THE INERTIA OF INNOVATION: TEMPORAL ROUTINES FOR GENERATIONAL PRODUCT INNOVATION IN COMPUTER SOFTWARE

by
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ABSTRACT

Scott F. Turner

THE INERTIA OF INNOVATION:
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IN COMPUTER SOFTWARE

(Under the direction of Dr. Richard A. Bettis)

This research project examines the role of inertia in explaining the innovative behavior of organizations. While the inertia lens has played a key role in our understanding of organizational change, the literature has neglected an important dimension of inertia: the consistency of change. Consistency of change refers to the principle that a body in motion remains in uniform motion unless acted upon by external forces (Newton, 1995/1687).

In this study, I develop a consistency of change theoretical perspective by integrating temporal pacing research (Brown and Eisenhardt, 1997) and routines-based theory from evolutionary economics (Nelson and Winter, 1982). This theoretical perspective focuses on the introduction and retention of temporal routines for incremental change, which are procedures for introducing incremental changes in organizations at consistent intervals across time.

This study applies the theoretical perspective in a context of generational product innovation and tests two core hypotheses. A generational product innovation represents a significant advance in the technical performance of an existing product (Lawless and Anderson, 1996). While scholars have devoted significant attention to innovation, relatively little research focuses on generational product innovation. Yet, in many high technology industries, like computer software and semiconductors, organizations compete on this basis.

By conducting this study, I intend to make three contributions. First, developing the temporal routines for incremental change theoretical perspective enhances our understanding of the dynamics of inertia. Second, with an emphasis on endogenous demand, the theoretical perspective provides an inter-organizational explanation for the introduction and retention of temporal routines for incremental change. Last, the study provides empirical evidence to support a temporal routines-based perspective of generational product innovation.

The empirical context is business productivity application segments of the U. S. microcomputer software industry from 1994 to 1998, including computer-aided design (CAD), desktop publishing, spreadsheets, and word-processing. To test the hypotheses, I use discrete-time event history analysis. In particular, the analytic technique is a probit model with sample selection.

My results indicate that, in a developed stage of the computer software industry, organizations employ temporal routines for generational product innovation. Further, with increasing organizational size, organizations have a greater tendency to employ these routines.

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CHAPTER 1

INTRODUCTION

Innovation is a subject of great interest among scholars and practitioners of strategic management. In this area, the body of knowledge is built largely from studies that examine innovation in the form of singular disruptive events. But we know little about the role of routines in the innovation process. Typically, we view routines as inertial and preserving the status quo (i.e., "a picture of stagnating routine," Schumpeter, 1942: 85), while innovation represents substantial breaks from established techniques. From this vantage point, the concepts of routine and innovation are in clear tension -- routines that preserve the status quo versus innovation that breaks it. Yet we may see more clearly with a shift in vantage point. By examining the intersection of these two concepts, or routines for innovation, we may gain a much richer understanding of change in organizations. While the theme of routines for innovation is not new (i.e., Brown and Eisenhardt, 1997; Nelson and Winter, 1982), its development in the literature is limited, particularly relative to the attention devoted to innovation as singular disruptive events.

Specifically, I examine the role of inertia in explaining the introduction of incremental changes, or incremental innovations, within organizations. Inertia is examined through a lens of temporal routines for incremental change, which is a theoretical perspective for explaining the introduction of incremental changes within organizations at consistent intervals across time. By focusing on consistency of change, this study contributes to our understanding of the dynamics of inertia.

In physics, inertia refers to the principle that, unless acted upon by an external force, (a) a body at rest remains at rest, and (b) a body in motion remains in a state of uniform motion (Newton, 1995/1687). The inertia perspective has been imported into organizational theory from physics, and this lens has played a key role in our understanding of organizational change (Hannan and Freeman, 1984). This stream of research places primary emphasis on explaining singular changes in organizational structure. However, little research examines the consistency of change, which represents a dynamic dimension of inertia. This dimension of inertia refers to the principle that a body in motion will remain in uniform motion (Newton, 1995/1687). To develop the consistency of change perspective, my theoretical foundation draws from routines-based theory in evolutionary economics (Nelson and Winter, 1982) and research on temporal pacing of change (Brown and Eisenhardt, 1997).

This study refers to the consistency of change perspective as the temporal routines for incremental change theoretical perspective. Note that there is a need to clearly distinguish between temporal routines as a concept (i.e., a procedure) and temporal routines for incremental change as a theoretical perspective. When referring to temporal routines for incremental change as a theoretical perspective, I will distinguish the usage by highlighting with the TRIC acronym. When referring to temporal routines for change as a concept, I will not use the TRIC acronym.

Temporal routines for incremental change can be a key element in an organizational strategy for change. These routines emphasize the inertial nature of the change process in organizations (e.g., releasing a new product innovation every 18 months). This issue has important implications for organizations, given that change can be costly. In addition to the direct costs associated with change, there may be large opportunity costs associated with a routine process of incremental change. If organizations allocate attention and resources to recurring incremental change, they may be overlooking larger, and potentially more important, change opportunities.

With respect to theory development, the focal research question is the following: Why are temporal routines for incremental change introduced and retained in organizations? There are two intended theoretical contributions. First, to the organizational ecology literature, this study enhances our understanding of the dynamics of inertia. In particular, my focus is on the consistent timing of incremental change within organizations. Here I integrate inductively-developed theory on temporal pacing of change (Brown and Eisenhardt, 1997) and routines-based theory from evolutionary economics (Nelson and Winter, 1982).

Second, to routines-based theory, I contribute an explanation for why temporal routines for incremental change are introduced and retained within organizations. Zollo and Winter (2002) recently observed that there is little understanding as to the emergence of routines in organizations. In evolutionary economics, Nelson and Winter (1982) emphasize routines as determined by intra-organizational pressure (i.e., implicit or explicit agreement among organizational members to maintain the routine). In the temporal pacing of change literature, research emphasizes routines as determined by external entrainment pressure. Entrainment refers to a pattern in which recurring activities in the environment stimulate consistent change across time within organizations (Ancona and Chong, 1996). In this study, the theoretical perspective emphasizes endogeneity in the demand for change, suggesting that temporal routines for incremental change develop between producers and their organizational customers as the result of the disruptive nature of change. Further, I suggest that organizational size is a key enabler for the introduction and retention of these routines.

Next I apply the temporal routines for incremental change (TRIC) theoretical perspective in a particular context, and I test two core hypotheses that are derived from the theoretical perspective. For the test, the three focal concepts are the introduction of an incremental change, the time since the previous change of the same type, and organizational size. The first hypothesis predicts the existence of temporal routines for incremental change in organizations. For the first hypothesis, I examine a curvilinear effect of the time since the previous change of the same type on the introduction of an incremental change within the organization. The second hypothesis predicts a strengthening effect of organizational size on temporal routines for incremental change. For the second hypothesis, I study an interactive effect between organizational size and the time since the previous change of the same type on the introduction of an incremental change within the organization.

Specifically, this study applies the temporal routines for incremental change (TRIC) perspective in the context of generational product innovation. A generational product innovation represents a significant advance in the technical performance of an existing product. For example, Word 2.0 and Word 3.0 are generational product innovations within the Microsoft Word family of word-processing software applications. While scholars devote significant attention to innovation, much of this research focuses on either minor or major technological changes. Little research examines generational product innovation, which represents a mid-range technological change. Yet, in many high technology industries, like computer software and semiconductors, organizations compete on this basis.

The application portion of this study has two intended contributions. First, it applies an underutilized theoretical perspective to the study of product innovation, employing routines-based theory from evolutionary economics (Nelson and Winter, 1982). Specifically, I utilize the temporal routines for incremental change (TRIC) theoretical perspective. This perspective can be contrasted against traditional lines of research in industrial organization economics and organizational ecology. In industrial organization economics, focal dependent variables are product and process innovation, and core determinants are organizational size and market concentration (Cohen and Levin, 1989; Cohen, 1995). This work is often referenced as the Schumpeterian line of research, stemming from the influential role of Schumpeter (1942). In organizational ecology, the focal dependent variable is change in organizational structure, and core determinants are organizational size and age (Baum, 1999; Hannan and Freeman, 1984).

The second intended contribution from the application portion of this study is a statistical test of temporal routines for incremental change using panel data. For routines-based theory, the base of empirical research is largely composed of computer simulations, case studies, and laboratory experiments. Yet our understanding of routines is inhibited by a notable lack of studies involving statistical analysis and longitudinal datasets (Aldrich, 1999; Cohen, et al., 1996). The need for such longitudinal analysis is particularly important given the repetitive nature of organizational routines. With specific reference to temporal routines-based research, the initial work in this area concentrates on inductive theory-building from case studies (Brown and Eisenhardt, 1997; Gersick, 1994). To my knowledge, this study provides the first statistical test of temporal routines using archival data.

The empirical context is business productivity application segments of the microcomputer software industry in the United States from 1994 to 1998. The dataset includes organizations that compete in four application segments: computer-aided design (CAD), desktop publishing, spreadsheets, and word-processing. I obtained the starting point of the dataset from PC Data, a market research firm that specializes in information technology markets, and I have extensively supplemented the initial dataset with archival research.

To test the hypotheses, I use discrete-time event history analysis. In particular, the analytic technique is a probit model with sample selection. My results indicate that, in a developed stage of the computer software industry, organizations employ temporal routines for generational product innovation. Further, with increasing organizational size, organizations have a greater tendency to employ these temporal routines.

The remainder of the dissertation is presented as follows. Chapter 2 reviews relevant literature in the following areas: inertia (physics, organizational ecology), organizational routines, and temporal pacing of change. Chapter 3 develops the temporal routines for incremental change (TRIC) theoretical perspective. This chapter includes the (a) statement of the boundary conditions and requisite assumptions, and (b) presentation of the argument in a casual diagram tradition. In Chapter 4, I apply the temporal routines for incremental change (TRIC) perspective in the context of generational product innovation in the microcomputer applications software industry, and I develop two core hypotheses that are derived from the theoretical perspective. This chapter includes the presentation of focal concepts and development of the logic underlying the hypotheses. Chapter 5 presents the empirical context, data, operational variables, and analytic technique. In Chapter 6, I present the results of the empirical analysis. Last, I present implications from the study in Chapter 7, followed by a brief conclusion.

CHAPTER 2

LITERATURE REVIEW

In this chapter, I review three areas of the literature with particular attention to their relevance for this study. These areas are (a) inertia (physics, organizational ecology), (b) organizational routines, and (c) temporal pacing of change. With particular emphasis on organizational routines, these areas form the conceptual foundation for this study.

2.1 INERTIA: PHYSICS

A primary contribution of this study is the reexamination of change through an inertia lens. Researchers have imported the inertia perspective into organizational theory and strategic management from physics, and this line of research employs inertia as a metaphor to explain organizational change. The application of inertia in an organizational context focuses primarily on one aspect of inertia: speed of structural adjustment to external forces (Baum, 1999; Hannan and Freeman, 1984). This application tends to focus on inertia from the following perspective: a body at rest remains at rest unless acted upon by an external force. Note that this is a static perspective of inertia. While instrumental in developing our understanding of organizations, this perspective is incomplete. Researchers have devoted little attention to inertia from the perspective of a body in motion remaining in uniform motion.[1]

To further develop the inertia perspective in organizations, I find notable value in first returning to the intellectual roots in the physics literature. This study frames inertia in organizations with respect to the laws of motion (Newton, 1995/1687). Newton considered these laws to be the basic postulates by which all motion could be described (Rothman, 1963). In particular, my attention focuses on the first and second laws of motion. The first law of motion is often referred to as the law of inertia:

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[1] Research by Terry Amburgey and his colleagues (e.g., Amburgey and Miner, 1992; Amburgey, et al., 1993) represents an exception. My work complements this line of research.

> **Law I**. Every body perseveres in its state of rest, or of uniform motion in a right line, unless it is compelled to change that state by forces impressed thereon (Newton, 1995/1687: 19).

For this research project, I highlight that two elements are embedded within the first law of motion. The first element emphasizes that a body at rest will remain at rest unless acted upon by a net external force. The second element states that a body in motion will remain in uniform motion in a straight line unless acted upon by a net external force. In this study, my attention is focused on the second element. In particular, I align a 'body in motion remains in uniform motion' with consistency of change in organizations.

The second law of motion examines the relationship between the forces acting upon a body and its corresponding acceleration.

> **Law II**. The alteration of motion is ever proportional to the motive force impressed; and is made in the direction of the right line in which that force is impressed (Newton, 1995/1687: 19).

The second law states that the acceleration of an object is proportional to the net force exerted on the object (Gettys, et al., 1989: 86). In equation form, Newton's second law is the following: $\Sigma F = m^*a$. The left side represents the net external force acting upon the object (ΣF). On the right side of the equation is the mass of the object (m), often referred to as the inertial mass, and the acceleration of the body (a). Based on Newton's second law, for a given net external force, an object with greater mass has lower acceleration (Gettys, et al., 1989).

2.2 INERTIA: ORGANIZATIONAL ECOLOGY

The laws of motion provide the framework for my review of inertia research in the organizations literature. The first law emphasizes that, unless acted upon by a net external force, (1) a body at rest will remain at rest and (2) a body in motion will remain in constant motion in the same direction. The second law emphasizes that, for a given net external force, an object with a larger mass will have slower acceleration (Newton, 1995/1687).

The importation of the inertia perspective by Hannan and Freeman (1984) provides the starting point for this discussion. Hannan and Freeman (1984) define inertia in terms of the adjustment speed of organizational structure given change in the environment. Structures of organizations have high inertia "when the speed of reorganization is much lower than the rate at which environmental conditions change" (Hannan and Freeman, 1984: 151). With respect to the laws of motion, the orientation of this work is from the perspective of a body at rest. The existing organizational structure is the body at rest, and acceleration refers to the rate at which change in organizational structure occurs. Hannan and Freeman (1984) posit positive effects of size and age on structural inertia. Implicitly, they align size and age with the concept of mass from the second law of motion.

Hannan and Freeman (1984) did not consider the dynamics of inertia. However, researchers examining organizational momentum have observed and started to address this gap in the theory (Amburgey, et al., 1993). In the organizations literature, momentum refers to the tendency of an organization to maintain or extend its previous behavior (Amburgey and Miner, 1992; Miller and Friesen, 1980).[2] In particular, the momentum stream of research focuses on the effect of previous changes on the likelihood of change. There are two categories of interest here: (a) the cumulative number of previous changes, and (b) the timing of previous changes.

The first category, cumulative number of previous changes, is termed repetitive momentum (Amburgey and Miner, 1992). It posits a positive effect of the cumulative number of previous changes of the same type on the likelihood of change. As presented in Amburgey, et al. (1993), the argument for repetitive momentum has two elements. First, the more experience or familiarity that an organization has with a particular type of change, the more likely it will view that change as a solution to a broader set of problems. Second, as an organization progresses along a learning curve (Yelle, 1979), the cost of making a given type of change decreases. As the cost decreases, making the change appears more favorable in addressing a larger number of scenarios (Amburgey, et al., 1993). In his review of the literature, Baum (1999) observed that the repetitive momentum concept has strong and consistent empirical support.

Researchers have devoted less attention to the second category, the timing of previous changes. Amburgey, et al. (1993) suggest a negative effect of the elapsed time since previous change of the same type on the likelihood of change. Their rationale is that an organization's search process for potential solutions is local, beginning with recently-enacted

[2] In physics, momentum (p) is the product of an object's mass, *m*, and its velocity, v (Gettys, et al., 1989).

solutions (Cyert and March, 1992/1963). In their study of the Finnish newspaper industry, Amburgey, et al. (1993) found empirical support for a negative effect. However, in reviewing the empirical research across studies, Baum (1999) found a mixture of evidence. Of thirteen relationships across six studies, Baum (1999) observed five negative effects, two positive effects, and six effects which were not statistically significant. I examine the role of the timing of previous changes in greater depth in Section 2.4, the temporal pacing of change section.

Similar to the broader inertia perspective (Newton, 1995/1687), note that the organizational momentum perspective contains two nested elements: (a) maintaining an existing change behavior, and (b) extending an existing change behavior. In the initial research in this area (Amburgey, et al., 1993; Miller and Friesen, 1980), extending a change behavior draws the most attention. However, little research examines the maintenance of a change behavior.[3] Amburgey, et al. (1993) observe that much greater attention is needed in the area of the dynamics of inertia.

See Figure 1 for a summary chart that compares the structural inertia and organizational momentum lines of research with the focal study, using the first two laws of motion as a means of comparison.

2.3 ORGANIZATIONAL ROUTINES

Underlying a notable portion of the research on inertia is the perspective of the behavior of organizations as a series of routines (Hannan and Freeman, 1984; Nelson and Winter, 1982). In this section, I provide a review of the routines literature, particularly as it pertains to this research project. First, I review the central tenets of a routines-based perspective of organizations from evolutionary economics. While evolutionary economics has deeper historical roots (Hodgson, 1994; Veblen, 1898), my attention focuses primarily on Nelson and Winter (1982). Andersen (1994: 18) identifies Nelson and Winter (1982) as a landmark work in evolutionary economics, largely for its role in laying a clear research program foundation.

Then I present the literature in two categories: (a) studying repertoires of routines, and (b) studying a given routine (Hannan and Freeman, 1989; Cohen, et al., 1996). Given the

[3] Brown and Eisenhardt's (1997) work on temporal pacing of change represents an exception, and it will be discussed in greater depth later in the study.

hierarchical nature of routines (Nelson, 1991; Simon, 1962), this categorization of the literature is a relative one.

2.3.1 Central Tenets of Routines-based Theory from Evolutionary Economics

Nelson and Winter (1982: 96-97) present three boundary conditions for routines-based theory: (a) the organizations are large and complex, (b) the production of goods and services does not change over extended periods of time, and (c) the organizations are not involved in the "production or management of economic change as their principal functions -- organizations such as R&D laboratories and consulting firms -- do not fit neatly into the routine operation mold." However, Nelson and Winter (1982) emphasize that routinized innovation by modern corporations is consistent with their argument.

Broadly, routines are repetitive patterns of organizational behavior.[4] More specifically, Cohen, et al. (1996: 683) define a routine as "an executable capability for repeated performance in some context that [has] been learned by an organization in response to selective pressures." A point of debate in the field concerns whether a routine is (a) an automatic, non-choice action pattern, or (b) an action pattern which may or may not involve deliberate choice (Cohen, et al., 1996). In this study, my orientation towards routines is in the latter group.

Researchers distinguish routines-based theory from orthodox theory in economics (Cyert and March, 1992/1963; Nelson and Winter, 1982). According to routines-based theory, organizations function according to their set of routines. According to orthodox theory, organizations optimize their behavior (e.g., profit maximization). In routines-based theory, organizations employ decision rules that are "plausibly responsive" to changes in organizational performance (Nelson and Winter, 1982). Organizations largely seek to preserve their existing operating routines, and where possible, establish modification routines to create a system for changing the set of operating routines.

