of the first signals of poor performance, it seems unlikely that organizational managers could correctly predict the best strategic orientation for them to choose. In the model, a time delay and updating routine in the formulation for the fit measurement routine reflected the process by which knowledge about strategic orientation increased over time. Decision makers use their perceptions of organization-environment fit in deciding how much to change the organization's strategic orientation in response to given levels of pressure to change.

The fit measurement routine modified the existing expression that determined how much change in strategic orientation is undertaken (Appendix A includes full details of the new formulation). With the modification, organizational change now required the confluence of three effects: sufficient ability to change, high enough pressure for change, and a perception of a mismatch between organization and environment:

$$\dot{S} = \alpha_S R \cdot B \cdot m, \qquad (7')$$

where m measures the perceived size and direction of the gap between the organization's strategic orientation and the required strategic orientation.

With the new routine in place, the problem of inappropriate reorientation was avoided. A second balancing loop had been created, adding a stabilizing negative feedback process to the model. Now, runaway change was prevented by ensuring that organizational leaders did not react to performance pressures when it was low competence—not low appropriateness—that caused poor performance. The new formulation allowed all equilibrium tests to be passed: The model could be initiated under any set of initial conditions and, as long as there was no change in required strategic orientation, no change in strategic orientation resulted. (Graphs of these simulation results are not presented, since they are very similar to Figures 2a and 2b.)

Testing environmental shifts. Next I examined the effects of changes in the environment. In some respects, results matched expectations: for instance, in keeping with both the punctuated change theory and the predictions of structural inertia (Hannan and Freeman, 1984), the higher the level of inertia when a shift in the organization's environment took place, the more time elapsed between the environmental change and the organization's change in required strategic orientation. Small shifts in the environment did not result in change when organizations had very high levels of inertia, whereas relatively young organizations were sensitive to even small changes in the required strategic orientation.

In other respects, agreement between model results and predictions was less evident. Following a one-time shift in required strategic orientation, the simulated organization initiated the change routine, as Figure 4a depicts. The environment shifts after about two quarters have elapsed, and another quarter or so later the organization begins to change in response. In this case, however, an extended change process, shown in Figure 4b, destroyed much of the organiza-

Figure 4a. Strategic orientation and required strategic orientation over time with one-time change in environment, under the fit measurement routine.

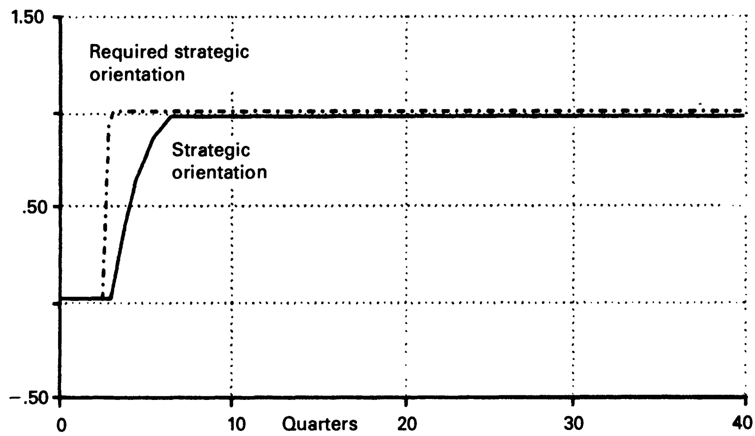


Figure 4b. Change in strategic orientation, with one-time change in environment, under the fit measurement routine.

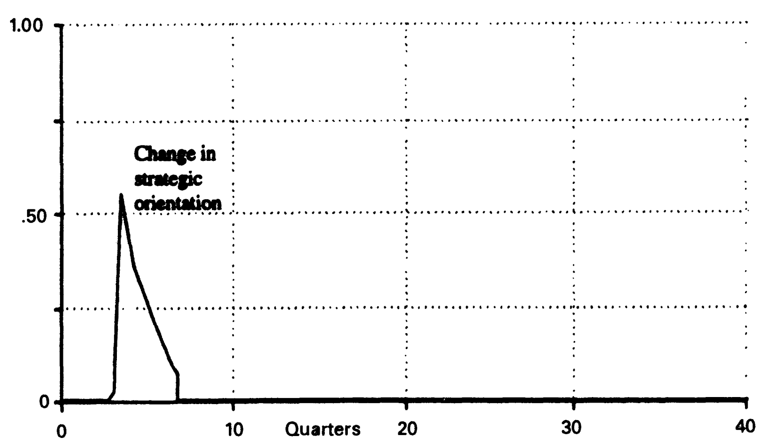
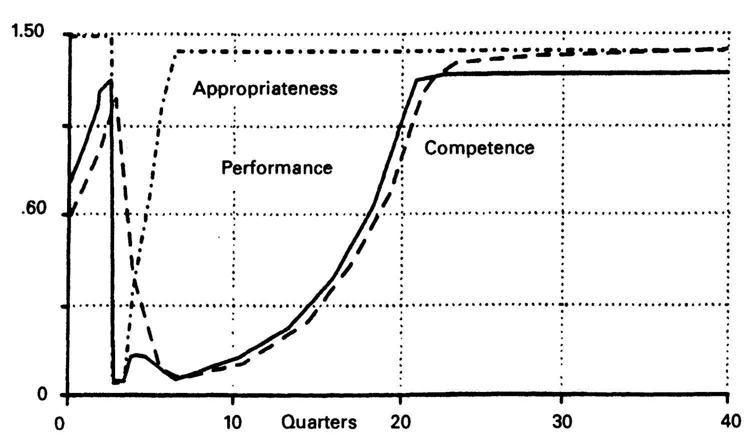


Figure 4c. Performance, with a one-time change in required strategic orientation, under the fit measurement routine.



tion's competence. As Figure 4c illustrates, during a long period of low performance that followed the change, competence and inertia were rebuilt only slowly. Wondering whether the extended reorientation matched the qualitative description of punctuated change provided by Tushman and Romanelli that "reorientations are relatively short periods of discontinuous change" (p. 171), I investigated how the length of the reorientation depended on parameter values selected for the simulation run.

Sensitivity tests revealed that I could improve the outcome with parameter changes. Performance increased when the organization was more responsive to performance pressures—i.e., when the parameter α_s was higher. Figure 5a shows the faster response of the organization to the jolt in its environment; Figure 5b depicts change in strategic orientation, and Figure 5c shows the response of performance, appropriateness, and competence. The increased responsiveness resulted in strategic orientation changing far more quickly to the appropriate value. While the small overshoot in the adjustment process carried some penalty for performance, overall performance was much improved over the previous case, with higher average levels of performance during the change period and a faster return to desired performance levels.

The simulations suggested that one strategy for avoiding organizational collapse in the aftermath of a reorientation is to respond very swiftly to pressure to change, even to overshoot if necessary. This can be seen by comparing the overshoot pattern depicted in Figure 5a with the more gradual pattern of change in Figure 4a. Although slow change is more cautiously planned and avoids potentially deleterious overshooting, it can destroy so much organizational competence that it is not an adaptive strategy for managing organizational change. Change that is too rapid, however, can be equally damaging: when responsiveness was increased further, allowing the organization to overshoot several times, performance fell.

The rapid response strategy proved vulnerable on two counts: in addition to the dangers of the organization over- and underresponding, the environment affects the optimal level of responsiveness. Responsiveness that was beneficial in environments with infrequent change could generate overly swift responses that hurt the organization in a fast-paced environment (i.e., one with multiple jolts). Under such conditions, a slowly responding organization could benefit from accumulating more information about the changing environment during the time it took to initiate action. The present results suggest that existing evidence for the benefits of responding quickly to environmental jolts (Haveman, Meyer, and Russo, 1993) may not be supported in environments that experience frequent shifts.

Constantly changing environments. No approach—neither high nor low responsiveness—allowed the organization to perform well in an environment experiencing ongoing change. While a less responsive organization at first responded relatively slowly to the environment, eventually it would undertake change more frequently, at which point the

Figure 5a. Strategic orientation and required strategic orientation, with one-time change in environment, under fit measurement routine and with a responsive organization.

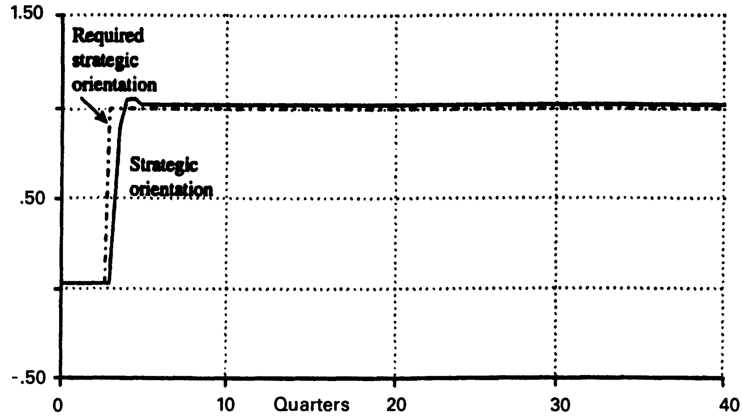


Figure 5b. Change in strategic orientation with one-time change in environment, under fit measurement routine and with a responsive organization.

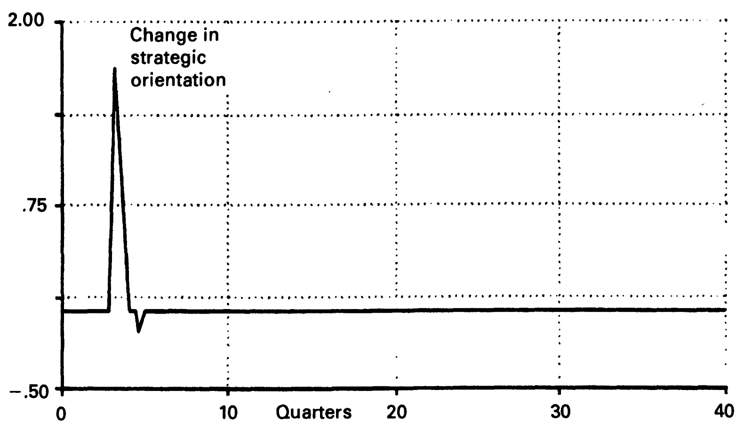
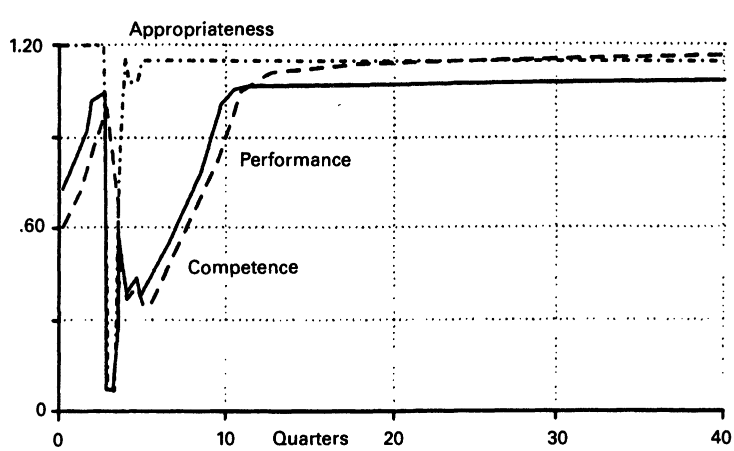


Figure 5c. Performance, appropriateness, and competence with one-time change in environment, under fit measurement routine and with a responsive organization.



reduction in competence would lower performance. A highly responsive organization underwent more frequent changes that quickly destroyed competence and reduced performance. In both cases, the organization could not long survive a changing environment, resulting in performance levels that hovered near zero for extended periods.