The arrival of problems (e.g., a rise in the price of an input factor) often stimulates change in a set of operating routines. This is particularly likely when a problem causes organizational performance to fall below a target, or aspiration, level. To address the

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4 My attention focuses on routines at the organizational level (Cyert and March, 1992/1963; Nelson and Winter, 1982), but researchers examine routines at multiple levels within organizations. See Weiss and Ilgen (1985) for research on routines at an individual level within organizations, and see Gersick and Hackman (1990) for an examination of routines at a group level.

problem, organizations search for solutions near the source of the problem (i.e., problemistic search), typically using the organization's existing set of routines as a reference point for developing solutions. The search process generates potential solutions to the problem, and if the organization expects the potential solutions to improve organizational performance, the organization adopts them (Cyert and March, 1992/1963; Nelson and Winter, 1982).[5]

Routines represent the genetic material of organizations. According to Nelson and Winter (1982: 128), "the heart of our theoretical proposal [is that] the behavior of firms can be explained by the routines that they employ." Hence, the organization is a bundle of routines (Dowell, 2000). In a routines-based perspective of organizations, I assume the presence of boundedly-rational actors. These actors have organization-specific foresight (Karim and Mitchell, 2000; Nelson, 1991) with a tendency to focus on local alternatives (Dowell, 2000).

Routines are the fundamental units of analysis in evolutionary economics, and they are hierarchical in nature. There are multiple perspectives on the hierarchical nature of routines. From one perspective, researchers view routines in a two-level hierarchy. Nelson and Winter (1982) present two general classes of routines. Operating routines are standard patterns of organizational activity in a given context. Modification routines are patterns of activity which systematically change the operating routines of an organization[6] (Nelson, 1991; Nelson and Winter, 1982).

From another perspective, researchers view individual routines in aggregation as larger repertoires of routines. Cohen, et al. (1996) describe this as the grain size issue, contrasting a single routine as a block of action against an interleaving of routines into larger repertoires of routines.[7] In the repertoires of routines tradition, Karim and Mitchell (2000) argue that in

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5 Researchers also examine alternative modes of search. For example, Levinthal and March (1981) assume that, if target performance exceeds actual performance, an organization engages in problemistic search. However, if actual performance exceeds target performance, an organization may engage in "irresponsible search" (i.e., undirected search) due to the accumulation of organizational slack.

6 More recently, Zollo and Winter (2002) have aligned the concept of modification routines with that of a dynamic capability (Teece, et al., 1997).

7 Aldrich (1999) presents the grain size issue within a larger frame of evolutionary theory, observing that units for selection can be (a) single routines, (b) repertoires of routines within organizations, and (c) organizations as single interconnected bundles of routines. And, although subject to greater debate, populations and communities can also serve as appropriate units for selection (Aldrich, 1999).

this aggregated form, a coordinated set of routines is a core resource for generating organizational value.

In this study, my alignment is with the tradition of examining routines in the form of operating and modification types. I also explicitly expand on the hierarchical nature of routines, looking within a given routine. I view each routine as being composed of sub-level components. The term, component, refers to underlying routines and artifacts that enable execution of the focal routine. The focal routine serves to integrate the sub-level routines and artifacts towards the fluid performance of work.

Relative to this study, the assumption that routines are self-sustaining is an important one. Nelson and Winter (1982) provide this condition as a basic assumption of the evolutionary model, highlighting that routines become established among organizational members. Nelson and Winter (1982) refer to this establishment as a de facto contract, or "routine as truce." However, the researchers also acknowledge that, in some cases, simply maintaining an existing routine is a difficult task; in these situations, Nelson and Winter (1982) argue that a smoothly-executed routine is the objective ("routines as target"). In the following sub-sections, I present two related areas of research on routines: (a) studying organizations as repertoires of routines, and (b) studying a given routine.

2.3.2 Studying Repertoires of Routines

Studies which examine repertoires of routines represent one core area of the literature (Cohen, et al., 1996; Hannan and Freeman, 1989). Within this broad area, there are two sub-categories. In the first sub-category, researchers focus on the process by which organizations function as a set of routines. This line of research differentiates routines by type, such as operating/modification (Nelson and Winter, 1982) and first-order/second-order (Cyert and March, 1992/1963; Levinthal and March, 1981). In the second sub-category, researchers focus on resources as aggregates of routines. This line of research differentiates routines with respect to the resources into which they are aggregated. Here, researchers have used product lines as operational measures of resources, which are composed of a given set of routines (Dowell, 2000; Karim and Mitchell, 2000). Below I present a brief overview of conceptual and empirical work in these two sub-categories.

In the first sub-category, researchers focus on describing the process by which multiple routines operate and interact to explain firm behavior. Cyert and March (1992/1963) focus their efforts on explaining firm behavior. In Nelson and Winter (1982), the researchers present a routines-based model of firm behavior as a step towards describing the behavior of industries. In this sub-category, computer simulation models are the primary means of analysis. The simulations have typically been successful in aligning with available empirical data, and the models produce interesting insights. In one case, using a pricing procedure simulation, Cyert and March (1992/1963) matched to the penny 95% of pricing predictions. In Nelson and Winter (1982), the researchers modeled microeconomic processes, primarily involving aspects of search and selection behavior, to aggregate up to a macroeconomic level. Levinthal and March (1981) and Mezias and Glynn (1993) are other examples of simulations that develop this stream of research.

In the second sub-category, research focuses on organizational change implications from a repertoires of routines perspective. Two studies in this area are Karim and Mitchell (2000) and Dowell (2000). In the first study, Karim and Mitchell (2000) examined the effect of acquisitions on organizational change through change in routines. In the second project, Dowell (2000) studied the effects of an organization's breadth of routines and its experience with the routines on survival, examining dissolution and acquisition as alternative modes of organizational termination.

Viewing resources as aggregates of routines, Karim and Mitchell (2000) found that the use of acquisitions as a means of resource reconfiguration led to greater organizational change. They found that organizations use acquisitions to primarily strengthen their existing resource base and also to make substantial transitions into new resource areas. They did not find acquisitions as a means for incremental transitions into related resource areas, suggesting that internal development is a preferred means of growth for incremental change (Karim and Mitchell, 2000).

Dowell (2000) examined routines as constraints on organizational change. The researcher presented (a) product line breadth as a measure of breadth of routines and (b) operating experience in a market segment as a measure of firm experience with a set of routines. Dowell found that the risk of firm dissolution first increases with breadth of routines and then beyond a threshold, it decreases. As such, there is survival value from increasing breadth of routines, but firms can find it difficult to reach the level at which these survival benefits are conferred. Dowell also found that risk of dissolution decreases at a decreasing rate with experience. With respect to probability of acquisition, Dowell found positive effects for breadth of routines and experience.

2.3.3 Studying a Given Routine

Studies that examine a given routine represent another core area for routines-based research (Cohen, et al., 1996; Hannan and Freeman, 1989). In this area, researchers direct attention to a focal routine, with acknowledgement that the focal routine is typically composed of sub-level routines and resources (Feldman, 2000; Nelson, 1991). Extending the Henderson and Clark (1990) typology, I present a framework for classifying research on innovation of routines.[8] This framework classifies research in which the focus is directed to change in a given routine. Henderson and Clark (1990) define product innovations along two dimensions: (1) degree of change in core components, and (2) degree of change in the linkages among components. In extending the typology to innovation of routines, the first dimension focuses on the extent to which the core components of an operating routine are being reinforced relative to overturned, and the second dimension focuses on the extent to which the work flow pattern that integrates the components of the operating routine is changed.

In Figure 2, I present five studies in this classification framework. The first study focuses on the consistency of product innovation routines across time (Brown and Eisenhardt, 1997). The second study focuses on incremental change in operating routines due to feedback from participants (Feldman, 2000). The third and fourth studies examine the effect of input changes on operating routines (Edmondson, et al., 2001; Mukherjee, et al., 2000). The fifth study examines the effect on routine performance from introducing novelty to an established routine (Cohen and Bacdayan, 1994). I do not intend for the positioning of the studies in Figure 2 to be exact, rather a relative comparison of research that focuses on change in a given routine along two meaningful dimensions.

[8] In related work, Dowell (2000: 173) suggests Henderson and Clark (1990) as a framework for classifying change in product routines. While the emphasis on routines differs between Dowell (2000) and this study, I also find Henderson and Clark (1990) as a valuable framework for classifying change in routines.

First, using an inductive theory-building approach involving multiple cases, Brown and Eisenhardt (1997) examined temporal routines for change in the computing industry. The researchers observed that organizations with temporal routines for change (e.g., consistently releasing a new product platform every 24 months) outperformed organizations that did not employ these routines. Brown and Eisenhardt (1997) defined performance in terms of positive characteristics (e.g., on schedule, on time to market) and negative characteristics (e.g., make-work) for the organization's product portfolio. I view this definition of performance as an internal dimension of organizational performance, aligning with the degree of fluidity in the process of product innovation. Based on their observations, the researchers hypothesized a positive effect of temporal routines on this internal dimension of organizational performance.[9] From their description, I infer that Brown and Eisenhardt (1997) were studying patterns consistent with temporal routines for incremental change. In Figure 2, I present this study as an examination of incremental innovation.

Second, using a single-case inductive approach, Feldman (2000) examined evolutionary change in an existing routine. The researcher examined the evolution of several routines nested under a broader operating routine for moving university students into residence halls, finding that the participants in the routines provided the stimulus for evolution of the routine. Based on her description, I view Feldman (2000) as a study of incremental changes to an existing routine, and I present the study in the corresponding cell in Figure 2. Relative to Brown and Eisenhardt (1997), Feldman (2000) describes greater change in the work flow of the routine. Therefore, its position along the work flow dimension reflects this greater degree of change.

Third, Mukherjee, et al. (2000) studied multiple cases within a single organization. The researchers examined the effect of change in the core components of an operating routine on its performance. The researchers conducted statistical tests of product line performance using longitudinal data, and they found that variance in the set of inputs to the operating routine led to disruptions in the performance of the routine. I interpret this study as examining innovation to an operating routine with variance on the degree of core component

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[9] Further, Brown and Eisenhardt (1997) observed a positive linkage between the internal dimension of organizational performance (i.e., product portfolio success) and external dimensions of organizational performance (e.g., market dominance). However, Brown and Eisenhardt (1997) did not provide an in-depth examination of this linkage.

change and an unchanged work flow pattern. As such, in Figure 2, I present this study as overlapping the incremental innovation and modular innovation cells.

In the fourth study, researchers examined the effect of introducing a new technology into an existing cardiac surgery routine (Edmondson, et al., 2001). Edmondson, et al. (2001) define success as the degree of use of the new technology in the hospital. As such, success refers to greater adoption of the new technology within the hospital. The researchers found that successful implementation of the new technology required fundamental change in the nature of the operating routine. For successful organizations, this perspective aligns with making a radical innovation to an existing operating routine. The new technology overturned several core components from the existing operating routine, which required major changes in the work flow pattern (i.e., the linkage among the components of the routine). In the less-successful organizations, participants viewed the new technology as a modular innovation to the existing operating routine. In this case, organizational leaders tried to introduce the new surgical technique without changing the existing work flow pattern (Edmondson, et al., 2001). Since this study has elements of radical innovation (perspective taken by more successful organizations) and modular innovation (perspective taken by less successful organizations), I present it as overlapping the two respective cells in Figure 2.

Last, Cohen and Bacdayan (1994) examined the formation, and subsequent disruption, of an organizational routine using a laboratory experiment. In this study, the researchers used a card-playing game as a routine, arguing that such games exhibit many characteristics of an organizational routine: reliability, repeated action sequences, occasional sub-optimality, and faster execution relative to deliberative decision-making. After participants established an organization routine through repeated plays of the game, the researchers imposed two manipulations. The first manipulation was routine novelty, where the researchers rearranged the seating of participants and changed a game rule to focus on a different-color card. The second manipulation was a time delay. In one condition, the delay was a two-to-four hour break, and in another condition, it was a one-to-two week delay. Cohen and Bacdayan found that the time delay did not have an effect on subsequent routine performance, while a minor change in routine novelty resulted in significantly slower performance of the routine. Here performance is defined in terms of the speed of execution in playing hands of the card game.

Since the novelty manipulation compares favorably with a change in work flow pattern, I present this study in the architectural innovation cell in Figure 2.

2.4 TEMPORAL PACING OF CHANGE

In the organizations literature, there is increasing interest in temporal factors relating to organizational change (Ancona, et al., 2001; Bluedorn, 2002). In this section, I review the literature on temporal pacing of change, particularly as it pertains to the focal study. The literature review has two sub-sections. The first sub-section focuses on the idea that temporal pacing of organizational change can be viewed as a special case of routines-based theory, where the routine is of a temporal nature. The second sub-section discusses entrainment, which is a process by which the regular occurrence of external entraining events dictates the pace of organizational change.

2.4.1 Temporal Routines for Change

In this project, my focus is on studying a given routine, and the type of routine is one of temporal consistency of incremental changes. Gersick (1994) and Brown and Eisenhardt (1997) are two important studies in the organizations literature that use inductive theory-building from cases to develop the idea of temporal pacing of change. In a single case, Gersick (1994) explored whether temporal pacing of change can explain the behavior of an organization. Using multiple cases, Brown and Eisenhardt (1997) developed theory to explain the effect of temporal pacing on organizational performance. In these studies, the temporal pacing of change can be viewed through a routines-based lens. While both studies examine temporal consistency in change behavior, note that the type of change differs across the two studies. Gersick (1994) observed change in the form of periodic major initiatives (e.g., attaining liquidity, establishing a joint venture), while Brown and Eisenhardt (1997) observed change of a smaller magnitude but of a consistent type (e.g., product innovations).

Gersick (1994) studied a single venture capital-funded start-up organization over time to determine whether temporal pacing could explain its pattern of behavior.[10] The researcher observed that major strategy initiatives by the start-up CEO were initiated in the summer, or

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[10] Gersick (1994) is an organization-level extension of her previous group-level research on temporal patterns of change (Gersick, 1988). In this research, Gersick (1988) observed that projects follow a similar pattern: a given form of behavior up to the middle point of total project time, then a transition, followed by a different form of behavior until task completion.

the mid-point of a year. In this case, the CEO used the summer as an opportunity to assess progress and initiate major strategic changes. These mid-year opportunities for strategic change were steps within a larger, five-year period. At the end of five years, the CEO expected a major performance assessment for the start-up organization. Gersick (1994) found that this type of temporal pacing facilitates punctuated patterns of change. Gersick (1994) contrasted this form of temporal pacing against temporal maintenance, where the objective is to preserve order rather than change it. If we interpret preserving order as reinforcing routine components and preserving the architecture (i.e., work flow pattern) of the routine, temporal maintenance is consistent with temporal routines for incremental change.

In Brown and Eisenhardt (1997), the researchers examined temporal and event-based pacing in the computing industry. This research project was an inductive case-based study examining nine business units from separate firms. The researchers observed that successful product portfolios were managed by temporal pacing, where businesses made consistent transitions between products every 12-24 months. By transitioning at predictable time intervals, the organizations developed a rhythm and focused flow of attention. Further, the temporal transitions across product generations aided organizations in the allocation of resources across phases of product development. Brown and Eisenhardt (1997) referred to the pattern as one of continuous change, as opposed to the punctuated pattern of change observed by Gersick (1994). Further, Gersick's (1994) description of temporal maintenance (i.e., preserving order) appears to describe the type of change examined in Brown and Eisenhardt (1997).

2.4.2 Entrainment and Temporal Pacing of Change

Researchers in the organizations literature have imported the perspective of entrainment from biology, defining entrainment as "the adjustment of the pace or cycle of an activity to match or synchronize with that of another activity" (Ancona and Chong, 1996: 253). Bluedorn (2002: 148) notes that one of the activities tends to be the "more powerful or dominant and [captures] the rhythm of the other." The more dominant activity is termed the entraining force. Researchers also refer to the entraining force as the zeitgeber, which is of German origin and means "time giver" (Ancona and Chong, 1996; Bluedorn, 2002). The key idea behind this argument is that the entraining force sets a temporal cycle of activity by which other organizations pace their behavior.

Kelly and McGrath (1985) offer empirical evidence that relates to the entrainment argument. The researchers examined the effect of time limits on group task performance. The study format was a laboratory experiment, where university students performed written assignments within groups. Kelly and McGrath found that group behaviors established under an initial time constraint (either 10 minutes or 20 minutes) persisted even after there was a change in the time constraint (either from 10 minutes to 20 minutes or the reverse). Further, the researchers found that the persistence effect from across-trial entrainment was strong relative to the effect of the within-trial length of time to complete the task.

2.5 SUMMARY OF THE LITERATURE REVIEW

In this chapter, I reviewed three areas of research relative to this study: inertia (physics, organizational ecology), organizational routines, and temporal pacing of change. These areas represent the conceptual base for the development of the temporal routines for incremental change (TRIC) theoretical perspective. This perspective emphasizes an organizational routine for incremental change, where the routine is one of temporal pacing. Organizations that exhibit temporal pacing of incremental change are inertial based on their consistent routine for change. The development of the theoretical perspective is presented in the following chapter.

CHAPTER 3

THEORY DEVELOPMENT

In this chapter, my objective is to develop an argument to explain why temporal routines for incremental change are introduced and maintained in organizations. Drawing from a routines-based perspective of organizations (Nelson and Winter, 1982), I contribute to inertia theory by developing a theoretical perspective for consistency of change. This perspective aligns with the idea of behavior corresponding to a circular flow (Nelson and Winter, 1982; Schumpeter, 1934). Circular flow emphasizes a tendency towards an equilibrium. Nelson and Winter (1982: 103) suggest that "there is, indeed, an internal equilibrium 'circular flow' of information in an organization in routine operation, but it is a flow that is continuously primed by external message sources and timekeeping devices."

In this study, I focus on a circular flow of innovation across time. In essence, I integrate the idea of a "consistent flow of information... continuously primed by... time-keeping devices" (Nelson and Winter, 1982: 103) with that of routinized innovation in organizations (Schumpeter, 1942). As such, the emphasis in this theoretical perspective is the consistent timing of innovation. This temporal perspective can be contrasted against an innovation-as-response, or event-based, perspective (Brown and Eisenhardt, 1997). According to the latter perspective, the introduction of an innovation could be a response to competitive rivalry, a response to an emerging opportunity in the environment, or a response to the completion of an innovation project.

The contributions to the literature are two-fold. First, to the organizational ecology literature, the contribution is to enhance our understanding of the dynamics of inertia (i.e., a body in motion remaining in uniform motion). Here I build on work by Hannan and Freeman (1984) and Terry Amburgey and his colleagues (Amburgey and Miner, 1992; Amburgey, et al., 1993). The second contribution is directed to the routines-based theory of organizations. Here I contribute an understanding of why organizations introduce and maintain temporal routines for incremental change. This perspective emphasizes that temporal routines for incremental change are introduced and maintained between producers and their organizational customers due to the disruptive nature of change.

I develop the theoretical perspective in a causal diagram tradition (Forrester, 1961; Repenning and Sterman, 2002; Sastry, 1997; Weick, 1979). Radzicki and Sterman (1994) suggest that the casual diagram, or system dynamics, tradition is particularly effective for theory-building with an evolutionary economics conceptual base. Further, this tradition requires specificity and logical discipline that strengthen the argument (Perlow, et al., 2002).

This chapter presents the theoretical perspective. The first sub-section introduces the temporal routines for incremental change (TRIC) perspective. In the next two sub-sections, I discuss the boundary conditions and assumptions underlying the argument. In the fourth section, I present the argument itself.

3.1 TEMPORAL ROUTINES FOR INCREMENTAL CHANGE

The temporal routines for incremental change (TRIC) perspective draws on the idea that a body in motion remains in uniform motion unless acted upon by external forces (Newton, 1995/1687). More specifically, the idea is that an organization that engages in a particular type of change (i.e., body in motion) will repeat that type of change at consistent intervals across time (i.e., uniform motion). Changes could include introducing product innovations (e.g., a new version of an existing product) or process innovations (e.g., modifying a production process) at consistent intervals across time. A temporal routine for incremental change is a procedure for making incremental changes to an organization's operating routines at consistent intervals across time (Brown and Eisenhardt, 1997; Henderson and Clark, 1990; Nelson and Winter, 1982). Since a temporal routine for incremental change modifies operating routines, it represents a particular form of modification routine.