The root of the problem the organization faced is this: If a new change effort followed too soon on the heels of a previous change, the organization had no opportunity to rebuild destroyed competence. One potential solution to this problem was to allow the organization to learn how to manage change by developing reorientation routines. While this idea was not featured in the punctuated change theory (Tushman and Romanelli, 1985), it has been proposed by others (Grusky, 1961; Starbuck, 1965; Levinthal and March, 1981). In such a case, the higher the level of accumulated experience with reorientation, the less organizational competence is destroyed in subsequent reorientations. If, however, the accumulation and maintenance of change-management expertise detracts from the accumulation and maintenance of the organization's operational routines, change still exacts a performance penalty, with ongoing change resulting in declining levels of competence. If change in the organization's environment is fast enough, similar collapse patterns eventually emerge; in fact, since learning to change made the organization more responsive to performance pressures, under this scenario the organization changed more often, eventually leading to greater disruption in operational routines and hence declining competence.[4]

This finding suggested that for the organization to succeed, the organization's leaders must, under some conditions, prevent change from taking place even when it appears to be indicated (i.e., even when *both* organization-environment fit *and* performance are low). The vulnerable time was the period immediately following a reorientation, for this is when competence was lowest. To prevent too much change from taking place, the organization needed to suspend its responses to signals of poor performance and fit.

Adding a trial-period routine. The trial-period routine enforces a waiting period following each reorientation during which executive leadership refrains from making further change. After a strategic orientation change, while results from the recent reorientation are not yet known, the organization focuses on implementing the new strategic orientation rather than on the more externally oriented activities of monitoring performance, searching for new strategic orientations, and tracking organization-environment fit. One way of thinking about the trial period is as a period of inward focus during which the organization deliberately ignores information from the environment. The result implies that the organization's leaders have a challenging job in managing organizational change: Not only must they track performance and fit, to initiate and guide reorientations, but they must also suspend the practice of monitoring, evaluating, and responding during the trial period.

Evidence exists for such behavior in real-world organizations. For instance, in the early 1990s General Electric CEO Jack

4
Tradeoffs between investing in learning to change versus improving operational competence are complex; like all model results, they depend on assumptions. In this case, the relative importance of appropriateness and competence is key, as are the performance implications of reacting quickly versus slowly to external changes. Yet I found that for a wide range of parameters, the theory-grounded model presented here depicts falling performance in rapidly changing environments, suggesting that the simple learning-to-change routine presented here cannot guarantee organizational survival in all settings.

Welch found that after years of implementing restructuring changes, the organization needed time to reap the benefits of the earlier reorganization—time free of further restructuring. Thus, while the 1980s saw "hardware" changes in GE's businesses and management structure, Welch foresaw the next decade as a period in which the company's "software," or culture and ways of doing business, would change through a process he christened "Work-Out" (GE, 1989). Working out how to implement the company's new strategic orientation was a slow process, as Welch predicted. In his 1991 letter to shareholders, Welch described how parts of the organization "needed to just sit there . . . like popcorn kernels in a warm pan." The waiting period eventually resulted in improvements as "suddenly, things began to pop, here and there, with big ideas, process breakthroughs" (GE, 1991: 4). Without an explicit trial period of "soft initiatives," Welch suggests, GE would not have realized the performance gains of the early 1990s (GE, 1993).

In the model, pressures to change dissipate after each reorientation and continue to dissipate for a specified period determined by the trial-period length. In some ways, this approach is consistent with the "clock-resetting" process, in which organizational change reinitializes the organization (Amburgey, Kelly, and Barnett, 1993). The present formulation differs from clock resetting in requiring this resetting process to be extended over a period of time, rather than taking place instantaneously. In other words, the clock is reset and then frozen for the length of the trial period.

The trial-period routine is implemented by a simple set of decision rules. Once a large enough change in strategic orientation has been initiated, the trial-period counter is initiated. For the duration of this period, all pressure for change is ignored. The sole modification to the existing model is a change in equation 16 that describes the decrease in pressure for change and the addition of several equations to determine when to initiate the routine; Appendix A contains details of the formulation. As long as the trial period is operating, pressure for change is zero.

Figure 6a shows the effects of a one-time shift in required strategic orientation. As shown in Figure 6b, two separate change efforts were required for the organization to get close enough to bring appropriateness to the right level. After the first trial period, the new strategic orientation was found to be unsatisfactory, causing performance pressures to build up once more. A second reorientation then took place.

Because the trial period could suspend the change process before the entire change was implemented, resulting in multiple shifts in response to one jolt in the environment, performance was not inevitably better under a trial-period approach than in the responsive case. In situations in which the environment changed only occasionally, the cost of extended periods of low appropriateness could exceed the benefit of slowing the pace of change. Thus Figure 6c shows that, while performance is higher with the trial-period routine than without it, in the present case of a one-time shift in the environment, the organization practicing the responsive strategy fares better. For a given environment, the strategy can be fine-tuned to address this problem: Adjustments to the decision rules (trial-period length, threshold change level, and responsiveness) optimize the number of punctuations and increase overall performance. In general, however, when a

Figure 6a. Strategic orientation and required strategic orientation with a one-time change in environment under a trial-period routine.