In particular, a temporal routine for incremental change represents an incremental innovation type of modification routine. See Figure 2 for an extension of the Henderson and Clark (1990) typology. In this sense, incremental innovation refers to reinforcing the core components of the operating routine and leaving the work flow pattern for integrating the components relatively unchanged. Note that extending the Henderson and Clark (1990) typology to routines is consistent with viewing innovation as change in routines (Nelson and Winter, 1982).

3.2 BOUNDARY CONDITIONS FOR ARGUMENT

Boundary conditions define the scope within which a theoretical perspective is expected to explain a given phenomenon. There are two boundary conditions for the temporal routines for incremental change (TRIC) theoretical perspective. First, I concentrate on routines involving component change, where components produced by one set of organizations (producers) are employed as inputs for production by another set of organizations (organizational customers). Note that all components do not need to be sold to organizational customers, but the argument requires that organizations compose a significant base of customers for the producers.

I use the component term broadly, referring to components as the core inputs required to perform a particular task. A component could refer to a product or service, an artifact enabling routine execution or a sub-level routine. As an example, from the perspective of its producer, a component is a product offering to organizational customers (e.g., control panels sold to industrial manufacturers). From the perspective of the industrial manufacturers, the component (e.g., the control panel) represents an artifact that enables the execution of its production routines.

Second, the scope of my argument is limited to those components that, upon adoption, become interdependent with other components in the operating routines of organizational customers. In this sense, routines are complex systems composed of sub-level components (Nelson, 1991; Simon, 1962). The second condition implies that the addition of a new component or change to an existing component results in non-trivial disruption costs for one or more operating routines within the organization. In a recent study, Mukherjee, et al. (2000) found evidence consistent with the idea that variation in a set of inputs results in disrupted performance of the routine.

3.3 ASSUMPTIONS FOR ARGUMENT

Within these boundary conditions, I require several assumptions to develop the argument. Foremost, the argument hinges on the assumptions from the routines-based theory of organizations (Nelson and Winter, 1982). Since the primary tenets of this theory were presented earlier, they will not be repeated here. However, I want to make explicit three assumptions required for the argument.

Assumption 1. An entrepreneur (producer) produces a new component, which is adopted by a significant base of organizational customers.

My argument requires Assumption 1 as a starting point. In essence, it represents the commercial birth of an industry centered on a component. While this study does not provide an argument for the initial adoption of the new component, I assume that the primary rationale is the perception of improved organizational performance from adoption of the new component. Also note that the significance of the base of organizational customers in Assumption 1 exhibits variation in the form of total market size and individual organizational size. I examine this variation in later sections of the study.

Assumption 2. In the early stages of industry development, organizational perceptions of changes to an existing component are favorable.

With reference to innovation and industry development (Abernathy, 1978), Assumption 2 is assumed to hold in a variety of industry settings. In studying the automobile industry, Abernathy (1978) observed that important functional improvements are made in the early stages of product life. These functional improvements provide substantial value to customers (Abernathy, 1978). This literature suggests that the perceptions of value from component changes are initially positive, supporting Assumption 2.

Assumption 3. Producers will make changes to an existing component in line with the preferences of their existing organizational customers.

Resource dependence theory supports Assumption 3. According to this theory, organizations are interdependent with resource providers in the external environment, and resource providers influence the behavior of their resource-dependent organizations (Pfeffer, 1982; Pfeffer and Salancik, 1978). Research by Clayton Christensen extends resource dependence theory, highlighting that the demands from an organization's existing customers drive its resource allocation decisions. In particular, this research found that the preferences of firms' existing customers strongly shaped the path of technological innovation in the hard disk drive industry (Christensen, 1992; Christensen and Bower, 1996).

3.4 ARGUMENT FOR TEMPORAL ROUTINES FOR INCREMENTAL CHANGE

In this section, I discuss a process by which temporal routines for incremental change are introduced and maintained in producing organizations. A key contribution from this argument is that endogeneity of demand for change leads to the formation of temporal routines for incremental change, suggesting that these routines emerge between a producer and its organizational customers due to the disruptive nature of change to operating routines.

The format for describing the conceptual model is as follows. First, from the perspective of organizational customers, I discuss how the adoption of a new component within an existing routine stimulates desire for changes to that component. Next the focus shifts to the producer of the component, describing how temporal routines for incremental change are introduced and maintained within the producer. From the producer perspective, incremental changes to the component require incremental changes to the operating routines which produce and support the component. Last, I return to organizational customers, describing how pressure for consistency of change is maintained between the producer and its organizational customers.

3.4.1 Stimulus for Component Change by Organizational Customers

I begin by examining, through a routines-based lens, the impact of introducing a new component within organizational customers. From Assumption 1, I begin the argument with the production of a new component, which is adopted by a significant base of organizational customers. Since the new component has linkages with other operating routine components, as it is adopted, the new component disrupts existing operating routines.

When the new component disrupts existing operating routines, organizational customers desire changes to the component such that it meets the requirements of their existing operating routines (Nelson and Winter, 1982). Organizational customers gain knowledge about desired changes to the component by observing how it interacts within their operating routines. With this knowledge, organizational customers provide feedback to the producer of the component. This feedback consists of suggestions for changing the component such that it enables a smoother flow of their operating routines (Nelson and Winter, 1982). In this sense, the objective is to reduce the friction caused by the introduction of the new component. Research suggests that a large percentage of this observation and feedback occurs during a relatively-short window of time following the new component adoption (Tyre and Orlikowski, 1994). Assuming that producers incorporate feedback from existing organizational customers into future changes to the component (Christensen and Bower, 1996; Pfeffer and Salancik, 1978), the organizational customers are likely to adopt component changes in the future. This reinforcing loop[11] is illustrated as cR1 in Figure 3.[12]

A balancing loop is also present, suggesting that the disruption of existing operating routines leads to change resistance (Nelson and Winter, 1982; Tyre and Orlikowski, 1994). This change resistance has a negative effect on the likelihood of adopting future component changes. This balancing loop is identified as cB1 in Figure 3. However, by Assumption 2, I assume that the change resistance pressure (cB1) is small relative to the component change pressure (cR1) in the early stages of industry development.

3.4.2 Emergence of Temporal Routines for Incremental Change in the Producer

In the previous section, I describe how the introduction of a new component into the operating routines of organizational customers provides a stimulant for future changes to the introduced component. In this section, my focus is on how temporal routines for incremental change are introduced and maintained in the producer. There are three sub-sections to the argument. The first sub-section focuses on demand for component changes (Figure 4). The second sub-section focuses on disruptions in existing operating routines due to component changes (Figure 5). And the final sub-section examines the routinization of component change (Figure 6). I begin with demand for component changes.

3.4.2.1 Demand for Component Change

Customer Pressure. In this sub-section, I argue that organizational customer pressure influences producer perceptions about the appropriateness of the component.[13]

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[11] In the recent casual diagram research, the terminology is reinforcing and balancing loops (e.g., Repenning and Sterman, 2002). Note that these loops could alternatively be termed positive feedback and negative feedback loops. For consistency purposes, I use the reinforcing and balancing loop terminology.

[12] I have chosen the following labeling scheme: 'c' identifies organizational customers (versus 'p' for producers), 'R' indicates that it is a reinforcing loop (versus 'B' for a balancing loop or 'F' for an exogenous factor), and '1' indicates its order in my presentation.

[13] Sastry (1997) uses appropriateness as a measure of the match between an organization's strategic orientation and the strategic orientation required in the environment. I use the term in a similar fashion.

Appropriateness refers to an organization's perception of the match between the performance of an existing component and the performance of the component as demanded in the environment. These appropriateness perceptions influence the likelihood of component change.

I divide the sources of pressure for change into two categories: (a) endogenous change pressure which results from the adoption of the new or changed component into the operating routines of organizational customers, and (b) exogenous change pressure which is perceived to impact the producer's ability to attract new customers and/or retain existing customers. Endogenous change pressure reflects the desire for component change which emanates from within the operating routines of existing organizational customers. The endogeneity of the change pressure is seen by a reinforcing loop in Figure 4 (pR1). An example of exogenous change pressure is the desire for component change based on technological or market opportunities in the environment (pF1).

I now describe the emergence of a stimulant for component change in the producer due to pressure from existing organizational customers (pR1). By Assumption 2, in the early stages of industry development, organizations perceive component changes as favorable (Abernathy, 1978). From a resource dependence perspective (Christensen and Bower, 1996; Pfeffer and Salancik, 1978), this suggests that pressure from existing organizational customers will trigger component change by the producer. In addition, organizations are more likely to engage in local search for component change opportunities (Cyert and March, 1992/1963). This is consistent with viewing existing organizational customers as a local source for component change ideas.

While the initial focus on change pressure is direct feedback from existing organizational customers, pressure also arises from the producer's perceptions about component appropriateness in order to attract new customers and/or retain existing customers (pF1). This external pressure may present an opportunity for producers to entrain their component change behavior. Entrainment arises if the producer develops a consistent temporal pattern of component change, by aligning its change behavior with outside stimulants (Ancona and Chong, 1996). In this study, my argument focuses primarily on entrainment emerging between producers and their existing organizational customers. However, a producer may also become entrained with consistent delivery of market or technological opportunities for changing the component. One example of consistent delivery of market opportunities is an annual trade show. An example of consistent delivery of technological opportunities is delivery of innovations in foundational technologies at consistent points across time (i.e., a release pattern consistent with Moore's Law).

Component Improvement. Given that component changes are in line with feedback from existing organizational customers (Christensen and Bower, 1996; Pfeffer and Salancik, 1978), I expect that changes to the component result in higher perceptions of appropriateness. This is represented by a balancing loop in Figure 4 (pB1).

3.4.2.2 Disruptions in Existing Operating Routines for the Producer

In this sub-section, I examine a balancing loop associated with disruptions to the existing operating routines for the producer. See pB2 in Figure 5.

In parallel with the disruption from component change within organizational customers, I assume that component change results in disruptions to the operating routines for the producer (pB2). In this case, disruption in operating routines results from the costs of transitioning from producing a given component to producing a changed version of the component. Specific examples of disruptions could include (a) the set-up costs for changing over an existing production line, and (b) investments of time and resources to recalibrate marketing and customer support routines to the changed version of the component. Since organizations resist disruptions in their existing operating routines, I expect the disruptions to result in increasing resistance to change within the organization. This internal resistance to change has a negative effect on the likelihood of component change. By Assumption 2, however, I assume that the internal resistance to changing the operating routines, resulting from component changes, is outweighed by organizational customer pressure to make component changes.

3.4.2.3 Routinization of Incremental Change in the Producer

In this sub-section, I examine the routinization of incremental change in the producer. This routinization is presented in Figure 6.

Consistency of Change Pressure (pR2). This argument focuses on internal pressure for organizations to make consistent changes, emphasizing the coordination value that results from consistent timing of change. The central theme of Nelson and Winter (1982) is that organizations behave according to routines. To establish a routine for change at the organization level requires reliability, including timeliness, in the delivery of inputs (Brown and Eisenhardt, 1997; Hannan and Freeman, 1984; Nelson and Winter, 1982). To coordinate sub-level routines within the larger routine for change, departments need reliable delivery of inputs across time. In addition to enabling micro-level coordination, reliability of sub-level routine completion times enables coordination of resources across departments. Therefore, I expect that greater efforts to routinize change leads to greater internal pressure for temporal consistency of change. And I expect that pressure for temporally consistent change leads to more timely delivery of inputs within the routine. In turn, this enhances the organization's ability to routinize change (Nelson and Winter, 1982).

Nelson and Winter (1982) emphasize that a routine becomes established among organizational members ("routine as truce"). At the group level, Gersick and Hackman (1990) refer to this phenomenon as preference for maintaining group norms. Here I expect that, once a temporal routine for incremental change is established, the nature of a routine as an established arrangement provides internal pressure to maintain the routine (Nelson and Winter, 1982). In summary, this argument focuses on the coordination value from consistency of change.

Time Since Previous Change (pBR1). The second factor for temporal consistency is the time since previous change. I identify this loop as pBR1, since it has both balancing and reinforcing effects. First, it is a balancing loop, but beyond a threshold, it becomes a reinforcing loop. This argument emphasizes that organizations prefer to introduce changes in operating routines at consistent, periodic intervals across time. Organizations prefer consistent, periodic change patterns to alternative patterns, such as inconsistent, periodic change or continuous change.

There are several reasons for the presence of a time interval between changes. First, organizational customers require a certain period of time to employ their operating routines with a new or changed component. This emphasizes that it takes time for organizational customers to learn what changes would enhance the flow of their operating routines. These change enhancements may be corrective (e.g., identifying problems in the product) or forward-looking (e.g., identifying desired new features). Second, as organizational customers convey feedback to producers, a time lag is present for the incorporation of this feedback into changes in the component. Third, for both organizational customers and the producer, there are disruption costs from (a) operating routine downtime associated with the introduction of a changed component, and (b) unanticipated interactions among components of the operating routine which disrupt the post-adoption operating routine performance. In light of these disruptive costs, researchers suggest that "production pressure" leads organizations to accept only periodic disruptions to their operating routines (Miller, 1982; Tyre and Orlikowski, 1994). This third rationale highlights a tension between the disruptive costs associated with introducing a changed component and the value obtained from the change. Further, recognizing the planning and coordination value from reliability of change timing (Hannan and Freeman, 1984; Nelson and Winter, 1982), producers and organizational customers prefer consistent periodic disruptions to operating routines.[14]

The description of the loop feedback is as follows. When a component change is made, a 'time since previous change' clock decreases (i.e., resets to zero). As the time since previous change increases, it initially increases the temporal consistency with an established routine for incremental change. Therefore initially as 'time since previous change' increases, the likelihood of component change increases. Beyond this threshold, as the time since previous change increases, the appropriateness of component change for temporal consistency within the established routine decreases. The threshold represents the established length of time between this type of incremental change in the organization.

Organizational Size (pF2). Here I suggest that the greater the size of an organization, the more likely that it will introduce and maintain a temporal routine for incremental change. Nelson and Winter (1982: 97) present organizational size as a boundary condition, suggesting that routines-based theory holds for "large and complex" organizations. Here I incorporate organizational size into the temporal routines for incremental change (TRIC) perspective. Given the complex nature of the model, I present size as an exogenous factor. I acknowledge that size has endogenous linkages within the overall model, but to focus my efforts, I treat organizational size as an exogenous factor.

[14] This temporal pattern of change may also be consistent with periodic delivery of market opportunities and/or technological opportunities in the industry, aligning with an external entrainment perspective (Ancona and Chong, 1996). In Figure 4, this entrainment influence can be viewed as exogenous pressure for change (pF1). I examine this issue in greater detail in the empirical portion of the study.

Organizational size is the magnitude of the organization. Size has an internal, bureaucratic dimension, reflected in the number of its employees. It also has an external, market-based dimension, reflected in its sales (Baum, 1999; Cohen and Levin, 1989). Here my argument focuses on the external dimension of organizational size.

There are three supporting rationale for a positive effect of organizational size on routinization of change: greater internal motivation, greater external pressure, and greater resources. First, organizations have a tendency to reinforce behavior patterns that are perceived as successful (Alchian, 1950; March, 1981), and organizations with greater size are likely to perceive their previous behavior as leading to success. This may be particularly likely when organizational size is measured in financial terms. Second, I expect producers with greater size to have greater numbers of organizational customers who depend on reliable delivery times for component changes. Here my assumption is that a greater of number of organizational customers leads to greater external pressure for reliability of the incremental change routine.[15]

The final support rationale assumes that maintaining a temporal routine for incremental change is not a simple task. While Nelson and Winter (1982: 112) typically assume that "a state of routine operation in an organization is in many ways self-sustaining," they also acknowledge that in some situations, "just keeping an existing routine running smoothly can be difficult." In these situations, the researchers suggest that the maintenance of the routine is a target; as such, the goal is to keep the routine under control. I suggest that this situation may characterize temporal routines for incremental change. Completion of an iteration of a temporal routine for incremental change occurs only periodically across time. Since the degree of fluidity in the execution of a routine depends on its repetition (Nelson and Winter, 1982; Zollo and Winter, 2002), achieving consistency in temporal routines for incremental change may be a difficult task.

Assuming that a temporal routine for incremental change is difficult to maintain, I suggest that availability of resources is a key element. With greater financial resources, in addition to greater ability to fund the specific change initiative, producers can invest in greater administrative infrastructure to control the temporal routine for change. These

[15] At the same time, I acknowledge that at extreme levels, an organization may possess sufficient size such that the external pressure would decrease (Pfeffer, 1982; Scherer, 1980).

organizations should have greater likelihood of maintaining a temporal routine for component change.

As a summary figure, the entire casual diagram for the producer is presented in Figure 7.[16]

3.4.3 Endogenous Loop for Incremental Change

I now return to the perspective of organizational customers to explain the reinforcing nature of temporal routines for incremental change. I assume that in the early stages of industry development, organizational customers perceive the adoption of component improvements as favorable (Abernathy, 1978). Earlier I described how the introduction of a new component disrupts the existing operating routines for organizational customers, leading to desires for changes to the component. Given this pressure for component change, I expect organizational customers to adopt component changes. But, while enhancing some aspects of the operating routines, I assume that adopting a changed component will introduce new disruptions to the set of operating routines. This assumes that changes to the component include new elements which interact in ways not foreseen by organizational customers. As such, the process repeats whereby the operating routine disruption leads to desire for additional changes to the component (cR1, Figure 3). By Assumption 2, I assume that this pressure for component change (cR1) outweighs the change resistance pressure (cB1).

At the same time, similar to producers, additional reinforcing pressure develops within the organizational customers. There is consistency of change pressure, encouraging temporal consistency in adopting component changes. Further, as the process of adopting component changes is routinized, there are decreases in the disruptive effects on operating routines.

In this sense, entrainment of component change develops between the producer and its organizational customers. Hence, a routine develops between the producer and organizational customers, such that there is pressure to maintain consistency of component change across time.

[16] As the producer establishes a modification routine for component change, I expect decreases in the disruptive effect of component change on existing operating routines. In efforts to present a relatively-simple model, I have not included this linkage.

3.4.4 Industry Development

In the previous sub-sections, I discuss how temporal routines for incremental change can emerge in the initial stages of industry development. I describe the model in terms of a single producer organization and its organizational customers. Assuming profitable conditions, I expect the entry of new producers into the industry.

For two reasons, I expect entering producers to establish temporal routines for incremental change which are consistent with the incumbent producer. First, I expect entering producers to attempt to imitate the routines of the incumbent producer (Massini, et al., 2002; Nelson and Winter, 1982). Imitation is particularly likely when uncertainty is high (Alchian, 1950; DiMaggio and Powell, 1983), and high uncertainty is likely in the early stages of industry development.