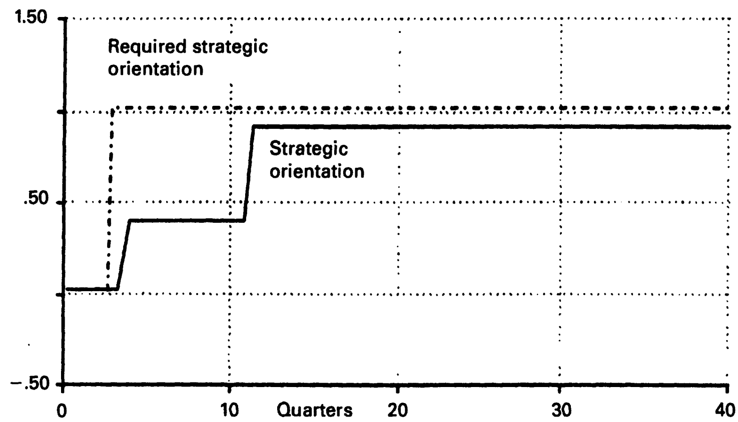


Figure 6b. Change in strategic orientation, with a one-time change in environment under a trial-period routine.

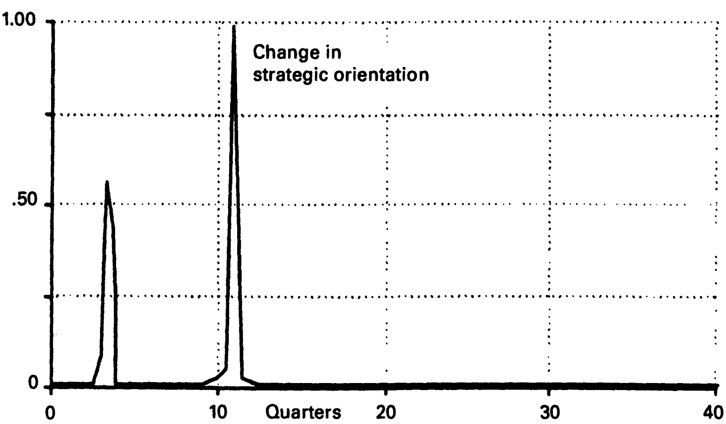
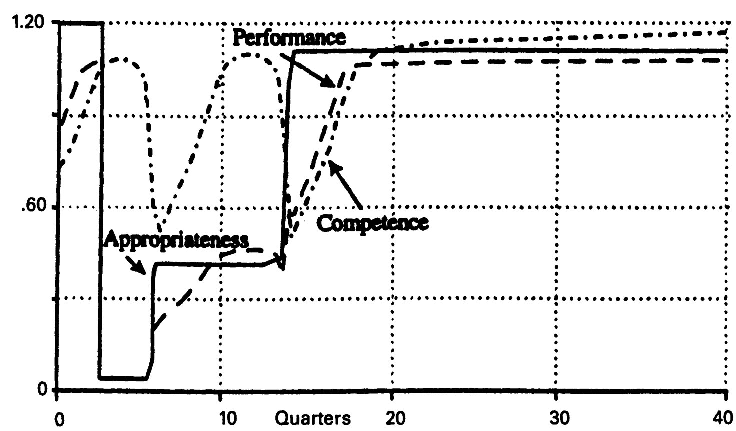


Figure 6c. Performance, competence, and appropriateness, with a one-time change in environment under a trial-period routine.



wide range of environments is considered, the model is more robust with the trial-period routine than under the rapid-response strategy: fewer scenarios result in organizational collapse.

As a case in point, I found that to survive in constantly changing environments, the organization had to follow a trial-period routine, undergoing regular reorientations spaced far enough apart to maintain competence. As a result, in environments with ongoing change, overall performance was much better with a trial-period routine than in earlier versions of the model. The more turbulent the environment, the greater the advantage to the organization of using trial periods to pace the change effort.

While the trial-period routine does not guarantee that organizational change will be successful, it provides conditions under which change can take place in the punctuated mode. I found that successful organizational leaders must track both performance and organization-environment fit, determine how responsive to make the organization as a function of environmental conditions, and enforce a waiting period after every significant change in strategic orientation. My findings also imply that in environments with infrequent change, pacing by external events works well, but when environmental change is frequent, organizations need an internally driven pacing mechanism—the trial period—to survive.

DISCUSSION AND CONCLUSIONS

The initial version of the model, formulated according to Tushman and Romanelli's (1985) theory, was incapable of producing punctuated change in a range of environments. I added two change management routines to generate the punctuated pattern of organizational evolution described by Tushman and Romanelli. The first is the tracking of organization-environment fit. In measuring fit, the organization avoids inappropriate reorientation by ensuring that change is undertaken only when appropriateness—a function of the match between the organization's strategic orientation and that required by its environment—is low. The second is the trial period. The trial-period routine is required for the organization to avoid destroying competence in turbulent environments. By suspending the change process after a given level of organizational change has been undertaken, organizational leaders using a trial-period routine protect the organization from collapse.

My findings also suggest a number of ways in which organizations can fail to manage change successfully. Recasting the results to generate a list of conditions for organizational failure provides a useful summary of the simulation results. Organizational change may cause failure if (1) the new strategic orientation selected by the organization does not match the requirements of its environment, (2) biases or inattention skew the organization's perception of fit and performance, (3) the organization is overly responsive to performance pressures and neglects organization-environment fit, (4) the organization is too slow in updating perceptions of its strategic fit, or (5) the organization is not responsive enough (or is too responsive) in adjusting strategic orientation, or (6) the organization fails to use a trial-period routine in a rapidly changing environment. Even with a trial period, simulation results not presented here show that organizations may perform poorly if the threshold for initiating the trial period is set too high or too low, the length of the trial period is inappropriate, or the time to decide to initiate the trial period is too short or too long.

I draw on the results to propose several additions to existing explanations of the organizational change process. First, without the two new routines (fit and trial), or with response times that are too short or too long, organizational reorientations destroy competence or appropriateness and so lead to eventual collapse. This protracted downward spiral is consistent with findings on vicious circles in failing organizations (Hall, 1976; Masuch, 1985; Hambrick and D'Aveni, 1988). Second, while existing research holds that organizations change because low levels of appropriateness generate performance pressures (Tushman, Newman, and Romanelli, 1986; Haveman, 1992), the simulations show that failure could be the consequence of low competence resulting from a poorly managed change process. The conventional explanation for increased hazards of failure following reorientation—organizations fail because they do not reorient quickly enough—should be expanded to account for the role of low competence in generating poor performance after a reorientation. In other words, organizations may fail because they change too much or too fast, sacrificing competence for appropriateness.