Second, I expect the routines established in the initial set of organizational customers to influence the routines of entering producers. This may occur directly by entrainment with existing organizational customers (Ancona and Chong, 1996). Or the effect may be less direct, whereby new organizational customers attempt to imitate the adoption routines of incumbent organizational customers, thus providing similar pressure for entering producers (Nelson and Winter, 1982). This reflects the persistence of a founding effect in change behavior within industries.[17]

Last, I return to Assumption 2. Assumption 2 states that in the early stages of industry development, pressure towards making or adopting incremental changes to a component are favorable. As described above, this assumption allows the development of pressure for consistency of incremental change behavior. In later stages of industry development, however, organizations may perceive lower appropriateness for making or adopting component changes. If organizational customers perceive the existing component as satisfactory relative to that demanded by the environment, in order to break the routine for incremental change, I highlight that the change in appropriateness must exceed the pressure to maintain the temporal routine for incremental change that has developed within and across organizations. Research by Kelly and McGrath (1985) supports this pattern of behavior persistence. In a series of lab experiments, the researchers found that group behaviors

[17] However, note that commonality of time intervals between component changes is not a requirement of the theoretical perspective. For example, one producer may establish a 18-month cycle of change, while another producer establishes a 36-month cycle of change.

developed under the presence of an external, entraining force persisted after the entraining force was removed.

In this chapter, I have presented the boundary conditions, requisite assumptions, and argument underlying the temporal routines for incremental change (TRIC) perspective. In the next chapter, this theoretical perspective is applied in a context of generational product innovation in the microcomputer applications software industry.

CHAPTER 4

THEORY APPLICATION

In the previous chapter, I developed a theoretical perspective to explain why temporal routines for incremental change are introduced and maintained in organizations. In this chapter, my objective is to apply this theoretical perspective in a particular context, deriving two core hypotheses for testing from the theoretical perspective. The linkage between the theory development and application focuses on modification routines in producers (Figure 6). From Figure 6, note that three of the concepts can be readily-observed as operationalized variables (component change, time since previous change, and organizational size). However, the two remaining concepts (temporal consistency and routinization of change) are difficult to observe. In developing the empirical model, I focus on the three concepts which can be readily-observed as operationalized variables.

By tracing through the feedback loops presented in Figure 6, I derive two core hypotheses for empirical testing. The first hypothesis is a prediction about the existence of temporal routines for incremental change. Up to a threshold, the feedback model suggests a positive effect of time since previous change on component change. Beyond the threshold, the model suggests a negative effect of time since previous change on component change. The second hypothesis is a prediction about the strengthening effect of organizational size on temporal routines for incremental change. This hypothesis states that the greater the organizational size, the more positive the initial effect of time since previous change on component change, and beyond a threshold, the more negative the effect of time since previous change on component change. Thus organizational size moderates the relationship between time since previous change and component change.

In this chapter, I examine the temporal routines for incremental change (TRIC) perspective in a context of generational product innovation. A generational product innovation represents a significant advance in the technical performance of an existing product. For example, Word 2.0 and Word 3.0 are generational product innovations within the Microsoft Word family of word-processing software applications. While scholars devote significant attention to innovation, relatively little research examines generational product innovation. See Figure 8 for the empirical model.

Generational product innovation provides an appropriate context for applying the temporal routines for incremental change (TRIC) perspective. The primary argument underlying the introduction and maintenance of temporal routines for incremental change focuses on the disruptive nature of modifying operating routines. I assume that organizations must calibrate a set of operating routines for a particular product configuration. These operating routines include production routines, marketing routines, and customer support routines. Therefore, a decision to change an existing product results in modifications to the current operating routines for the existing product. As such, a generational product innovation is an observable representation of underlying change in operating routines.

Also, I highlight that my focus is directed to the technological dimension of product innovation. In the innovation literature, researchers have distinguished between technological and market-based dimensions of product innovation (Abernathy and Clark, 1985). As an example of the latter, the introduction of an academic version of Microsoft Word is a market-based innovation. In the economics literature, a key rationale for this type of innovation by organizations is market expansion and obtaining a greater share of total surplus through price discrimination (Pigou, 1962/1920). Recently, Varian (2000) has examined alternative forms of market-based innovation in the software industry. While market-based innovations are clearly important, explaining the introduction of these types of innovation lies beyond the scope of this study. In particular, it is beyond the bounds of this theoretical perspective, which focuses on repeated interactions between producers and organizational customers whereas market-based innovation is more likely to engage producers with new sets of customers.

In the empirical analysis, I control for accepted determinants of innovation behavior, drawing particularly from the industrial organization economics and organizational ecology literatures. These determinants include (a) market-level factors, and (b) organization-level factors. The market-level factors are market size, market concentration, and innovation activity by competing organizations. The organization-level factors are organizational age, organizational size, and the cumulative number of previous innovations released by the organization.

4.1 GENERATIONAL PRODUCT INNOVATION IN THE CONTEXT OF TECHNOLOGICAL CHANGE RESEARCH

In this section, I describe generational product innovation within a larger context of research on technological change. The dominant perspective in technological change research is that of punctuated equilibrium (Mokyr, 1990; Tushman and Anderson, 1986). Drawing from ecological research, a punctuated equilibrium model describes several stages of technological progress, corresponding to variation, selection, and retention (Anderson and Tushman, 1990). In the variation stage, or era of ferment, multiple technologies exist. Then, through a competitive selection process, a single technology emerges as the dominant design. During the retention stage, reinforcing innovations advance the dominant design. Later another era of ferment punctuates the retention stage, signaling a transition to a new dominant design. Eras of ferment are typically viewed as short, relative to eras of incremental change. According to this perspective, reinforcing technological progress occurs within dominant designs (Abernathy, 1978), and disruptive progress occurs across dominant designs (Anderson and Tushman, 1990). Within a punctuated equilibrium perspective, generational product innovation represents technological progress within an era of incremental change (Banbury, 1997; Banbury and Mitchell, 1995).

In contrast to a punctuated equilibrium model, Brown and Eisenhardt (1997) observed a more continuous pattern of technological change in their study of innovation in the computing industry. Rather than long spans of incremental change with brief punctuations of disruptive change, the researchers describe a pattern consistent with more frequent mid-range change. According to the Brown and Eisenhardt (1997) perspective, generational product innovation is consistent with mid-range innovations occurring at consistent intervals of time.[18]

[18] Aligning generational product innovation with the Brown and Eisenhardt (1997) perspective is appropriate, assuming that these innovations are incremental innovations, as opposed to architectural innovations, as defined by Henderson and Clark (1990). Based on the study description, Brown and Eisenhardt (1997) appear to be observing incremental product innovations.

4.2 COMPARING GENERATIONAL PRODUCT INNOVATION ACROSS INDUSTRIES

In this section, I present examples of generational product innovation, relative to other types of innovation involving technical improvement, for two distinct industries: application software and automobiles. Similar innovation comparisons can be made in other industries, such as semiconductors (Lawless and Anderson, 1996) and consumer electronics (Sanderson and Uzumeri, 1995).

In this study, my attention focuses on innovations that improve the technical performance of existing products. To facilitate the following comparison, I concentrate on three types of innovation. The first is a minor innovation, which offers small technical improvement to an existing product. At the other extreme is a major innovation, which offers significant technical improvement and reconfigures the product architecture. Between these two extremes is a generational product innovation, which offers significant technical improvement within an existing product architecture. This innovation classification is for illustration purposes only, and it draws from Henderson and Clark (1990) and Meyer and Lopez (1993).

Microsoft Word is the representative product for the applications software industry. In November 1983, Microsoft released Word on the DOS operating platform. Two examples of minor innovations are Word 1.1 (DOS) and Word 3.01 (Macintosh). Word 1.1 (DOS) added several minor features to Word (DOS), and Word 3.01 (Macintosh) corrected several bugs present in Word 3.0 (Macintosh). Two examples of major innovations are the January 1985 release of Word (Macintosh) and the December 1989 release of Word (Windows). Both products were the first releases of Word on their respective operating platforms. Examples of generational product innovations are Word 3.0 (DOS) and Word 6.0 (Windows). Word 3.0 (DOS) followed Word 2.0 (DOS), providing new features (e.g., outlining, math capabilities) and increased speed. Word 6.0 (Windows) followed Word 2.0 (Windows), providing new features (e.g., AutoFormat, AutoCorrect) and ease-of-use enhancements.

The Ford Mustang is the representative product for the automobile industry (*New York Times*, 2003). In April 1964, Ford released the Mustang. Two examples of minor innovations are the 1970 Mustang and the 1977 Mustang II. Relative to their preceding versions, both products made minor changes, either stylistic (e.g., removal of side scoops) or technical (e.g., minor redesign of the 351 V8 engines). Two examples of major innovations are the 1974 Mustang II and the 1979 Mustang. Each product involved a major platform change relative to its preceding version. The 1974 Mustang II was redesigned for the Pinto structure and suspension, while the 1979 Mustang was built upon the Ford Fairmont "Fox" chassis. Finally, two examples of generational product innovations are the 1968 Mustang and the 1999 Mustang. Relative to their preceding versions, both products offered new or substantially-redesigned engines as well as styling changes.

4.3 CONCEPTS

Generational Product Innovation. To define the generational product innovation concept, I refer to Henderson and Clark (1990) and Lawless and Anderson (1996). Henderson and Clark (1990) define product innovations along two dimensions: (1) degree of change in core design concepts, and (2) degree of change in the linkages among core components. The first dimension focuses attention on the extent to which core product attributes are reinforced relative to being overturned, and the second dimension focuses on the extent to which the product architecture changes. This study focuses on product innovations in which the core design concepts are reinforced and the product architecture is unchanged. Henderson and Clark (1990) refer to this type of innovation as an incremental innovation.

According to Lawless and Anderson (1996), a generational product innovation is a particular form of incremental innovation. The researchers state that generational innovations have two focal characteristics. First, the innovation represents a significant advance in the technical performance of an existing product. Similarly, Lawless and Anderson (1996) describe a generational innovation as an advance within a technology regime. Second, these innovations are backward-compatible, such that older generations tend to compete alongside newer generations (Lawless and Anderson, 1996). While I define generational product innovation as an incremental innovation, one could also consider an architectural innovation as a generational innovation (Henderson and Clark, 1990; Henderson, 1993).[19] The core concepts are reinforced according to either definition: (a) viewing generational product innovation as incremental innovation, or (b) viewing

[19] In footnote 1 of Henderson and Clark (1990: 10), the researchers highlight that in earlier drafts of their paper, they used the term, generational innovation, rather than architectural innovation.

generational product innovation as architectural innovation. But, if viewed in the latter sense (Henderson, 1993), the linkages between core components change.

To clarify the definition of generational product innovation, I present an example from the AutoSketch family of CAD microcomputer software. In this example, the introduction of AutoSketch 3.0, which followed AutoSketch 2.0 (both DOS products), is classified as a generational product innovation. Relative to AutoSketch 2.0, AutoSketch 3.0 contained new features that improved its performance, particularly its ease of use and ease of learning. As one example, AutoSketch 3.0 added a new text editor that allowed users to import and export text (*PC Week*, 1990). Alternatively, I classify the introduction of AutoSketch for Windows as an architectural innovation. For AutoSketch for Windows, the developers reinforced the core design concepts, but they changed the product architecture.

In summary, a generational product innovation is defined as a significant advance in the technical performance of an existing product. The core concepts are reinforced, and the product architecture remains unchanged (Henderson and Clark, 1990; Lawless and Anderson, 1996).

Time Since Previous Innovation. Drawing from the organizational ecology literature (Amburgey, et al., 1993; Baum, 1999), I define this concept as the elapsed time since the previous product innovation of the same type. With respect to generational product innovation, previous product innovation of the same type refers to either (a) the initial introduction of the product on the market or (b) the most recent generational product innovation introduced to the market.

Organizational ecology researchers have argued for a negative effect of time since previous innovation on the likelihood of another innovation of the same type (Amburgey, et al., 1993). The focal argument is that, by local search, organizations are most likely to employ recently-used modification routines (Cyert and March, 1992/1963). Therefore, as the elapsed time since a previous innovation increases, the organization is less likely to introduce an innovation of the same type (Amburgey, et al., 1993; Baum, 1999).[20]

[20] In related work, Putsis and Bayus (2001) found that the older the technology underlying a product line, the more likely an organization is to withdraw products from the market. Equating time since previous innovation with the technological age of the product suggests that time since previous innovation may impact the likelihood of introducing another innovation of the same type through selection. This highlights a need to account for the potential of selection bias, which is discussed in Section 5.5.

Returning to the AutoSketch product example, after the initial release of AutoSketch, the time since previous innovation increments by one for each time period until the release of a generational product innovation (AutoSketch 2.0). In the first period following the release of AutoSketch 2.0, the time since previous innovation resets back to one. It then increments by one for each time period until the release of another generational product innovation.

In summary, I define time since previous innovation as the elapsed time since the previous product innovation of the same type.

Organizational Size. In defining organizational size, I refer broadly to innovation research in the industrial organization economics and organizational ecology literatures. As developed in these literatures, organizational size is a multi-dimensional concept. The literatures focus on two dimensions of organizational size: (a) external to the organization, and (b) internal to the organization. Both dimensions are recognized in industrial organization economics and organizational ecology. However, industrial organization economics places greater emphasis on the external dimension (Scherer, 1980), while organizational ecology places greater emphasis on the internal dimension (Baum, 1999). Incorporating both dimensions, organizational size represents the magnitude of an organizational unit.

From the external perspective, researchers often operationalize organizational size as the volume of sales for a given organizational unit (Cohen and Levin, 1989). In industrial organization economics, the external perspective reflects a market-based orientation. From this perspective, in a Schumpeterian tradition, researchers present a number of conceptual arguments for a positive effect of size on innovation. These arguments include (a) assuming imperfect markets, size is correlated with available financial resources, suggesting that larger organizations have greater ability to undertake innovation, and (b) size with respect to scale economies, such that larger organizations can justify greater investment in specialized resources for producing innovations or justify greater investment in process innovations from a cost-spreading perspective (Cohen and Klepper, 1996; Scherer, 1980). In industrial organization economics, researchers present a negative effect of size on innovation based on a reduced competitive incentive argument (Scherer, 1980). Researchers in organizational ecology also present arguments for both positive and negative effects of size on innovation from an external perspective (Haveman, 1993).

From the internal perspective, researchers typically operationalize organizational size as the number of employees in the organizational unit. In both organizational ecology and industrial organization economics, the internal perspective reflects a bureaucratic orientation. From this perspective, researchers in organizational ecology base their arguments on a negative effect of size on innovation. These arguments suggest that larger organizations have greater diffusion of control and decision-making, such that changing organizational structure is more difficult in larger organizations (Hannan and Freeman, 1984; Haveman, 1993). Researchers present a similar argument in industrial organization economics, suggesting that as organizations increase in size, there is a loss of managerial control. Also, individual scientists have reduced incentive for innovation, assuming their ability to capture the rewards of innovation decreases with increasing size (Cohen and Levin, 1989).

In the AutoSketch example, organizational size refers to the magnitude of the business unit that governs the production, development, and support for the AutoSketch product. From the external perspective, organizational size may be represented by the volume of sales of the AutoSketch product. From the internal perspective, organizational size may be represented by the number of employees involved in the development, production and support of the AutoSketch product.

In summary, I define organizational size as the magnitude of an organizational unit. Organizational size is a multi-dimensional concept, including dimensions that are internal and external to the organizational unit.

4.4 HYPOTHESES

4.4.1 Effect of Time Since Previous Innovation on Generational Product Innovation

As organizational customers adopt the initial product innovation, due to component interdependencies, their operating routines are disrupted (Nelson, 1991; Simon, 1962). Since organizations resist changes in their operating routines (Nelson and Winter, 1982), organizational customers provide product change recommendations to the producer in order to minimize disruptions within their operating routines. By resource dependence theory (Pfeffer and Salancik, 1978; Christensen, 1992), producers will modify their product in line with organizational customer recommendations. As organizational customers adopt the modified version of the product, the cycle repeats.

In this process, temporal routines for generational product innovation are developed within and between producers and organizational customers. Producers are most likely to introduce generational product innovations that are consistent within these established routines. This recognizes the planning and coordination value from reliable timing of generational product innovation releases (Hannan and Freeman, 1984; Nelson and Winter, 1982). For example, organizational customers are more likely to adopt generational product innovations if the customer is able to establish modification routines for the adoption process. If an existing producer is inconsistent with delivery of its generational product innovations, or if it chooses to break a delivery routine that has been established with a set of organizational customers, then its organizational customers may seek alternative producers. Similarly, within their own operations, producers obtain planning and coordination value from reliable timing of generational product innovation releases.

As the time since previous innovation increases initially, introduction of a generational product innovation becomes more consistent within an established temporal routine for generational product innovation. Thus, as time since previous innovation increases, organizations are initially more likely to introduce generational product innovations. Beyond a threshold, as the time since previous innovation increases, the introduction of a generational product innovation becomes less consistent with the established temporal routine. Therefore, beyond a threshold, organizations are less likely to introduce generational product innovations. The expected relationship for Hypothesis 1 is presented in Figure 9.

Hypothesis 1. The greater the time since previous innovation, initially the greater the likelihood of a generational product innovation event. Beyond a threshold, the greater the time since previous innovation, the less likely is a generational product innovation event.

4.4.2 Moderating Effect of Organizational Size

Here I argue that, as producers increase in size, they are more likely to employ temporal routines for generational product innovation. This rationale emphasizes the external dimension of organizational size. First, organizations have a tendency to reinforce behaviors that are perceived as successful (Alchian, 1950; March, 1981), and organizations with greater size are likely to perceive their previous behavior as leading to success. This may be particularly the case with respect to external dimensions of size, such as revenue. Second, I expect producers with greater size to have greater numbers of organizational customers who depend on reliable delivery times for generational product innovations, which presents greater pressure for temporal routines.

Third, as Nelson and Winter (1982: 112) observe, in some cases, simply maintaining an existing routine is a difficult task. In these situations, the goal is to keep the routine under control. I suggest that maintaining temporal routines for generational product innovation may represent a difficult task. Completion of an iteration of this type of routine occurs only periodically across time. Since the degree of fluidity in the execution of a routine depends on its repetition (Nelson and Winter, 1982; Zollo and Winter, 2002), achieving consistency in temporal routines for generational product innovation may be a difficult task. If this is the case, the greater availability of financial resources associated with organizational size (Schumpeter, 1942) allows organizations to invest in greater administrative infrastructure to control the temporal routine. This is in addition to the greater ability to fund specific generational product innovations. These organizations should have greater likelihood of maintaining a temporal routine for generational product innovation. See Figure 10 for the expected relationship for Hypothesis 2.

Hypothesis 2. The greater the organizational size, the more positive the initial effect of time since previous innovation on the likelihood of a generational product innovation event. Beyond a threshold, the greater the organizational size, the more negative the effect of time since previous innovation on the likelihood of a generational product innovation event.

Taken together, these hypotheses suggest that organizations employ temporal routines for generational product innovation. And, as organizations increase in size, they are more likely to employ these routines. In the next chapter, I present the empirical context and methods by which the hypotheses are tested.

CHAPTER 5

METHODOLOGY

This chapter presents the methodological approach for testing the presented hypotheses. There are five sections to this chapter. First, I describe the empirical context as segments of the microcomputer software applications industry. The next section presents the appropriateness of this context. Third, I discuss the constructed dataset. The fourth section presents the operational variables. Last, I discuss the analytic technique.

5.1 DESCRIPTION OF THE EMPIRICAL CONTEXT

In this section, I provide a brief historical overview of the empirical context, beginning with microcomputer hardware. Then I review the four software categories featured in this study: CAD, desktop publishing, spreadsheets, and word-processing. I provide a definition for the focal product in the category as well as offer several key product introduction dates.

5.1.1 Microcomputer Hardware

The birth of the microcomputer hardware industry is often listed as January 1975. This is the month in which *Popular Electronics* featured the MITS/Altair microcomputer on its cover. Langlois (1992) identifies the commercial start of the microcomputer industry as 1977, a year that included the release of three notable hardware platforms: Apple II, Commodore PET, and the Tandy TRS-80 Model. Cringely (1996) identifies August 1981 as the beginning of the second era in microcomputing. In this month, IBM introduced its personal computer (Langlois, 1992; Cringely, 1996). In January 1984, Apple released its Macintosh microcomputer (Campbell-Kelly, 2001).

5.1.2 CAD Segment

> (Computer-Aided Design) Using computers to design products... A graphics tablet is used for drawing, and a scanner may be attached for additional input. CAD software is available for generic design or specialized uses, such as

> architectural, electrical and mechanical. More complex forms of CAD are solid modeling and parametric modeling, which allows objects to be created with real-world characteristics. For example, in solid modeling, objects can be sectioned (sliced down the middle) to reveal their internal structure. In parametric modeling, objects have meaningful relationships with each other (TechEncyclopedia, 2002).

While CAD systems have been in use since the 1960s, the birth of the commercial CAD software segment for the microcomputer is typically associated with the first shipment of AutoCAD in December 1982. AutoCAD, and competing products such as CADPLAN and Versacad, soon settled into list prices of approximately $3000. In the mid-1980s, numerous entrants appeared in the lower-end of the CAD market. These products were all less than $1000 in list price, and they included such products as Drafix CAD, Generic CADD, MacDraft, MiniCAD, and TurboCAD. Two later entrants in the low-end CAD category were strong competitors for market leadership in the 1990s. In December 1993, AutoDesk released AutoCAD LT for Windows. And in December 1994, Visio Corporation shipped Visio Technical.

5.1.3 Desktop Publishing Segment

> A desktop publishing program, also called a page layout program, provides complete page design capabilities, including magazine style columns, rules and borders, page, chapter and caption numbering as well as precise typographic alignment. A key feature is its ability to manage text and graphics on screen in a [what-you-see-is-what-you-get] style. The program can flow text around graphic objects in a variety of ways (TechEncyclopedia, 2002).

The birth of desktop publishing software for the microcomputer is 1985. In this study, I focus on the high-end desktop publishing category (approximately $500-$900 in list price). In this category, PageMaker, QuarkXpress, Ventura, and FrameMaker have competed for market leadership in the 1980s and 1990s. In July 1985, Aldus released PageMaker on the Macintosh platform. This is typically viewed as the beginning of the commercial desktop publishing software segment for the microcomputer. The first versions of Ventura and Quark Express (later QuarkXPress) shipped in early 1987. Ventura first shipped for IBM PCs with GEM, and Quark Express first shipped on the Macintosh. Frame Technology shipped FrameMaker on the Macintosh platform in April 1990.

5.1.4 Spreadsheets Segment

> Software that simulates a paper spreadsheet, or worksheet, in which columns of numbers are summed for budgets and plans. It appears on screen as a matrix of rows and columns, the intersections of which are identified as cells. Spreadsheets can have thousands of cells and can be scrolled horizontally and vertically in order to view them... The cells are filled with: 1. labels, 2. numeric values, and 3. formulas. Labels can be any descriptive text... values are the actual numeric data used in the budget or plan, and the formulas command the spreadsheet to [perform] calculations (TechEncyclopedia, 2002).

The commercial spreadsheet segment began in October 1979 with the release of VisiCalc on the Apple II (Langlois, 1992). Dan Bricklin and Robert Frankston were the developers of VisiCalc. With respect to market leadership over the years, other notable products include Supercalc, Multiplan, 1-2-3, and Excel. Supercalc, the first follower to VisiCalc, was first shown in August 1981. Microsoft released MultiPlan for the Apple II in August 1982. In January 1983, Lotus 1-2-3 shipped on the IBM PC. And, in September 1985, Microsoft released Excel for the Macintosh.

5.1.5 Word-Processing Segment

> [Creates] text documents. Selected features of a full-featured word processor include: text editing, search and replace, mail merge, print preview, footnotes/endnotes, spell checker, thesaurus, and file management (TechEncyclopedia, 2002).

By the end of 1976, Michael Shrayer had developed the first word processor, Electric Pencil, for the MITS/Altair computer (Langlois, 1992). In the 1980s and 1990s, several key products that competed for market leadership were WordStar, WordPerfect, MacWrite and Word. MicroPro released WordStar, a dominant early word processor, for the IBM PC in March 1982. WordPerfect shipped on the IBM PC platform in October 1982. MacWrite, initially bundled with the Macintosh, shipped in January 1984. And Microsoft released Word in November 1983 on the IBM PC platform.

5.2 APPROPRIATENESS OF THE EMPIRICAL CONTEXT

In this section, I discuss the appropriateness of the applications software industry as an empirical context. First, I examine the two boundary conditions for the temporal routines for incremental change (TRIC) theoretical perspective. Second, I discuss the context relative to two of the three key assumptions for the perspective. As Assumption 1 simply recognizes the commercial birth of an industry, I assume it to be largely self-evident. In addition, the previous section offers related supporting evidence. Assumption 2 states that organizations perceive changes to an existing product as desirable in the initial stages of the industry, and Assumption 3 states that producers will make changes to an existing component in line with the preferences of their existing organizational customers. The trade press for the software industry provides supporting evidence for the appropriateness of this context.

> **Boundary Condition 1**. The argument focuses on a context where components are produced by one set of organizations (producers) and employed as inputs for production by another set of organizations (organizational customers).

In essence, this assumption simply recognizes that corporate customers are a significant presence in markets for business productivity software application products. While likely self-evident, supporting discussion can be found under Boundary Condition 2.

> **Boundary Condition 2**. The scope of the argument is limited to those components that, upon adoption, become interdependent with other components in the operating routines of organizational customers. This condition implies that the addition of a component or change to an existing component results in non-trivial disruptions for one or more operating routines.

In the applications software industry, there is substantial support for the assertion that the addition of, or change in, a software component results in non-trivial disruptions to existing operating routines for adopting organizations. According to one administrator, the upgrade process is a "logistical nightmare." Another remarks that "the cost of the package is peanuts compared to the amount of administrative time involved in an upgrade" (*InfoWorld*, 1988). Specific examples include (a) downtime associated with new bugs, (b) revision of training programs, (c) logistical costs of installation, (d) increases in support questions following an upgrade, and (e) hardware upgrades which may be induced by software upgrades (*InfoWorld*, 1988, 1989).

> **Assumption 2**. In the early stages of industry development, organizational perceptions of changes to an existing component are favorable.

As indicated earlier, the academic literature on industry evolution (Abernathy, 1978) supports Assumption 2. I also find support for software applications in particular. As an example from the demand side of component change, Wordstar was an early leader in the market for word-processing software. At one point, an industry observer notes that "Wordstar users have been practically begging Micropro for a new update of their favorite word processor..." (*InfoWorld*, 1987). On the supply side, Cringely (1996: 226) notes that producers immediately begin revisions to their product releases in order to fix bugs and stay current with the technology. Researchers observe that, in Microsoft's case, persistence with upgrades often led to success in the marketplace (Cusumano and Selby, 1995; Liebowitz and Margolis, 1999).[21]

> **Assumption 3**. Producers will make changes to an existing component in line with the preferences of their existing organizational customers.

This assumption appears to be well-supported for product innovations by many organizations in the application software industry. When releasing generational product innovations, organizations often highlight the role of existing customers in shaping the innovation process. Representative comments include "the new release of Total Word incorporates improvements requested by our customers" offered by Vickie Boddie, president of Volkswriter (*Computer Reseller News*, 1990), and "639 user enhancement requests have been incorporated into WordPerfect 6.0 for DOS" (*Business Wire*, 1993). Perhaps the strongest statement in support of this assumption is offered by John Walker, founder of Autodesk and co-author of AutoCAD:

> Any doubts about the veracity of our claim 'our development agenda is taken directly from the list of user-requested features' can be easily dispelled by comparing [our user-requested] wish list with the features in AutoCAD releases up to the present day (Walker, 1994).

Further, microcomputer software is a component within a larger, complex technological system. While not a boundary condition or assumption for the temporal routines for

[21] But one anecdote suggests that the demand perspective on upgrades may be changing over time. "Once the driving force behind technological change, [customers] have instead become the protectors of the status quo... five years ago having the latest version of an application was an unquestioned necessity... but today, software upgrades and changes are driven more by the immediate needs of a project or by corporate dictum than by users eager to use only the newest version of a product" (*InfoWorld*, 1990).

incremental change (TRIC) perspective, this factor suggests an additional source of pressure for temporal routines from complement producers. These complements include microprocessors, other computer hardware (e.g., memory, storage), and operating system software.

5.3 DATA

I obtained the starting point of the dataset from PC Data, a market research firm that specializes in information technology markets.[22] The dataset from PC Data includes monthly product sales data in several categories of business productivity computer software from 1994-1998. These segments are CAD, desktop publishing, spreadsheets, and word processing. PC Data estimated that its data represents the following annual percentages of the U.S. retail software market from 1994-1998: 33%, 60%, 70%, 80%, and 80%.[23] In addition, the dataset is extensively supplemented with archival research. Below I describe the construction of the CAD segment dataset, and I employed a similar process for the other three segments.

I constructed a CAD market category where products can be assumed to be substitutes in terms of functionality. The initial PC Data database had two limitations that prevented the initial comparison of products as substitutes. First, PC Data reported the product data at a stock-keeping unit. Therefore, when multiple formats or versions existed within a product family, I aggregated the individual products into one representative product family. For example, Turbo Cad, Turbo Cad 5.0, Turbo Cad Academic, etc. were aggregated into a representative Turbo Cad product family. The Turbo Cad product family represents the product offering from the Turbo Cad organization. In many cases, the organizations in this study are business units within larger firms.

Second, the PC Data database included products that cannot be considered substitutes. For example, PC Data had add-on products and products that are similar in content but different in functionality grouped alongside "traditional" products. To address this issue, I constructed more precise market segments with the assistance of secondary data sources. This construction proceeded in two phases: (1) reducing the PC Data database into a set of

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22 NPD INTELECT acquired PC Data in March 2001.

23 These estimates were obtained through direct correspondence with PC Data.

products which perform similar functions, and (2) segmenting the remaining products into competitively-equivalent markets.

The first phase of construction required the identification of products which perform similar functions. This categorization relied on the primary classification by PC Data, which represents an industry standard. Then I narrowed the PC Data list of products to a more precise set, using secondary data sources to confirm product similarity. Secondary data sources were accessed primarily through information databases, such as Dow Jones Interactive, Infotrac, and Proquest. Specific referenced publications included *Business Wire, Computer Graphics World, Home Office Computing, InfoWorld, MacUser, MacWEEK, PC/Computing, PC Magazine, PC Week, PR Newswire, Personal Computer World, The Software Encyclopedia*, *Windows Magazine,* and *Windows Sources*. Company web pages were also accessed as needed and available.

The second phase of construction further segmented products into competitively-equivalent markets. This ensured comparison within distinct market segments. I segmented the product markets by format and tier of market. First, in terms of format, the categorization was based on operating platform. During the 1994-1998 empirical window, a clear market distinction can be made between products for (1) IBM-compatible and (2) Macintosh computers. Within the IBM-compatible system, two dominant operating platforms were present: (a) DOS, and (b) Windows. Therefore, I segmented the products into three respective operating platforms: (1) DOS for IBM-compatible, (2) Windows for IBM-compatible, and (3) Macintosh. Second, market tier refers to the feature/price level within a product category (e.g., high-end, low-end). I used product comparison reports in the trade press from 1988-1998 to guide segmentation by market tier.

Based on these reports, I divided the CAD market into high-end CAD software for the microcomputer (approximately $3000 in list price) and low-end CAD software (less than $1000 in list price). However, only certain high-end CAD products are sold through the retail channel, which is tracked by PC Data. Therefore, this study does not analyze the high-end CAD segment. My review of product comparison articles in the trade press revealed a lack of clear segmentation within the sub-$1000 products. I found product comparisons based on sub-$1000, sub-$500, sub-$400, and sub-$250 segments. As a result, I plotted the sub-$1000 products by list price and searched for the presence of identifiable clusters. The highest frequency of products had a list price of $500, with numerous products above and below $500. Therefore, I judged the sub-$1000 market to be the most appropriate level for analysis and did not further segment the data. Examples of products in this segment include AutoCAD LT, MiniCAD, and TurboCAD.

The final stage of archival research involved tracing the innovation history of each product family. I used these histories to identify the cumulative number and timing of generational product innovation releases. The tracing process included a review of every issue of *InfoWorld*, a weekly industry trade publication, from 1981-1990.[24] Further, the tracing process involved archival searches with secondary data sources via information databases and company web pages. Consistent availability of product innovation data via information databases began in approximately the mid-1980s. Therefore, the combination of reviewing *InfoWorld* from 1981-1990 and searching information databases from their earliest available dates (typically the early 1980s) through the end of 1998 provided a comprehensive approach to gathering archival data. Finally, if necessary and available, I contacted companies directly to help resolve any uncertainties.

In addition to the CAD segment, I analyzed the desktop publishing, spreadsheets, and word-processing segments. The dataset construction process was similar for the three remaining segments. Guided by the trade press, I identified two market segments for desktop publishing: high-end (approximately $500-$900 in list price) and low-end (approximately $100-$300). However, PC Data did not list a well-known low-end desktop publishing product. Therefore, this study does not analyze the low-end segment. I identified a single segment for spreadsheets, with list prices in the range of $100 to $600. For the word-processing category, I identified two segments: high-end (approximately $350-$700 in list price) and low-end (approximately $50-$250). There was very little innovation activity in the low-end word processing market, and interestingly the category itself largely disappeared by the end of 1998. Due to lack of variance on the dependent variable, this study does not analyze the low-end of the word processing market.

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[24] In August 1981, IBM introduced its personal computer (Langlois, 1992; Cringely, 1996), and as a result, 1981 has been labeled as the beginning of the second era in microcomputing (Cringely, 1996).

5.4 OPERATIONAL VARIABLES

There are three focal variables in the empirical model. The dependent variable is generational product innovation, and the explanatory variables are the time since previous innovation and organizational size. Control variables include age, cumulative number of product innovations, market concentration, market size, market generational product innovations, and platform. After data collection, I calculated the operational variables using a series of Visual Basic macro programs within a Microsoft Excel spreadsheet. In addition to the standard calculation procedures, where appropriate, the process involved the development and execution of recalculation procedures as a means to check that the proper calculations had been carried out.

Table 1 provides a summary description of the variables, and Table 2 provides descriptive statistics. Figure 11 provides additional descriptive information, by market category, for the time since previous innovation at the occurrence of generational product innovation events.

Dependent variable. Generational product innovation (GenProdInnov) was operationalized by a binary variable (1 for the month in which a generational product innovation release occurs, and 0 otherwise).[25] In operationalizing the concept, I focused my attention on identifying whether a release represented a significant advance in technical performance, relative to the existing product. One potential concern associated with this measure was to ensure that generational releases are distinguished from minor, bug-fix releases. In both cases, I expect the technical performance of the product to improve (Lawless and Anderson, 1996), but the significance of the advance is much smaller in the latter release. Further, while generational release dates can be identified with archival data, the trade press does not publish many of the bug-fix release dates. To address this potential limitation, I reviewed trade press information for individual product innovation releases.

[25] As described in the previous section, I aggregated multiple versions and formats into representative product families. Among the forty-six organizations competing in these market segments, there were three cases in which generational product innovation activity occurred for more than one version of the product (e.g., WordStar, WordStar 2000) within the market segment. In only one case, TurboCad on the Windows platform, did this issue extend into the time window of the dataset, although the other two cases are relevant for historical tracking of variables. By using the history of product development for the three products, I identified a dominant version of the product and used innovation activity for the dominant product version to represent the innovation activity for the organization.

In operationalizing the generational product innovation concept within application software, my attention focused on three dimensions: (a) the number and magnitude of feature additions/enhancements, (b) the numbering convention for the product innovation release (i.e., Version 1.0, 1.01, 1.1, 2.0), and (c) the pricing schedule for the product innovation release (e.g., upgrade list price relative to full list price). Through historical observation of the trade press, I found that the latter two dimensions are typically reflections of the first dimension. Examining trade press information with particular attention to these three dimensions provided a heuristic guide for distinguishing generational product innovation releases from minor, bug-fix releases. As an example, for the price dimension, a useful guide was whether the upgrade list price was greater than or less than 10% of the full list price.

My objective was to achieve triangulation in determining whether a product release was classified as a generational product innovation. I examined multiple accounts in the trade press with attention directed to the three aforementioned dimensions. For the majority of product releases, data was available on all three dimensions, and the evidence on these dimensions was consistent (either toward a generational product innovation classification or against it). When the evidence was conflicting across dimensions, or when trade press information was missing for a particular dimension, my classification was based on the majority of evidence for the three dimensions.

Explanatory variables. Time since previous innovation (TimeSinceInnov) is the elapsed time since previous product innovation. The previous innovation may be the initial product release or the most recent generational product innovation. I represented time since previous innovation with a clock, which started at one for the first month after an innovation (the initial innovation or a generational product innovation). The clock increased by one for each month until the first month after a new generational product innovation was released; at this point, the clock reset to one.

The organizational size measure (OrgSize) was represented by the total number of product units sold by the organization, lagged one time period and logged.[26] Since I study the interaction between the explanatory variables, for interpretative purposes, I centered the organizational size and time since previous innovation variables (Aiken and West, 1991).

[26] For calculation purposes (e.g., zero as a nuisance value), I added one to the lag of organizational size prior to taking its base-10 logarithm.

Control variables. Age of the organizational unit (Age) is the time since the initial release of the product. With respect to age, researchers have argued that, over time, organizations develop routines which inhibit change (Hannan and Freeman, 1984). Other research suggests that organizations become more fluid with age. In attempts to reconcile this work, Singh and Lumsden (1990) suggest that the effect of age on organizational change depends on whether the change is core or peripheral. However, a recent review of empirical work in this area highlights mixed findings on the age-change relationship, beyond consideration of the core-peripheral reconciliation efforts (Baum, 1999).

Cumulative number of previous innovations (TotPrevInnov) was operationalized by a count measure, which increased by one for each introduction of a generational product innovation. The cumulative number of generational product innovations is a measure of repetitive momentum (Amburgey and Miner, 1992; Amburgey, et al., 1993). In this case, increases in cumulative innovation lead to greater experience with innovation, which suggests increased likelihood of future innovations (Amburgey and Miner, 1992). Reviewing across empirical studies, Baum (1999) found strong support for a positive effect of repetitive momentum on innovation.

Market concentration (MktConc) was represented by a Herfindahl concentration index, using market share in terms of unit sales. The Herfindahl index is defined as the sum of the squared values of products' market share (Curry and George, 1983). A large body of work in industrial organization economics examines the effect of market concentration on innovation (Cohen, 1995; Cohen and Levin, 1989). This stream of research provides alternative arguments about this relationship. Some researchers argue for a positive effect. This argument suggests that in concentrated markets, rivalry has greater certainty. And less certainty regarding extent of rivalry could reduce incentives for innovation (Schumpeter, 1942). Others argue for a negative effect, suggesting that greater market concentration leads to less direct competitive incentive for investment in innovation (Hennipman, 1954; Scherer, 1980).