Previous simulation models of revolutionary organizational change have used clock-resetting rules to represent the change management process (Mezias and Glynn, 1993). If the length of the trial period is very short, the present model approximates the clock-resetting approach. In general, however, the more accurate metaphor may be *stopping* the clock, not resetting it. Without a sufficiently long settling-down period after a reorientation, the simulations could not produce punctuated change. This is because the computer model, in keeping with the behavioral decision-making perspective, incorporates time delays during which information is collected, ideas are communicated within the organization, expectations are compared to perceptions, and pressures are built up. Tushman and Romanelli (1985) stress the cumulative nature of both inertia and pressure to change—effects that are downplayed in other models in which time delays and accumulating stocks are not explicitly modeled. When these features are taken into account, it becomes clear that a trial-period approach, rather than simple clock resetting, is required if the organization is to survive a large transformation. Examples such as General Electric's experience with change management in the early 1990s provide evidence that successful change in complex organizations can involve long trial periods—years in the case of GE.

A single shift in the environment may generate a multiple-step organizational revolution, as simulations of the revised theory show. In the past, the punctuated change theory has been identified with single-punctuation changes rather than multiple-part change, perhaps because there was no reason to look for multiple responses to an environmental jolt, but some recent findings support the new predictions: Tyre and Orlikowski (1994) have documented two-part technological adaptations that fit a pattern similar to the simulation results.

Traditional explanations of organizational change emphasize performance pressures as the fundamental force for change (Levinthal and March, 1981; Tushman and Romanelli, 1985; Mezias and Glynn, 1993). According to the revised theory, conceptions of fit may be as important as interpretations of performance in shaping successful change. It has been difficult for academics to agree on definitions of fit (Drazin and Van de Ven, 1985; Venkatraman and Ramanujan, 1986; Edwards, 1994). But we might learn from successful real-world managers who measure the match between the organization's strategic orientation and that required by the environment. Very little research has investigated how managers in changing environments measure and interpret fit. A promising step in this direction is Gersick's (1994) study of a high-tech start-up in which temporal pacing guided how managers attended to their environment. She found that information useful in gauging fit was incorporated into decision making during the phases that marked organizational transitions.

Pacing mechanisms, which determine the temporal pattern of organizational change, provide a second point of agreement between empirical research and my findings. Gersick (1994) observed both time-based and event-driven pacing, which correspond to the trial-period approach in the revised model and the performance-pressure approach in the original model. Time-based pacing, or internal pacing, allows the temporal pattern of organizational change to be set by the organization, using the calendar—six-month periods in the case of the CEO Gersick studied. In the simulations, I found such pacing to benefit the organization when its environment is turbulent, as it preserves organizational competence by forcing the organization to change less often than it would if responding directly to the environment. In relatively calm environments that experience less frequent change, I discovered that organizations can fare well using external pacing, in which organizational change is triggered by environmental shifts.

Like all models, the revised model is a simplification that leaves out much. For instance, it does not account for the time and expense entailed in finding a new strategic orientation, as well as the possibility that decision makers may select an inappropriate orientation; if these were added to the model, the riskiness of a reorientation would be increased, resulting in longer convergent periods, more dramatic punctuations, and even longer intervals of low performance following a reorientation. Other potential extensions include incorporating an aspiration-updating process by which performance standards adapt to experience (Lant, 1992), supplementing the change routine with the threat-rigidity response theory (Staw, Sandelands, and Dutton, 1981) to account for constraints in responding to threatening conditions, and adding an asymmetrical dimension to decision making to account for the finding that dissonant or negative information from the environment is more difficult to perceive than consonant information (Jackson and Dutton, 1988). An increasingly elaborate model that integrated more theories, however, would produce results that are increasingly difficult to interpret.

I strove for a compromise between detail and simplicity by keeping close to the original theory. Tushman and Romanelli's (1985) explicitly causal verbal model served as an ideal guide through this patch of the organizational theory jungle. As my results show, the original punctuated change theory provided fertile ground for generating new ideas, exploring the determinants of different patterns of organizational change, and explaining a wide range of empirical findings. System dynamics contributed a useful tool for my investigations by highlighting how an organization's history and its leaders' strategies influence its evolution over time. Finally, while Péli and colleagues (1994) admitted that "pedantic" methods may be needed for theory exploration, the present study suggests that a careful analysis of an existing theory can also be very generative, helping to test and extend verbal theories, conceive novel theoretical propositions, and provide new explanations for empirical results about the complex phenomena of organizational change.

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APPENDIX A: Model Listing

Below is a complete, equation-by-equation list of the simulation model generated by the ithink simulation software. Because the ithink variable names do not correspond directly to the terms assigned to variables in the text, both terms are given here. The two new routines are documented in the last two sections.

Inertia Sector

inertia(t) = inertia(t − dt) + (inertia_increase − inertia_decrease) * dt.

INIT inertia = .5. Inertia measures the stock of organizational relationships and networks. Representing the effects of institutionalization processes, inertia arises from socially derived processes (e.g., homogenization of the employee base) as well as from elaboration of structural relationships (e.g., solidification of supplier relations). Inertia affects the firm's performance, flexibility, and ability to take in and act on new information. Notation: I; units: inertia units.

inertia_increase = (.005 + inertia)*fractional_inertia_increase/5.

Inertia increases as a result of two processes. First, every time period, basic group processes and socialization build up a small, fixed increment of inertia. Second, existing inertia generates more inertia by a fractional increase. The buildup of inertia is limited by a saturating effect of existing high inertia. This effect limits total inertia to a maximum of 1; see below. A third determinant of inertia increase is the inertia growth scaling factor, which allows the size of the inertia increase to be varied. Notation: inertia_increase, i_i; fixed increment, i_0 = .005; inertia growth scaling factor, $\alpha_i = 1/5$; units: inertia units per quarter.

Punctuated Change

inertia__decrease = inertia*fractional__inertia__decrease.

Inertia decreases as a fraction of its existing level. When there is a change in the organization's strategic orientation, this proportion increases from 0. With very large changes, the fractional change approaches 1. By using a fraction between 0 and 1, inertia is prevented from becoming negative even when the increase in inertia is small and the change in strategic orientation is large. The denominator ensures that the rate is correctly computed. Notation: i_d; units: inertia units/quarter.

competence = inertia*1.2.

The firm's competence, which can also be thought of as its efficiency, depends on two factors: the network it has built up with its environment (e.g., suppliers, customers) and the internal consistency it has built up (e.g., the socialization, operating rules, and other factors that govern employee performance). These are combined and represented in the single variable, competence. Competence is directly related to inertia by a linear factor. This multiplier is used to allow competence to reach a specified maximum. The maximum is greater than 1 to allow performance to exceed the desired performance. Notation: competence, *C;* inertia-competence scale factor, $\alpha_c = 1.2$; units: measure of competence (output-to-input ratios, for example).

ability__to__change__SO = GRAPH(inertia).

(0.5, 1.00), (0.542, 1.00), (0.583, 0.998), (0.625, 0.995), (0.667, 0.975), (0.708, 0.8), (0.75, 0.5), (0.792, 0.15), (0.833, 0.025), (0.875, 0.006), (0.917, 0.003), (0.958, 0.001), (1, 0.0001).

The firm's ability to change its strategic orientation (SO) is based on its tolerance for violating existing norms and its ability to disrupt the networks that link it to suppliers, customers, and others. These factors are related to inertia. Thus the ability to change SO is a function of inertia. When inertia is at low levels or 0, ability to change is at its maximum of 1. If inertia is at its maximum of 1, ability to change approaches 0 but is always greater than 0 because even high inertia cannot preclude change. Notation: ability to change SO, *B;* functional relationship between ability to change and inertia, f_B; units: dimensionless.

fractional__inertia__decrease = GRAPH[ABS(SO__change)].

(0.00, 0.00), (0.02, 0.5), (0.04, 0.8), (0.06, 0.9), (0.08, 0.94), (0.1, 0.966), (0.12, 0.98), (0.14, 0.99), (0.16, 0.999), (0.18, 1.00), (0.2, 1.00).

Inertia is reduced as a function of change in SO. If there is no change in SO this decrease is 0; as the magnitude of the organizational change increases, so too does the decrement in inertia. If the change in SO is large enough, the stock of existing inertia is destroyed. Notation: f_d; units: dimensionless units per quarter.

fractional__inertia__increase = GRAPH(inertia).

(0.7, 1.00), (0.725, 0.999), (0.75, 0.99), (0.775, 0.955), (0.8, 0.85), (0.825, 0.7), (0.85, 0.5), (0.875, 0.3), (0.9, 0.15), (0.925, 0.045), (0.95, 0.01), (0.975, 0.001), (1.00, 0.00).

The effect of a high level of existing inertia modifies the inflow into the inertia stock to ensure that the stock is limited to a maximum value. If the stock is less than 0.7, the full increment is added; but as the stock of inertia approaches 1, the increment is more and more steeply reduced to its minimum value of 0. For example, for the firm's workforce to become more inertial by becoming more homogenized, it must already have some homogeneity, allowing new recruits to be identified as appropriate for the firm's culture. Yet once the firm is very homogenous, adding more recruits who are well-matched to the existing culture will not further develop the firm's culture. Notation: f_i; units: dimensionless units per quarter.

Strategic Orientation Sector

strategic__orientation(t) = strategic__orientation(t − dt) + (SO__change) * dt.

INIT strategic__orientation = required__strategic__orientation.

The firm's strategic orientation is a unidimensional variable. It is a state variable because it is the outcome of the cumulation of past decisions on strategic orientation. It can only be changed by the management's decision to undertake a change in its SO. Initially, the firm's SO is set to be equal to that required by the environment. Notation: *S;* units: measure of SO, in this case unidimensional.

SO__change = (ability__to__change__SO*pressure__to__change* SO__response__gain)*SO__indicator.

The change in the firm's strategic orientation is determined by several factors simultaneously. First, pressure to change provides the impetus to change. This is modified by the organization's ability to change, which is a function of the level of inertia. SO response gain measures the amount of change undertaken by an organization in response to a unit of pressure to change. A further effect is provided by management's measurement of the organization-environment fit. Thus, the variable called SO indicator captures the perceived gap between required and actual strategic orientation. Notation: *SO* change, S'; ability to change, B; pressure to change, R; *SO* indicator, m; units: SO units per quarter.

required__strategic__orientation = 0 + exogenous input.

The strategic orientation required by the environment is an exogenous input in the base model. For equilibrium tests, the input is a constant; for one-time changes in the environment, it is a step input, and for constantly changing environments, it is a ramp input. Because the scaling of this variable is arbitrary, I generally choose values between 0 and 1. Notation: S^*; units: SO units.

SO__indicator = 1 + 0*SO__shortfall__indicator.

Two alternative forms for the strategic orientation indicator are shown here. These are chosen by changing the appropriate multipliers before each factor. The base case uses 1, which means that the organization is not measuring fit at all. The second case, in which SO shortfall indicator is multiplied by 1 and the first factor is switched to 0, models an organization that tracks an indicator of the gap between required and actual strategic orientation. Notation: m; units: dimensionless.

SO__response__gain = 2.