Market size (MktSize) was represented by the total number of product units sold in a given market, lagged one time period and logged.[27] Arguments for an effect of market size

[27] Similar to organizational size, I added one to the lag of market size prior to taking its logarithm. In a few instances in late 1998, a given month had zero product sales for an application category on the DOS platform.

on innovative activity include organizations' positioning themselves in emerging niches (Porter, 1980) or organizations' trying to reinvigorate declining markets (Miller, 1990). Researchers have found significant effects of market size, and change in market size, on competitive behavior (Bayus and Putsis, 1999; Miller and Chen, 1994).

Market generational product innovations (MktInnov) is a binary variable that indicates whether any peer organizations within a market released a generational product innovation in the previous time period. I employed a binary variable due to the few instances in which more than one innovation release by peer organizations occurred in the previous time period. Institutional theorists have argued that organizations imitate the behavior of their peers (DiMaggio and Powell, 1983). And researchers of competitive rivalry suggest that organizations are likely to respond to competitive moves by peer organizations (Chen, 1996). Relative to this measure, I highlight that in the applications software industry, there tends to be significant levels of signaling and transparency associated with innovation releases. Thus I expect that peer organizations have knowledge of upcoming innovation releases prior to the actual event.

Dummy variables for operating system markets (DOS, WIN) were included. These variables were effect-coded: DOS organization-month observations (1 for DOS, 0 for WIN), Windows organization-month observations (0 for DOS, 1 for WIN), and Macintosh organization-month observations (-1 for DOS, -1 for WIN). As such, a negative effect for either the DOS variable or the WIN variable indicates a respective likelihood of generational product innovation that is significantly below the average likelihood. This average likelihood is calculated across DOS, Windows, and Macintosh platforms for all organization-month observations.

Market density (MktDens) was represented by the total number of organizations operating in a market, lagged one time period. I included this variable in a selection equation, but it was not included in the focal equation. As will be explained in the next section, the analytic technique involves simultaneous estimation of two equations. With this approach, the selection equation requires at least one unique variable. While many of the variables in the focal model and selection model were common, I included market density as unique to the selection equation. The variable draws from density dependence research in organizational ecology (Hannan and Freeman, 1989). Researchers argue for a curvilinear effect of density on survival. Due to institutional legitimacy, increases in density initially increase the likelihood of survival. Then beyond a threshold, due to competitive interactions, increases in density decrease the likelihood of survival (Baum, 1999; Hannan and Freeman, 1989). Since the empirical analysis focuses on a developed industry state, and to minimize the number of variables in the model given limited variation on the dependent variable, I included only a linear effect for density, expecting a negative effect of density on survival based on the competitive interactions argument.[28]

5.5 ANALYTIC TECHNIQUE

In this section, I describe the analytic technique that was used to test the hypotheses. The technique is a probit model with selection, using pooled data. Since organizations may select out of a market during the time window of data, the model needs to account for the potential of survival bias in the estimates. As such, I employed a probit model with selection (van de Ven and van Praag, 1981), which extends from Heckman (1979). This model does not involve two-stage estimation, rather it estimates the two equations (focal equation and selection equation) simultaneously using maximum likelihood. I used the heckprob command in the Stata statistical software package to perform the analyses.

As an illustration of survival bias, consider the following scenario. Suppose that the objective is to understand the effect of organizational size on the likelihood of generational product innovation. Further suppose that (1) organizational size has positive effects on the likelihood of generational product innovation and the likelihood of survival, and (2) the likelihood of generational product innovation is higher among surviving organizations than among otherwise identical organizations that are failing. In this scenario, the marginal effect of organizational size has two elements: (a) its influence on the likelihood of survival, and (b) its influence on the likelihood of generational product innovation among the surviving organizations. Under these conditions, without controlling for selection, the model would overstate the marginal effect of organizational size on the likelihood of generational product innovation (Greene, 2000). For more information regarding sample selection bias, see Greene (2000) and Heckman (1979).

[28] In additional analyses, including a squared density variable had an insignificant effect on the likelihood of selection. Its inclusion also resulted in poor estimation of the simultaneous equations models.

Selection of the probit technique was influenced by several factors: censoring, a repeated-event dependent variable, variation within and across organizations, and infrequency of event occurrences. In event history studies, censoring is often a concern. In this study, left-censoring refers to generational product innovation activity prior to the start of the data window, and right-censoring refers to innovation activity after the end of the data window. Left-censoring is not a large concern because generational innovations are repeated events, and with archival research, I was able to collect pre-window data for the occurrence of earlier events (Allison, 1984). Here the primary limitation associated with left-censoring was that the empirical window begins at a relatively-mature stage of the industry.

Allison (1995) argues that discrete-time probit or logit models are appropriate techniques for event history studies, given right-censored cases and time-varying covariates. Probit and logit models are standard approaches to analyzing binary choices. The models differ in their assumptions about the distribution of the error term. Probit models assume a cumulative normal distribution, while logit models assume that the cumulative distribution is logistic. However, these models typically yield similar results, as the difference in distributions is small, with the exception of the tails (Maddala, 1992). In further support of discrete-time probit and logit models, Petersen (1995: 499) comments that "if the probability of an event in each time interval is small, then the coefficients obtained from a discrete-time specification for most models will be quite close to those obtained from a continuous-time specification." In this study, on average, the probability of an event in any time period is small (0.027).

Standard probit and logit models may be complicated by the longitudinal nature of the study. The unobserved factors within organizations may lead to correlated error terms, if additional controls are not implemented. But statisticians and econometricians have found that ignoring the error correlations and using a standard probit model with pooled data yields consistent, though inefficient, estimates (Maddala, 1987; Robinson, 1982). As such, Maddala (1987) has recommended the use of the standard probit with pooled data prior to the use of more elaborate models.

Of the more elaborate models, there are two of potential interest: (a) fixed effects logit model, and (b) random effects probit model (Maddala, 1987; Verbeek, 2000). A fixed effects logit model controls for an effect of each organization, emphasizing within-organization variation. For this study, the major disadvantage of this approach would arise from the relatively-small number of generational product innovation events occurring within organizations during the window of data. As such, there is likely to be low power associated with the use of a fixed effects logit model.

The second option, the random effects probit model, is more favorable but also has limitations. Relative to the pooled probit model, it yields more efficient estimates. The common form of the random effects probit is the Gauss-Quadrature model, which handles unbalanced panel data well. Its primary disadvantage is the assumption that the random effects are uncorrelated with the explanatory variables. In many cases, however, this assumption will be violated. The Chamberlain model, a correlated random effects approach, provides a more flexible technique. It allows the random effects to depend on current, future, and past explanatory variables (Maddala, 1987). Unfortunately, the Chamberlain model is not well-suited for unbalanced panel data.

Given the above factors, I selected the standard probit model with pooled data as the most appropriate technique, and I incorporate selection into the model (Allison, 1995; Maddala, 1987; van de Ven and van Praag, 1981).

CHAPTER 6

RESULTS

In this chapter, I present the results of the hypothesis tests as well as a set of extending analyses. There are three key findings. First, in a developed stage in the microcomputer applications software industry, organizations employ temporal routines for generational product innovation. Second, with increasing size, organizations have a greater tendency to employ these temporal routines. These two findings are consistent with the temporal routines for incremental change (TRIC) theoretical perspective, but alternative arguments could also be consistent with the empirical evidence. In one set of extending analyses, I examine a core alternative argument based on the idea of exogenous entrainment from the temporal pacing of change literature. In this case, I find empirical evidence that is consistent with the temporal routines for incremental change (TRIC) perspective, even after controlling for potentially-entraining external factors in the form of technological and market opportunities.

Table 3 presents the results from the probit models with selection. The focal equation has generational product innovation as the dependent variable, and these results are presented above the selection equation results in Table 3. The dependent variable for the selection equation is whether an organization remains on the market. For the selection equation, I denote all organization-months in which an organization did not leave the market by a one. I treat all organization-months in which an organization left the market as censored observations, and they are denoted by a zero. In the analyses, the total number of observations was 2617 organization-months: 2592 uncensored observations (indicating that the organization remained on the market throughout the month) and 25 censored observations (indicating that the organization did not remain on the market beyond that month). Overall I observed 71 generational product innovation events among 46 organizations competing in four categories of microcomputer software applications from 1994 to 1998.

To test the hypotheses, I examined three nested models, presented in Table 3. Model 1 is the baseline model, which has a set of control variables and intercept term. To assess the results for Hypothesis 1, Model 2 added two measures to the baseline model: (a) time since previous innovation, (b) the square of time since previous innovation. Model 3 examined the consistency of the evidence with respect to Hypothesis 2. Model 3 added two interaction terms: (a) organizational size and time since previous innovation, and (b) organizational size and the square of time since previous innovation.

The analyses employed a standard probit model with pooled data (Maddala, 1987; Robinson, 1982). I conducted additional analyses with a random effects probit to examine the sensitivity of the model specification. The results for the random effects probit were the same as those for the pooled probit, which occurs when the random effects are not significant.

All three nested models were statistically significant at $\alpha = 0.05$: Model 1 ($p = 0.013$), Model 2 ($p < 0.001$), and Model 3 ($p < 0.001$). The overall model significance is evident from the likelihood ratio test results. These results compare the loglikelihood of the estimated model against the loglikelihood of a model containing only the intercept. The test statistic for the likelihood ratio is distributed as a χ^2. Table 3 also provides the increase in the likelihood ratio between nested models. An increase in the likelihood ratio test statistic indicates whether introducing additional explanatory variables provides a statistically significant improvement in model fit, relative to the previous nested model. Moving from Model 1 to Model 2, I found a significant model improvement ($p < 0.001$). Moving from Model 2 to Model 3 also resulted in significant improvement ($p = 0.012$).[29]

As discussed earlier, the probit model with selection accounts for the possibilities of sample selection bias. By examining the results of a likelihood ratio test as to whether rho = 0, there is evidence to indicate whether sample selection bias is present. This test determines whether the two equations (focal and selection) are independent. In the three nested models, I did not find evidence of selection bias potential at $\alpha = 0.10$.

[29] In separate analyses of the probit models, I found that the saturated focal model (Model 3) explains approximately 13% of the variance in generational product innovation, and the selection model (using Models 2 and 3) explains approximately 25-30% of the variance in organization selection.

The next two sections describe the results of the three nested models. My primary attention was on the generational product innovation equation, as it provides evidence for the hypotheses.[30]

6.1 EVIDENCE FOR THE PRESENCE OF TEMPORAL ROUTINES FOR INCREMENTAL CHANGE

Model 2 assesses the empirical evidence for Hypothesis 1. This hypothesis focuses on the presence of temporal routines for generational product innovation. It posits a positive effect for time since previous innovation, and a negative effect of the square of time since previous innovation, on the likelihood of generational product innovation. I found strong support for Hypothesis 1, finding a positive effect of time since previous innovation ($p < 0.001$) and a negative effect of the square of time since previous innovation ($p < 0.001$). In assessing the results, my primary attention is directed to the coefficient for the square of time since previous innovation. Note that the significance of the TimeSinceInnov coefficient indicates that, at TimeSinceInnov = 0 (its mean, since the variable is centered), the effect of time since previous innovation on generational product innovation is positive.

In examining the control variables for Model 2, there were several other influential variables. Organizations competing in the DOS market were less likely to introduce generational product innovations ($p = 0.061$). This likely reflects the ascent of the Windows market in the 1994-1998 time frame. I found a negative effect of market concentration on the likelihood of generational product innovation ($p = 0.063$), and I found a positive effect of organizational size on the likelihood of generational product innovation ($p = 0.015$). This is consistent with the size aspect of the Schumpeterian argument in IO economics, but it provides evidence counter to the concentration aspect of the Schumpeterian argument. Consistent with Hannan and Freeman (1984), I observed a negative effect of age on the likelihood of generational product innovation ($p = 0.024$).

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30 Although not the focus of this study, the selection equation also provides interesting insights into competition in the computer software market. In Models 2 and 3, I observed a positive effect of market concentration on the likelihood of an organization remaining in the market ($p < 0.05$). I also found a positive effect of organizational size on the likelihood for an organization to remain in a market ($p < 0.001$). Last, a negative effect of time since previous innovation on the likelihood of remaining in the market ($p < 0.01$) was observed.

6.2 EVIDENCE FOR MODERATING EFFECT OF ORGANIZATIONAL SIZE

Model 3 provides empirical evidence regarding Hypothesis 2. The argument underlying this hypothesis suggests that, as size increases, organizations are more likely to employ temporal routines for generational product innovation. According to Hypothesis 2, I expect to find a positive effect of the interaction between organizational size and time since previous innovation. Here, as organizational size increases, a more positive initial effect of time since previous innovation is expected on the likelihood of generational product innovation. I expect a negative effect for the interaction between organizational size and the square of time since previous innovation. Here, as organizational size increases beyond a threshold, I expect a more negative effect of time since previous innovation on the likelihood of generational product innovation. Again, my primary attention is directed to the interaction between organizational size and the square of time since previous innovation in assessing the evidence relative to Hypothesis 2. The results provided support for Hypothesis 2, finding a positive effect of the interaction between organizational size and time since previous innovation ($p = 0.060$) and a negative effect of the interaction between organizational size and the square of time since previous innovation ($p = 0.003$).[31]

Given the interactive nature of the effect of organizational size and time since previous innovation, I further examined this relationship (Aiken and West, 1991). First, I plotted the effect of time since previous innovation on the likelihood of generational product innovation for three levels of organizational size: $OrgSize_L$ (small organizations: one standard deviation below the mean), $OrgSize_M$ (medium-sized organizations: at the mean of organizational size), and $OrgSize_H$ (large organizations: one standard deviation above the mean). For time since previous innovation, the plot covers a range from low, or one standard deviation below its mean ($TimeSinceInnov_L$), to high, or one standard deviation above its mean

[31] In the analyses, I used a log-transformation of organizational size given my expectation of diminishing returns. To examine the sensitivity of this specification, I ran analyses using an untransformed organizational size measure. In this set of analyses, the simultaneous-equation probit model did not perform well consistently. Therefore, since the earlier analyses did not indicate survival bias, I used a nested set of pooled probit models without selection. First, I added the interaction between organizational size and time since previous innovation, and I found that the interaction had a significant effect ($p = 0.001$) in the hypothesized direction. Next I found that, while its coefficient is in the hypothesized direction, subsequent inclusion of the interaction between organizational size and the square of time since previous innovation did not result in significant model improvement ($p = 0.36$). As such, I found that the interaction effect of organizational size occurred only on the upward slope of the relationship between time since previous innovation and generational product innovation. Therefore, using an untransformed organizational size measure, the level of support is reduced.

($TimeSinceInnov_H$). The plot used coefficients obtained from Model 3 in Table 3, and all control variables were fixed at their respective means. See Figure 12 for this plot.

Along the y-axis for Figure 12 is a Z-score, which is an unobservable variable common to probit models. To equate the Z-score with the probability of the occurrence of a generational product innovation event, consider a standard normal distribution curve. The probability of event occurrence is equal to the area under the curve from negative infinity to the Z-score. As reference, a -2.4 Z-score is equivalent to < 1% probability of event occurrence (single asterisk, Figure 12). A -1.25 Z-score is equivalent to 11% probability of event occurrence (double asterisk, Figure 12).

From Figure 12, when organizational size was low, there was little curvature in the relationship between time since previous innovation and likelihood of generational product innovation. However, as organizational size increased, Figure 12 highlights an increasingly inverse-U shaped relationship. These visual observations are consistent with Hypothesis 2. Also, beyond an initial period of time since previous innovation, as organizational size increased, there was a corresponding increase in likelihood of generational product innovation.

Note that the peak of the curve corresponds with the most likely length of time until a generational product innovation event. This length of time can be calculated by using coefficient estimates from Model 3 (Table 3). For this calculation, I took the derivative of the estimated GenProdInnov function with respect to TimeSinceInnov and set it equal to zero. For medium-sized organizations, I found that the most likely length of time until a generational product innovation is 30 months. See Appendix 1 for this calculation.

Next I transitioned from visual observation to statistical analysis using a series of simple slope tests recommended in Aiken and West (1991). Here nine simple slopes examined the effect of time since previous innovation on generational product innovation. These tests were various combinations of organizational size ($OrgSize_L$, $OrgSize_M$, $OrgSize_H$) and time since previous innovation ($TimeSinceInnov_L$, $TimeSinceInnov_M$, $TimeSinceInnov_H$). See Table 4 for the test results.

Consistent with the visual observations, I found that, for small organizations, there was not a statistically significant effect of time since previous innovation at $\alpha = 0.10$. For medium-sized organizations and large organizations, when the time since previous innovation was low, there was a positive effect on generational product innovation ($p < 0.001$). And, when the time since previous innovation was high, there was a negative effect on generational product innovation ($p < 0.05$). There was a greater effect for large organizations relative to medium-sized organizations, but this difference was much smaller relative to the difference between small and medium-sized organizations.

By using another set of simple slope tests, I examined the effect of organizational size on generational product innovation at various levels of time since previous innovation. In this case, slope tests examined the effect of organizational size on generational product innovation at three levels of time since previous innovation: $TimeSinceInnov_L$, $TimeSinceInnov_M$, and $TimeSinceInnov_H$. Here I observed that when little time had elapsed since the previous innovation ($TimeSinceInnov_L$), there was a negative effect of size on the likelihood of generational product innovation -- but this effect was not significant at $\alpha = 0.10$. Beyond this initial time period following an innovation ($TimeSinceInnov_M$ and $TimeSinceInnov_H$), there was a positive effect of organizational size on the likelihood of generational product innovation ($p < 0.001$).

6.3 EXTENSION OF ANALYSES: EXAMINING ALTERNATIVE ARGUMENTS

The standard analyses included a set of control variables to help account for alternative explanations of innovation activity. However, in this study, there are limitations associated with using control variables to rule out alternative arguments. One limitation is the availability of data and its cost of acquisition. A second limitation focuses on the power of the test. While this sample has a relatively-large number of organization-month observations (2617), there are relatively-few generational product innovation events in the sample (71). While the first limitation is largely unavoidable, in part, I can address the second limitation by including a greater number of control variables in separate sets of extending analyses.

6.3.1 Innovation As Response to Change in Market Size

In the standard analyses, I controlled for the recent level of market size. Alternatively, the recent change in market size may be a determinant of innovation activity. This is consistent with a view of innovation in response to recent growth or decline in market size (Bayus and Putsis, 1999; Miller and Chen, 1994). To examine this argument, with the first-lag of market size (MktSize) already in the model, I added the second-lag of market size.

Note that, with the first-lag in the model, adding the second-lag is equivalent to examining the recent change in market size. The addition of the second lag of market size did not result in significant improvement to the baseline model, Model 1 in Table 3 ($p = 0.88$). I also re-examined the findings for Models 1 through 3 after the inclusion of the second lag of market size. In all cases, the model results were equivalent, and the second lag of market size did not result in a statistically-significant improvement to the models.

6.3.2 Innovation As Response to Change in Organizational Size

In the standard analyses, I included the level of organizational size as (a) a control variable and (b) in interactions with time since previous innovation. An alternative argument is that organizations release new products in response to demand saturation (Putsis, 1989). By controlling for the recent change in organizational size, I can examine the argument that organizations innovate in response to decreasing demand for their product. To examine this argument, with the first-lag of organizational size (OrgSize) already in the model, I added the second-lag of organizational size. Similar to the previous description for market size, this is equivalent to controlling for recent change in organizational size. The addition of the second-lag of organizational size did not result in significant improvement to the baseline model, Model 1 in Table 3 ($p = 0.95$). I re-examined the findings for Models 1 through 3 after inclusion of the second-lag of organizational size. In all cases, the model results were equivalent, and the second-lag of organizational size did not result in statistically-significant improvement for the models.