This factor determines the responsiveness of the organization to a given amount of pressure to change, modified by the corresponding ability to change. The larger it is, the more change in strategic orientation that results from a given impetus to change. Notation: α_s; units: dimensionless.

SO__shortfall = required__strategic__orientation − strategic__orientation.

This measures the gap in strategic orientation or, conversely, the organization-environment fit. SO shortfall is simply the difference between the firm's actual SO and that required for it to perform appropriately. To reach maximal appropriateness, the firm must change its SO by the full amount of the shortfall. Notation: G; units: SO units.

appropriateness = GRAPH[ABS(SO__shortfall)].

(0.00, 1.20), (0.1, 1.00), (0.2, 0.8), (0.3, 0.648), (0.4, 0.5), (0.5, 0.4), (0.6, 0.3), (0.7, 0.2), (0.8, 0.12), (0.9, 0.06), (1, 0.03), (1.10, 0.012), (1.20, 0.00).

The appropriateness of the firm's strategic orientation is determined by the size of the difference between the firm's SO and that required by the environment. It is a nonlinear decreasing function: if the gap is less than 0.1 units or so, the firm's appropriateness is at its maximum value, just above 1 (it maxes out at a value greater than 1 so that high appropriateness can compensate for low competence). If the gap is about 1 or greater, appropriateness falls to a negligible value. Notation:, f_A; units: appropriateness units (e.g., measure in lawsuits from regulators, rate of decline of market share, etc.).

Performance Sector

perceived__performance(t) = perceived__performance(t − dt) + (perceived__performance__change) * dt.

INIT perceived__performance = mean (performance,desired__performance).

Perceived performance is a smoothed average of performance. It is thus a stock of information that is modified over time by changes in perceived performance. At the beginning of the simulation, it is equal to the mean of actual and desired performance. This ensures that the model simulation begins with the organization in the favorable position of perceiving its performance to be relatively high. Notation: P^p; units: performance units.

perceived__performance__change = (performance − perceived__performance)/perception__time.

Punctuated Change

The change in perceived performance is proportional to the difference between the current value of perceived performance and the actual performance. Each month, a fraction of this difference is added to the perceived performance average. The fraction is inversely related to the perception time. Thus, the updating process is modeled as a change every time period equal to a given fraction of the difference between present perceived performance and actual performance; it is an exponential adjustment process. The smoothing is necessary to capture the effects of perception and measurement delays. Notation: P^p; units: performance units per quarter.

desired_performance = 1.

In this base case, desired performance is a constant set at unity for convenience. Later versions of the model can explore feedback processes that determine this goal. In either case, the desired performance represents a goal against which the firm compares perceived performance. Notation: P^*; units: performance units.

performance_shortfall = desired_performance – perceived_performance.

The difference between desired and perceived performance gives the performance shortfall. The larger the shortfall, the stronger will be the firm's corrective action. A negative shortfall means that perceived performance exceeds desired performance. Notation: P^g; units: performance units.

perception_time = GRAPH(inertia).

(0.00, 3.00), (0.0833, 3.00), (0.167, 3.00), (0.25, 3.20), (0.333, 3.50), (0.417, 4.00), (0.5, 4.50), (0.583, 5.00), (0.667, 5.50), (0.75, 5.80), (0.833, 6.00), (0.917, 6.00), (1.00, 6.00).

The time required to perceive performance gives the smoothing time constant used in calculating the perceived performance. It varies in relation to the socially anchored inertia of the firm, because a firm with a large amount of inertia is less able to take in new information from its environment. The maximum of 6 quarters is reached for maximum inertia (1); with very low levels of inertia, the perception time is its minimum of 3 quarters. Notation: performance perception time, τ_p; functional relationship between inertia and performance perception time, $f_\tau(I)$; units: quarters.

performance = GRAPH(appropriateness*competence).

(0.00, 0.00), (0.125, 0.125), (0.25, 0.25), (0.375, 0.375), (0.5, 0.5), (0.625, 0.625), (0.75, 0.75), (0.875, 0.875), (1.00, 1.00), (1.12, 1.05), (1.25, 1.07), (1.38, 1.08), (1.50, 1.09).

Performance is determined by two factors: the appropriateness of the firm's strategic orientation and its competence in implementing its strategic orientation. Because each of the two factors are allowed to go slightly over unity (so that high levels in one dimension can compensate for slightly unsatisfactory levels in the other), the product of the two can exceed unity. The saturating graph function is used to ensure that the dimensions of performance trade off only at relatively high values of both. The maximum value of performance is about 10 percent higher than desired performance. Notation: P; units: performance units (e.g., measurable in profit).

Pressure to Change Routine

pressure_to_change(t) = pressure_to_change(t – dt) + (change_pressure_incr – change_pressure_decr) * dt.

INIT pressure_to_change = 0.

Pressure to change is a stock that represents the accumulation of performance pressures. Its rate of change is the rate of increase of pressure to change less the rate of decrease in pressure. The initial value is set at 0 so that the model is initialized with no pressure to change. Notation: R; units: measure of pressure to change.

change_pressure_incr = if performance_shortfall > 0 then performance_shortfall, else min [performance_shortfall, (– 1*pressure _to_change)].

Pressure to change is increased by positive performance shortfalls. When performance shortfall is negative, this increase becomes negative, too, so that perceived performance in excess of desired performance reduces pressure to change. The minimum function is used to ensure that negative pressure to change is not generated when the magnitude of a negative value of performance shortfall is larger than the pressure to change stock. Notation: r_i; units: pressure units per quarter.

change__pressure__decr = if TPR__switch*trial__period__routine = 0, then pressure__to__change*fract__change__pressure__decr, else (pressure__to__change/DT + change__pressure__incr).

In the default case, the trial-period routine is not in operation, and pressure to change is decreased by a fractional amount given by the fractional decrease in pressure to change. When the trial-period routine is activated and the trial period is in effect, then the decrease in pressure to change is equal to the sum of existing and incoming pressure to change. Under such conditions, no pressure to change can accumulate. Notation: r_d; units: pressure units per quarter.

fract__change__pressure__decr = GRAPH[ABS(SO__change)].

(0.00, 0.2), (0.0167, 0.28), (0.0333, 0.36), (0.05, 0.44), (0.0667, 0.52), (0.0833, 0.6), (0.1, 0.68), (0.117, 0.76), (0.133, 0.84), (0.15, 0.92), (0.167, 0.97), (0.183, 0.99), (0.2, 1.00).

The fractional decrease in pressure to change is a function of the magnitude of change in strategic orientation. When strategic orientation is changed by a large amount, all pressure for change is removed. If there is no change in strategic orientation, nothing acts to relieve pressure to change, and there is only a small fall in pressure to change. This small fraction corresponds to an ongoing forgetting process whereby pressure to change generated several quarters ago is no longer taken into account by organizational decision makers. Notation: f_r; units: dimensionless units per quarter.

Fit Measurement Routine

perceived__SO__shortfall = smth1(SO__shortfall,SO__gap__perception__time,0).

Because the organization cannot instantaneously measure dimensions of its environment and its own performance, there is necessarily a difference between the actual strategic orientation shortfall, which determines actual performance, and that perceived by executives. In this case, perceived SO shortfall is a simple first-order smoothing of actual SO shortfall (i.e., the perceived value is updated every time period by a constant fraction of the gap between the actual and the perceived levels). This updating is governed by the time constant described below. To ensure initialization in equilibrium, the initial value of perceived SO shortfall is 0. Notation: G^p; units: performance units.

SO__gap__perception__time = .25.

This is the time constant governing the updating of organizational members' perception of the gap in strategic orientation. The perception time accounts for the time to gather data on organization-environment fit and interpret the information. Notation: τ_g; units: quarters.

SO__gap__threshold = 0.1.

This variable represents the minimum value that the perceived SO shortfall must exceed for decision makers to respond to pressure to change. Notation: G^t; units: SO units.

SO__shortfall__indicator = if abs(perceived__SO__shortfall) < SO__gap__threshold, then 0, else perceived__SO__shortfall.

The SO shortfall indicator provides a measure of the organization-environment fit used by the organization's executives in deciding whether to undertake a change in strategic orientation. The threshold SO gap is used to ensure that the organization will not react to a perceived SO gap when it is small enough that it can be ignored. Notation: *m;* units: dimensionless.

Trial-period Routine

trial__indicator(t) = trial__indicator(t – dt) + (trial__indic__infl – trial__indic__outfl) * dt.

INIT trial__indicator = 0.

This stock is a bookkeeping measure introduced to count off the length of the trial period. Once a large enough change in strategic orientation has been undertaken, this stock is increased by a one-time step and is then drawn down over time as the trial period progresses. Units: dimensionless.

trial__indic__infl = if change__indicator = 0 and trial__indicator = 0, then trial__period__length/(DT), else 0.

Punctuated Change

The inflow into the trial-period indicator is 0 unless the variable "change indicator" is greater than 0 and there is no trial period already in effect. When this inflow is non-zero, it is set to be long enough to allow the stock called trial period to stay above 0 for the length of time given by the trial period length. Units: dimensionless.

trial__indic__outfl = if trial__indicator > 1, then 1, else trial__indicator/DT.

As the trial period progresses, the trial-period indicator is drawn down by one unit every time period as a means of counting off the length of the trial period. Units: dimensionless.

change__indicator = if perceived__SO__change < chng__indic__threshold, then 0, else 1.

Change indicator is a variable that indicates whether the change in strategic orientation is large enough to initiate a trial period. If this indicator is 1, then the current change in strategic orientation is larger than the threshold value; if it is 0, then the change in strategic orientation has been small. Units: dimensionless.

chng__indic__threshold = .5.

This threshold specifies how large the change in strategic orientation must be to initiate the trial period. Units: SO units/quarter.

perceived__SO__change = DELAY[ABS(SO__change), SO__perception __time].

The perceived change in strategic orientation is, of course, related to the actual change in strategic orientation. Because there are inevitable delays in measuring, interpreting, and deciding to react to changes within the organization, there is a delay between the actual change in strategic orientation and the perceived SO change. Units: SO units/quarter.

SO__perception__time = .5.

This perception time measures the delay between the organization undertaking a change in strategic orientation and the initiation of the trial period. The delay is a result of cognitive, decision-making, communication, and implementation processes. It is rather short, because it seems likely that the same executives who have undertaken the reorientation are the ones who decide to implement a trial-period routine. Units: quarters.

TPR__switch = 0.

This switch activates the trial-period routine, making it possible for a large enough change in strategic orientation to trigger a trial period. Units: dimensionless.

trial__period__length = 6.

This measures the length of time during which pressure to change is ignored following a large enough reorientation. Units: quarters.

trial__period__routine = if change__indicator > 0 or trial__indicator > 1, then 1, else 0.

The trial-period routine is a switch that gives a value of 1 when the trial-period routine has been undertaken. If there has not been a large enough change in strategic orientation to cause the routine to be initiated, this indicator takes on a value of 0. Units: dimensionless.

Appendix B: Parameter Values for Figures (Changes from Default)
For definitions and default values, see model listing.

	Figure				
Variable	2	3	4	5	6
S^*	0	0	0, then 1	0, then 1	0, then 1
I_0	0.7	0.68	0.6	0.6	0.6
α_s	2	2	2	7	2
τ_g	N/A	N/A	0.25	0.25	0.25
G^t	N/A	N/A	0.1	0.1	0.1
τ_p	N/A	N/A	N/A	N/A	0.5
τ_t	N/A	N/A	N/A	N/A	6
S^t	N/A	N/A	N/A	N/A	0.5