6.3.3 Innovation As Response to Innovation by Peer Organizations

To control for the influence of innovation by peer organizations, I initially included a variable that indicated whether any peer organizations released a generational product innovation in the previous time period (MktInnov). This is consistent with arguments for innovation activity based on institutional theory (DiMaggio and Powell, 1983) and competitive rivalry (Chen, 1996). To further examine this issue, I added two additional lags for innovation activity by peer organizations. Adding the second lag to the baseline model did not result in a significant model improvement ($p = 0.96$). Adding the third lag to the model that included the second lag did not result in significant improvement ($p = 0.44$). I re-examined the findings for Models 1 through 3 after the inclusion of the additional lags. The model results were equivalent to those without the additional lags, and the additional lags of innovation activity by peer organizations were not statistically significant.

6.3.4 Temporal Routines As Result of Diminished Competition

In Section 6.2, I described the test results for the effect of interactions between (a) organizational size and time since previous innovation, and (b) organizational size and the square of time since previous innovation, on generational product innovation. However, an alternative explanation could be that these routines arise due to limited competition in these markets, rather than the influence of organizational size. To examine this possibility, rather than interacting organizational size and the time since previous innovation variables, I interacted market concentration and the time since previous innovation variables. Although not presented in Table 3, this model can be considered as Model 4. The incremental improvement from Model 2 to Model 4 was not statistically-significant at $\alpha = 0.10$. Therefore, it appears that the existence of these routines was not due to limited competition.

6.4 EXTENSION OF ANALYSES: EXAMINING THE POTENTIAL FOR EXTERNAL ENTRAINMENT

As presented to this point, the results are consistent with the existence of temporal routines for generational product innovation. In the theory development section, my argument centers on these routines resulting from endogenous demand for change, emphasizing the disruptive nature of interactions between producers and their organizational customers. However, an alternative argument based on consistency in the delivery of technological and market opportunities across time could also align with the empirical evidence. This alternative argument focuses on the idea of entrainment (Ancona and Chong, 1996; Bluedorn, 2002) and is discussed in Section 3.4.2.1. In this section, my objective is to extend the analyses to further investigate this possibility. In particular, I demonstrate that, even after controlling for potentially-entraining technological and market opportunity events, a curvilinear effect of time since previous innovation on generational product innovation is present. This finding provides an additional level of support for the temporal routines for incremental change (TRIC) perspective.

In the context of microcomputer application software innovations, there are several candidates for exogenous entraining factors. In this extended analysis, I considered three technological and market opportunity variables as synchronous entraining factors. Synchronous entrainment refers to generational product innovation releases of application software that occur in the same month as technological or market opportunity events (Bluedorn, 2002). As discussed earlier, microcomputer applications software is part of a larger, complex technological system. In addition to applications software, two of the fundamental components in this system are (a) the microprocessor, and (b) operating system software. Therefore, for the technological opportunity variables, I considered the release of generational product innovations in microprocessors and operating system software. For the market opportunity variable, I considered the annual occurrence of a major industry trade show.

6.4.1 Technological and Market Opportunity Data

For data availability reasons, I focused only on application software for DOS and Windows platforms. For these platforms within the 1994-1998 time window, there were a total of 1679 organization-month observations and 49 generational product innovation events. To collect data for the technological and market opportunity variables, I turned to archival data sources.

First, for microprocessors, Intel was the dominant supplier of microprocessors for the IBM-compatible microcomputer in this time window. Using archival data available on the Intel website (Intel, 2003a, 2003b), I examined the organization's history of microprocessor innovations in the 1994-1998 timeframe. Two key dimensions of technological innovation in this industry are (a) increases in the number of transistors and (b) increases in the clockspeed. Significant increases in the number of transistors are associated with the introduction of new classes of microprocessors (e.g., Pentium, Pentium II), while increases in clockspeed tend to be minor, more frequent innovations. I operationalized technological performance in terms of significant increases in the number of transistors, observing two generational product innovations within this time period. The first innovation was the November 1995 release of the Pentium Pro microprocessor, which increased the number of transistors from 3.3 million to 5.5 million. The second innovation was the May 1997 release of the Pentium II microprocessor, which increased the number of transistors from 5.5 million to 7.5 million. Note that these two releases are consistent with Moore's Law, the oft-cited 18-month cycle of innovation in the semiconductor industry. The microprocessor innovation variable (TechOppMP) is a binary variable, with zeros representing the absence of generational product innovation releases and ones representing the occurrence of generational product innovation releases.

Second, for operating system software, Microsoft was the dominant supplier of operating system software for the IBM-compatible microcomputer in this time window. Using archival data obtained from the Factiva information database, I identified four generational product innovations in this time period. The first two innovations focus on both corporate customers and end-consumers: (a) Windows 95, released in August 1995, and (b) Windows 98, released in June 1998. The second two innovations focus on corporate customers: (c) Windows NT 3.5, released in September 1995, and (d) Windows NT 4.0, released in August 1996. Microsoft did not release a generational product innovation for the DOS operating system in this time frame. The operating system innovation variable (TechOppOS) is a binary variable, with zeros representing the absence of generational product innovation releases and ones representing the occurrence of generational product innovation releases.

Last, for the market opportunity variable, the COMDEX/Fall trade show is recognized as the largest computer trade show in the world. Within the 1994-1998 time window, the COMDEX/Fall trade occurred each year in mid-November in Las Vegas. For organizations competing in the computing industry, COMDEX/Fall represents the trade show of the year. This is particularly the case for products aimed at IBM-compatible platforms, as Macworld Expos offer well-recognized alternative avenues for showcasing products for the Macintosh platform. The market opportunity variable (MktOpp) is a binary variable, with ones for November months, indicating the occurrence of the COMDEX/Fall trade show.

6.4.2 Analyses and Results

In this analysis extension, I examined three nested probits models using discrete-time event history analysis. Initially I ran the models using the simultaneous equation approach which incorporates selection, but these models did not consistently perform well. Since I did not find evidence of selection bias in the earlier models, I performed a series of pooled probit models without incorporating selection. See Table 5 for the results of these models.[32]

Model 1 is a replication of the second model from the earlier analysis (Table 3), focusing only on DOS/Windows platforms. It includes the control variables, time since previous innovation, and the square of time since previous innovation. Here the results largely replicated the earlier analyses (Table 3). One notable exception was the lack of statistical significance for the market concentration variable. This suggests that the effect of market concentration is more relevant in Macintosh markets.

Model 2 added the technological and market opportunity variables to Model 1. There was a significant incremental improvement from Model 1 to Model 2 ($p = 0.012$). Note that all three of the technological and market opportunity variables were uniquely significant at $\alpha = 0.10$. This suggests that organizations producing application software may, in part, be entraining their release of generational product innovations to exogenous technological and market opportunities. This argument may be particularly appropriate for those opportunities that are clearly consistent in their temporal cycles: (a) the market opportunity variable (the COMDEX/Fall trade show occurs each November) and (b) the microprocessor technological opportunity variable (as observers often refer to Moore's Law in describing the rate of technological innovation in this industry).

At the same time, note that the time since previous innovation was positive ($p = 0.001$), and the square of time since previous innovation was negative ($p < 0.001$). Therefore, even after controlling for potentially-entraining exogenous factors, there is still a strong curvilinear effect of time since previous innovation on generational product innovation. This finding provides additional support for my argument that generational product innovations are, in part, driven by endogenous demand due to the disruptive nature of interactions between producers and their organizational customers.

Model 3 adds an interaction between organizational size and time since previous innovation, and including this interaction resulted in a significant improvement to the model ($p = 0.02$). Last, I added an interaction between organizational size and the square of time since previous innovation. While its coefficient was in the expected direction, adding this

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32 Respectively, the three models explained approximately 16%, 18%, and 19% of the variance in generational product innovation.

interaction did not result in a significant improvement to the model ($p = 0.65$). Therefore, after incorporating the technological and market opportunity variables, the interactive effect of organizational size occurred only on the upward slope of the relationship between time since previous innovation and generational product innovation. This finding remains consistent with an enabling role of organizational size for temporal routines for generational product innovation, but the level of support is reduced.

6.5 EXTENSION OF ANALYSES: QUALITATIVE EXAMINATION

In my statistical analyses, the final external entrainment model (Model 3, Table 5) explained approximately 20% of the variance in the likelihood of generational product innovation. This highlights that approximately 80% of the variance still remains to be explained. In this section, I qualitatively review the innovation histories of five organizations that competed in the CAD market segment. This review provides a closer examination of the empirical evidence relative to my hypotheses. In addition, the histories highlight several potential factors for consideration in future research.

I selected the following product organizations for qualitative review: IBM/CAD 3X, MacDraft, AutoCAD LT, TurboCAD, and Visio Technical. Collectively, the selected organizations competed on all three operating system platforms. And in the 1994-1998 time frame, the organizations spanned from low to high in terms of organizational size. For organizations with at least three generational product innovations, I calculated a coefficient of variation for the length of time until generational product innovation release on a given operating system platform. The coefficient of variation is equal to the standard deviation of the values divided by the mean of the values. This measure of relative dispersion provides an imperfect proxy for the temporal routineness of an organization's innovative behavior.

One limitation in my qualitative analysis involves measurement timing, particularly between the occurrence of generational product innovation events and the availability of the organizational size measure (i.e., 1994-1998). For three of the organization-platform cases, the innovation behavior by the organization completely precedes the 1994-1998 time window. These cases were IBM/CAD 3X (DOS), MacDraft (Windows), and TurboCAD (DOS). To some extent, this problem can be corrected using references to market share in the pre-1994 trade press.

6.5.1 A Selection of Organizations from the CAD Market

IBM/CAD 3X. IBM CAD released the IBM/CAD 3X product in November 1993. According to Mike Wong, president of IBM CAD, the organization designed IBM/CAD 3X to compete in the entry-level CAD market with the recently-released AutoCAD LT (*PC Week*, 1993). However, IBM/CAD 3X operated on the DOS and OS/2 platforms, while AutoCAD LT was designed for Windows. The IBM/CAD 3X product did not perform well in the marketplace. Shortly after its introduction, its market share for the DOS platform peaked at approximately 10%. Its market share soon fell below 1%, and the product did not remain on the market beyond mid-1995.

MacDraft. Innovative Data Design released MacDraft for the Macintosh operating platform in August 1985. MacDraft was the first CAD product on the Macintosh platform. Between its initial release and the middle of 1994, Innovative Data Design released three generational product innovations for MacDraft on the Macintosh. The first two generational product innovations were lengthy efforts, taking 56 and 42 months respectively. Further, in this general time frame, Innovative Data Design released a higher-end product, Dreams, that some industry observers believed would replace MacDraft. Trade press accounts indicate that MacDraft had not kept up with technological opportunities from hardware advances or competitive threats from new entrants to the market. For the third generational product innovation release of MacDraft, the length of time from the previous generational release was only 9 months. Given an average time between generational innovations of 36 months, MacDraft was lagging in its innovative pace. In addition, with a coefficient of variation of 0.68, MacDraft was not consistent in the temporal nature of its generational innovations. In the early years, MacDraft performed well in the Macintosh market, but by 1994, its market share was approximately 5%.

Innovative Data Design released a Windows version of MacDraft in February 1992, but the organization did not release any generational product innovations for the Windows version. After a market share of 1-3% in early 1994, MacDraft for Windows soon fell below 1% and was removed from the market by May 1995. Innovative Data Design did not survive beyond early 1996, but the MacDraft product was acquired by MicroSpot USA, Inc.

AutoCAD LT. Autodesk released AutoCAD LT in December 1993. Within the overall Autodesk product line, the AutoCAD LT product was located between (1) AutoSketch and

Generic CADD, a recent acquisition, at the low end, and (2) AutoCAD at the high end. In the 1994-1998 time window, AutoCAD LT had a median market share of approximately 20%. By the end of 1998, Autodesk had released four generational product innovations for AutoCAD LT. With an average time between generational innovations of 15 months, its innovative pace was frequent. And, with a coefficient of variation of 0.16, the organization had a consistent temporal routine for generational product innovation. Note that AutoCAD LT maintained this consistent pace of innovation, rather than innovating as a reaction to arising opportunities or threats, including a substantial compatibility problem for users of its first generational product innovation. According to the trade press, in its early years, the releases of AutoCAD LT tended to track the releases of the high-end AutoCAD product.

TurboCAD. Milan Systems America released TurboCAD for the DOS operating system in early 1987. In 1988, International Microcomputer Software, Inc. (IMSI) acquired Milan Systems America and continued to operate the organization as a separate unit in Atlanta. IMSI released two generational product innovations of TurboCAD for the DOS platform. The time until the first generational product innovation event was 44 months, and after this event, the time until the second generational product innovation event was 23 months. In the 1994-1998 time frame, TurboCAD had a median market share of approximately 60% on the DOS operating platform.

On the Windows platform, IMSI released four generational product innovations of TurboCAD. The mean time between generational releases was 14 months, and the coefficient of variation was 0.42. Therefore, on the Windows platform, TurboCAD had a frequent rate of innovation, and its temporal consistency was medium. In the 1994-1998 time window, TurboCAD had a median market share of approximately 40% on the Windows platform. On the Macintosh platform, IMSI released two generational product innovations of TurboCAD. For the two generational innovations, the time between product releases was 15 and 16 months respectively. In the 1994-1998 time window, TurboCAD had a median market share of approximately 50% on the Macintosh platform.

Visio Technical. The Shapeware Corporation, later renamed the Visio Corporation, released Visio Technical for Windows 3.0 in December 1994. The founder of the organization, Jeremy Jaech, also co-founded the Aldus Corporation and served as the technical leader for the PageMaker desktop publishing product. In the 1994-1998 time window, Visio released four generational product innovations of Visio Technical. With an average time between generational innovation releases of 8 months, its pace of innovation was extremely fast. And with a coefficient of variation of 0.18, its temporal consistency of innovation behavior was high. By the end of 1998, Visio Technical achieved a median market share of approximately 15%.

6.5.2 A Summary of the Cases

From the perspective of temporal routines for generational product innovation, I find four categories of innovation behavior: (1) non-repeating, (2) repeating, low temporal consistency, (3) repeating, medium temporal consistency, and (4) repeating, high temporal consistency. Generally I divided the organizations into temporal consistency categories using their coefficient of variation values: low consistency (above 0.60), medium consistency (approximately 0.40), and high consistency (below 0.20).

In the non-repeating category, there are two products: IBM/CAD 3X (DOS) and MacDraft (Windows). In the low temporal consistency category, there are two products: MacDraft (Macintosh) and TurboCAD (DOS). TurboCAD (Windows) is the lone product in the medium temporal consistency category. In the high temporal consistency category, there are three products: AutoCAD LT (Windows), TurboCAD (Macintosh), and Visio Technical (Windows).

6.5.3 Insights from the Cases

The cases are broadly consistent with Hypotheses 1 and 2. They also highlight potential explanations for points of divergence with the expected relationships, suggesting additional factors as influences on the innovation behavior of these organizations. As one insight, these results suggest that the relationship between organizational size and generational product innovation may be better represented by a positive threshold effect, rather than a relationship with steadily diminishing returns. Next, from a multi-level perspective, I consider other factors that may be influencing the temporal routineness of the innovation behavior of these organizations.

Market-Level. First, I find that market selection may prevent routines for generational product innovation from developing. The IBM/CAD 3X (DOS) and MacDraft (Windows) products are examples of this phenomenon. In these cases, the products developed by these organizations did not perform well in the market, and the organizations likely perceived that the expected return from investing in generational product innovation would not be satisfactory. This may also reflect a liability of newness (Hannan and Freeman, 1989) associated with market entry for these organizations. In particular, they may have faced difficulties in establishing legitimate market positions (e.g., IBM as an applications software provider, MacDraft as a "Mac" product on a Windows platform).

Second, the maturity of the market segment appears to be a factor. TurboCAD (DOS) and MacDraft (Macintosh) had low temporal consistency for their generational product innovation releases. Given their respective organizational sizes, Hypothesis 2 would predict higher temporal consistency. However, both organizations were early entrants in the development of the DOS and Macintosh CAD markets. Therefore, the maturity of a market segment may represent an important factor for the development of routines for innovation.

Organization-Level. Factors at the level of the business unit may also influence the innovation behavior of organizations. First, the expansion of the markets served by an organization may influence its innovation behavior. For example, TurboCAD (Windows) had medium temporal consistency for its generational product innovation releases. But given its organizational size, Hypothesis 2 would predict higher consistency. The efforts by IMSI to expand into new markets for TurboCAD may explain its reduced consistency of innovation behavior. In the time span of its first two generational product innovations on the Windows platform, IMSI was in the process of acquiring IGC Technology. IGC Technology produced the Pegasys CAD product, which IMSI intended to bridge into TurboCAD for the Macintosh platform. Further, in the time span of its third and fourth generational product innovations on the Windows platform, IMSI was increasing the breadth of its TurboCAD product line for Windows (e.g., TurboCAD Design 2D/3D, TurboCAD 2D/3D Professional). This expansion in breadth may have inhibited the coordinative capabilities of the organization and obstructed its ability to consistently release generational product innovations.

Second, related innovation activities within the organization may influence generational product innovation behavior. As one example, in the early stages of its history, trade press accounts suggest that AutoCAD LT tracked the releases of the high-end AutoCAD product. This suggests that, in the early stages, the pace of generational innovation for the AutoCAD

LT product was influenced by the pace of generational innovation for the AutoCAD product. Note that this does not exclude the argument for customer pressure as a determinant of the timing of innovation. But in this case, customers may have been influencing the innovative pace of the AutoCAD product (Walker, 1994) which then influenced the timing of generational product innovation releases for AutoCAD LT.

As another example, uncertainty stemming from a related product innovation may help explain the low temporal consistency of generational innovation for the MacDraft (Macintosh) product. In this case, Innovative Data Design released Dreams, a product that was expected to replace the MacDraft (Macintosh) product. But subsequent market demand for MacDraft (Macintosh) was such that the organization eventually continued to invest in generational product innovation for MacDraft (Macintosh).

The third factor considers the pre-entry possession of related organizational routines (i.e., previously-developed in similar markets) as an influence on generational product innovation behavior (Carroll, et al., 1996; Kim and Kogut, 1996). In his founding of the Visio Corporation, Jeremy Jaech brought a core group of Aldus developers with him. Together with Jaech, these developers were a large part of the success of the PageMaker desktop publishing product. Therefore, the high temporal consistency of generational product innovation for Visio Technical may, in part, stem from the pre-entry possession of routines for innovation that were developed in the desktop publishing market.

Last, the dominant logic of top management may influence generational product innovation behavior (Prahalad and Bettis, 1986; Bettis and Prahalad, 1995). For example, the dominant logic that Jeremy Jaech and his managers established at Aldus in the desktop publishing market may have significantly influenced their later innovation behavior at Visio. While listed as organization-level factors, note that the last two factors may also be viewed at group and individual levels.

6.6 LIMITATIONS

There are several limitations associated with the empirical assessment. First, I studied generational product innovation in a single industry, which may limit the generalizability of the work. While generational product innovations are visible and relatively frequent in applications computer software, it is important to examine the generalizability of the concept.

Here I consider both product and generational aspects. With respect to the emphasis on product innovation, in the United States, approximately three-quarters of industrial R&D is directed to product innovation (Scherer and Ross, 1990). With respect to generational innovation, Scherer and Ross (1990: 642) note that "most industries experience a continuing stream of innovations over time, and in many cases, each completed new product or process sets an agenda focusing improvement work for the next technological generation."[33] While limiting in some ways, studying innovation in a single industry context offers the opportunity to develop an appropriate operationalization of the innovation concept. Cohen and Levin (1989: 1026) note that currently there is not a measure of innovation that "permits readily interpretable cross-industry comparisons."

Second, in addition to a cross-sectional limitation (i.e., a single industry), the data is limited longitudinally. Due to cost and data availability limitations, I could only examine a relatively-developed stage of the computer software industry. This necessarily limits my ability to empirically study how these routines emerged in the earliest stages of the industry.

Third, the number of generational product innovation events in the dataset is relatively small. The limited number of events posed a power concern, limiting my analytic technique options. In particular, I was unable to employ fixed effects which could control for the likelihood of innovation by each organization. Fortunately, statisticians and econometricians demonstrate that this limitation is a minor one, resulting only in less efficient estimates (Maddala, 1987; Robinson, 1982). Therefore, while the theory allows organizations to differ in the length of time between generational product innovations, the empirical test is limited by an assumption of commonality in time intervals across organizations. Note that in order to examine a fixed organization effect for temporal routines, it may be necessary to include not only an effect for the likelihood of innovation by each organization but also a fixed effect for time since previous innovation by each organization. In this case, future empirical work in this area could require substantial length in data panels to study organization-specific temporal routines.

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33 Similarly Schumpeter notes that "improvement in the quality of products is hence a practically universal feature of the development of individual concerns and industries" (1942: 92) and further that "a new type of machine is in general but a link in a chain of improvements" (1942: 98).

6.7 SUMMARY OF RESULTS

In the empirical analyses, I found results that are consistent with the temporal routines for incremental change (TRIC) theoretical perspective. First, in a developed stage of the microcomputer applications software industry, organizations employed temporal routines for generational product innovation. Second, with increasing size, organizations had a greater tendency to employ these routines. Third, even after controlling for potentially-entraining exogenous factors (e.g., generational product innovation releases of microprocessors, annual trade shows), there was empirical support for the temporal routines for incremental change (TRIC) perspective. Finally, the insights drawn from my qualitative review of several organizational cases in the CAD market offer a number of interesting factors to consider in future research.

CHAPTER 7

IMPLICATIONS

In this chapter, I consider implications for practitioners, government policy, and academic researchers. I also highlight several opportunities for future research.

7.1 PRACTITIONERS

In this study, I found a strong inertial component to innovative behavior in organizations, and I found that this tendency towards consistent innovation is stronger in larger organizations. While organizations garner certain benefits from these temporal routines for innovation (Brown and Eisenhardt, 1997), there are also important detriments to consider. For example, organizations may continue to consistently introduce innovations along the same technological trajectory, even after conditions have changed such that organizational customers either no longer demand additional innovations or no longer demand additional innovations at the same rate.

This theme is illustrated in a recent cover story article in a high-technology trade publication (*Red Herring*, 2003). The author of the article is Michael Malone, and the extended title is "Forget Moore's Law... Because it's unhealthy. Because it has become our obsession. Because it is dangerous -- a runaway train, roaring down a path to disaster." In the article, Malone suggests that customers are starting to break their routines for generational adoption of new microprocessors ("[declaring] their independence from Moore's Law"). Commenting on this break in the cycle of generational adoption, Marc Andreessen, the cofounder of Netscape, notes "this is a fundamental, even revolutionary, change in the IT world... It's going to be disastrous for a lot of big companies out there." Beyond semiconductors, Malone suggests that this change has implications for a host of organizations in industries that employ temporal routines for innovation similar to, or in line with, Moore's Law (e.g., bandwidth in telecommunications, data/storage in bioinformatics).

Facing this type of situation, one option for producers is to decrease their rate of innovation, while continuing along the same technological trajectory (e.g., release new generations every 36 months rather than every 18 months). Alternatively, greater performance may result from shifting technological trajectories. This theme has been examined in much of the technological change research and covers a range of industries from hard disk drives (Christensen, 1992) to ice-harvesting/manufacturing (Utterback, 1996). In this case, organizations may be able to apply established temporal routines for innovation along new technological trajectories.

From an alternative perspective, this study argues that organizations are more receptive to change at certain points in time. This argument may have important implications for organizational leaders that seek to implement new (i.e., non-routine) change initiatives. Typically implementing change initiatives within organizations is a challenging task, given employee resistance to change involving their operating routines. Yet programmed change, in the form of modification routines (e.g., temporal routines), reduces the resistance to change from employees. As a consequence, organizational leaders may obtain value from introducing new change initiatives at points in time in which routine changes are being introduced. At these points in time, employees expect a disruption to their operating routines. As such, managers may find higher employee receptivity to new change initiatives, resulting in higher implementation success for the initiatives.

7.2 GOVERNMENT POLICY

From this study, I draw notable implications for anti-trust policy. While the effect of market power on social welfare is of long-standing interest in economics and public policy, Teece and Coleman (1998) indicate that we still know relatively little about the effect of market power on innovation in high-technology industries. This issue is particularly salient in the computer software industry, most notably regarding the attention directed to Microsoft (Liebowitz and Margolis, 1999; U.S. Senate Judiciary Committee, 1998).

In this study, I found no evidence to suggest that large organizations exploit customers by reducing their innovative behavior. In fact, in most cases, the larger organizations had a higher likelihood of generational product innovation, relative to their peers. In the main analyses, I did observe a marginally-significant negative effect of market concentration on generational product innovation ($a = 0.10$). As markets became more concentrated, organizations had a reduced likelihood of generational product innovation. But subsequent analyses indicated that this effect was not present in the DOS/Windows markets.

To summarize, while greater concentration reduces the likelihood of generational product innovation in certain applications software markets, the larger organizations are not the laggards. In this case, the larger organizations tend to lead the industry with respect to the likelihood of generational product innovation. This finding suggests that the level of scrutiny directed toward the effect of market power on innovation in the software industry may be unwarranted.

7.3 ACADEMIC RESEARCHERS

In the organizations literatures, a common perspective is that organizations change as the result of changing conditions in the environment (e.g., decreased market concentration). And, within its environmental context, the ability of an organization to change is either facilitated or inhibited by a number of current characteristics of the organization (e.g., age, size). In these literatures, the tendency is to examine organizational change as isolated, individual events. Examples include acquisitions or changes in organizational leadership. Yet in this study, I find that a powerful determinant of organizational change is the historical pattern of change behavior in the organization.

This view is consistent with a dynamics of inertia, or organizational momentum, perspective (Amburgey and Miner, 1992; Amburgey, et al., 1993). In organizational ecology, much of the attention has been directed to repetitive momentum, which argues for a positive effect of the cumulative number of previous changes on the likelihood of future change. In reviewing this empirical research, Baum (1999) found that repetitive momentum is relatively unique in that it has strong and consistent support across empirical studies. However, the current view of the dynamics of inertia is incomplete.

In addition to the effect of the cumulative number of previous changes, there is an important effect of the time since previous change on the likelihood of change. The organizational ecology literature currently focuses on a negative effect of the time since previous change on the likelihood of change (Baum, 1999). The rationale is that organizations search locally in time for change solutions. Thus, organizations are more likely to repeat recently-enacted change behaviors. In this study, I argue that due to the disruptive nature of change, organizations are more likely to change at consistent, periodic time intervals.

This study demonstrates that viewing or examining organizational change as isolated, individual events is insufficient. Rather we need to understand individual changes as elements within a larger, historical pattern of change for the organization.

This study also contributes to research streams that examine the effect of an existing customer base on the innovative behavior of organizations. From an economic perspective, Cohen and Klepper (1996) found an influence of the size of the existing customer base on the amount of innovation activity for an organization. From a resource dependence perspective, Christensen and Bower (1996) found that the existing customer base influences the type of innovation activity for an organization. In this study, I find that an existing customer base can also influence the timing of innovation activity for an organization.

7.4 FUTURE RESEARCH OPPORTUNITIES

Given that further inquiry along these lines appears promising, I offer several suggestions for future research. From the perspective of temporal routines for change, we need a better understanding of the determinants and consequences of these routines. The set of extending analyses suggests several factors that may influence temporal routines for change: (1) the linkage between routines and exogenous entraining factors, (2) the maturity of the market, (3) the presence of expansion initiatives within the organization, (4) organizational experience with routines for change in related environments, and (5) the beliefs of top management concerning the value of routines for change.

More broadly (i.e., beyond temporal issues), we need a better understanding of organizational routines for change. While there is promising initial work (e.g., Hargadon and Sutton, 1997), the work presently appears to be at the stage of identification of routines in distinct industries or settings. As this work continues to develop, there will be greater value in developing classification schemes (Cardinal, et al., Working Paper). These classifications may be cross-sectional (i.e., routine differences across organizations or industries) or longitudinal (i.e., routine differences across time within organizations and industries). These classifications can help to advance research into the ways in which routines for change impact organizational performance.

CHAPTER 8

CONCLUSIONS

In this study, my objective was to extend understanding regarding the inertia of innovative behavior in the form of temporal routines for incremental change. With respect to theory development, I offered an explanation for temporal routines for incremental change as the result of endogenous demand for change, emphasizing the interactions between producers and their organizational customers. This development complements existing research in routines-based theory (Nelson and Winter, 1982), which has emphasized routines as determined intra-organizationally (i.e., routines established among organizational members). It also complements research on the time-based pacing of change (Bluedorn, 2002), which emphasizes routines as determined extra-organizationally (i.e., exogenous entrainment). In an application and test, I found statistical evidence consistent with the temporal routines for incremental change (TRIC) theoretical perspective.

More broadly, this study contributes to our understanding of why organizations change. In the organizations literature, a common perspective emphasizes organizational change as a response to events in the environment (i.e., actions by competitors). Given the occurrence of such events, the ability for organizations to change is based on a set of current organizational characteristics (e.g., age, size). However, this perspective largely neglects the influence of the historical pattern of change behavior in the organization (i.e., the timing of previous changes). This historical pattern can provide substantial insight into the expected change behavior of organizations.

The importance of routinized innovation in stimulating technological change and subsequently economic performance is not new (Schumpeter, 1942). But our understanding of routines for innovation, or routines for change, remains quite limited. The initial discoveries offer encouragement, in the form of explanatory power, for further developing this line of research. While much of the theoretical landscape remains open, our need for developing a body of empirical research on these routines is striking. The existence of this gap may provide an indication of the challenges associated with empirical work in this area. My hope is that the present study offers some light along this path.

APPENDIX 1

Time Until Generational Product Innovation Calculation

The following abbreviations are used below: (1) GPI for generational product innovation, (2) X for the set of control variables, (3) TS for the time since previous innovation, and (4) OrgSize for organizational size.

$$GPI = \beta_0 + \beta_1(X) + \beta_2(TS) + \beta_3(TS^2) + \beta_4(OrgSize)*(TS) + \beta_5(OrgSize)*(TS^2) + \varepsilon$$

Taking the derivative of GPI with respect to TS,
$$d(GPI)/d(TS) = \beta_2 + 2*\beta_3(TS) + \beta_4(OrgSize) + 2*\beta_5(OrgSize)*(TS)$$

Setting d(GPI)/d(TS) = 0,
$$0 = \beta_2 + 2*\beta_3(TS) + \beta_4(OrgSize) + 2*\beta_5(OrgSize)*(TS)$$

Since OrgSize is mean-centered, for medium-sized organizations, setting OrgSize = 0,
$$0 = \beta_2 + 2*\beta_3(TS) + \beta_4(0) + 2*\beta_5(0)*(TS)$$

Substituting in the coefficient estimates from Model 3 (Table 3),
$$0 = 0.02043 + 2*(-0.00134)(TS)$$
TS = 7.6 months

Since TS is mean-centered, add the mean of TS,
Length of Time = TS(mean) + 7.6 months
= 22.5 months + 7.6 months
Length of Time = 30.1 months

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Table 1. Description of Variables

Focal dependent variable

- GenProdInnov: Binary variable indicating whether a generational product innovation has been released by the focal organization (1: yes, 0: no)

Selection dependent variable

- OnMkt: Binary variable indicating whether the organization's product remains on the market through the end of the time period (1: yes, 0: no)

Control variables

Market Characteristics

- DOS, WIN: Effect-coded variables indicating DOS, Windows, and Macintosh markets
- MktSize: Total number of product units sold, by units, in respective market category (lagged one month, logged)
- MktConc: Sum of squared market shares, by units, in respective market (lagged one month)
- MktInnov: Binary variable indicating whether any peer organizations within the market released a generational product innovation (lagged one month)
- MktDens: Total number of organizations operating in respective market (lagged one month)

Organizational Characteristics

- Age: Number of months since initial product in the product family was introduced
- TotPrevInnov: Cumulative number of previous generational product innovations by organization

Explanatory variables

Organizational Size

- OrgSize: Number of products sold by organization in market (lagged one month, logged, centered)

Time Since Previous Innovation

- TimeSinceInnov: Number of months that have elapsed since the initial market release or since the previous generational product innovation (centered)

† Lagged measures of a number of control and explanatory variables are employed to address potential simultaneity. As such, these lagged measures are viewed as pre-determined. The variables using lagged measures are MktSize, MktConc, MktInnov, MktDens, and OrgSize. An alternative rationale for using lagged measures, although not my focal one, is that decisions for organizational action in time, t, are based on conditions in a previous time period. For other variables, lagged measures were not used. These variables are either (a) fixed variables (DOS, WIN), (b) exogenous, time-dependent variables (Age), or (c) count/clock variables that are either fixed following an innovation event (TotPrevInnov) or time-dependent following an innovation event (TimeSinceInnov).

Table 2. Variable Summary Statistics and Product-Moment Correlations (N = 2617 organization-months)

	Variable	Mean	StdDev	Min	Max	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	GenProdInnov	0.027	0.162	0.000	1.000	1.000														
2	OnMkt	0.990	0.097	0.000	1.000	0.016	1.000													
3	DOS	-0.138	0.748	-1.000	1.000	-0.035	-0.034	1.000												
4	WIN	0.063	0.881	-1.000	1.000	0.041	0.029	0.557	1.000											
5	MktDens	4.759	1.811	1.000	10.000	0.020	-0.022	0.052	0.253	1.000										
6	MktSize	3.605	0.723	0.778	5.010	0.057	0.039	-0.087	0.439	0.250	1.000									
7	MktConc	0.552	0.233	0.198	1.000	-0.073	-0.023	0.204	-0.266	-0.465	-0.265	1.000								
8	MktInnov	0.102	0.303	0.000	1.000	0.006	-0.006	-0.050	0.129	0.187	0.110	-0.213	1.000							
9	Age	113.354	45.721	2.000	201.000	-0.043	0.016	0.177	-0.048	-0.370	-0.135	0.394	-0.122	1.000						
10	TotPrevInnov	3.089	2.113	0.000	8.000	-0.048	0.032	0.255	-0.164	-0.251	-0.255	0.242	-0.123	0.501	1.000					
11	OrgSize	0.000	1.272	-2.292	2.558	0.076	0.151	-0.093	0.268	-0.064	0.416	-0.286	0.041	0.110	0.122	1.000				
12	TimeSinceInnov	0.000	19.273	-21.540	69.460	-0.022	-0.137	0.233	-0.245	-0.175	-0.381	0.510	-0.111	0.298	-0.047	-0.524	1.000			
13	TimeSinceInnovSqr	371.295	632.480	0.212	4824.701	-0.068	-0.139	0.204	-0.122	-0.125	-0.273	0.351	-0.076	0.171	-0.061	-0.387	0.718	1.000		
14	OrgSize*TimeSinceInnov	-12.845	27.375	-156.937	49.378	0.065	0.149	-0.180	0.064	0.136	0.100	-0.332	0.083	-0.263	-0.001	0.240	-0.591	-0.754	1.000	
15	OrgSize*TimeSinceInnovSq	-311.472	1279.002	-10743.940	1143.421	0.043	0.172	-0.151	0.166	0.091	0.293	-0.346	0.067	-0.139	0.075	0.562	-0.723	-0.882	0.765	1.000

1	GenProdInnov	Generational Product Innovation
2	OnMkt	On-Market Status of Organization
3	DOS	DOS Operating Platform
4	WIN	Windows Operating Platform
5	MktDens	Market Density
6	MktSize	Market Size
7	MktConc	Market Concentration
8	MktInnov	Innovation by Peer Organizations
9	Age	Organizational Age
10	TotPrevInnov	Cumulative Number of Previous Innovations by Organization
11	OrgSize	Organizational Size
12	TimeSinceInnov	Time Since Previous Innovation
13	TimeSinceInnovSqr	Square of Time Since Previous Innovation
14	OrgSize*TimeSinceInnov	Interaction between Organizational Size and Time Since Previous Innovation
15	OrgSize*TimeSinceInnovSq	Interaction between Organizational Size and Square of Time Since Previous Innovation

Table 3. Probit Estimates for Generational Product Innovation and On-Market Selection
(N = 2617 organization-months, 2592 on-market observations, 71 generational product innovation events)

		1			2			3		
DV	IVs	Coeff.	S. E.	t-statistic	Coeff.	S. E.	t-statistic	Coeff.	S. E.	t-statistic
GenProdInnov	Intercept	-1.629	0.485	-3.36**	-1.238	0.527	-2.35*	-1.211	0.542	-2.23*
	DOS	-0.251	0.160	-1.57	-0.320	0.171	-1.87†	-0.305	0.173	-1.76†
	WIN	0.106	0.121	0.88	0.177	0.128	1.38	0.166	0.129	1.29
	MktSize	0.039	0.132	0.30	0.065	0.138	0.47	0.060	0.146	0.41
	MktConc	-0.478	0.311	-1.54	-0.636	0.342	-1.86†	-0.689	0.352	-1.96†
	MktInnov	-0.091	0.164	-0.55	-0.083	0.170	-0.49	-0.080	0.170	-0.47
	Age	-0.001	0.001	-0.98	-0.004	0.002	-2.26*	-0.003	0.002	-2.08*
	TotPrevInnov	-0.045	0.035	-1.27	-0.012	0.041	-0.29	-0.017	0.041	-0.42
	OrgSize	0.121	0.085	1.43	0.195	0.080	2.44*	0.309	0.114	2.72**
	TimeSinceInnov				0.025	0.006	4.16***	0.020	0.006	3.25**
	TimeSinceInnovSq				-0.001	0.000	-3.80***	-0.001	0.000	-3.64***
	OrgSize*TimeSinceInnov							0.009	0.005	1.88†
	OrgSize*TimeSinceInnovSq							-0.001	0.000	-2.99**
OnMkt	Intercept	2.585	0.665	3.89***	2.531	0.672	3.76***	2.541	0.671	3.79***
	DOS	-0.165	0.188	-0.88	-0.162	0.189	-0.86	-0.164	0.188	-0.87
	WIN	0.161	0.227	0.71	0.156	0.231	0.68	0.154	0.229	0.67
	MktDens	-0.055	0.069	-0.79	-0.052	0.071	-0.73	-0.054	0.071	-0.76
	MktSize	0.044	0.151	0.29	0.041	0.155	0.27	0.044	0.154	0.28
	MktConc	1.322	0.535	2.47*	1.348	0.533	2.53*	1.351	0.533	2.54*
	Age	0.002	0.003	0.82	0.003	0.003	1.05	0.003	0.003	0.96
	OrgSize	0.706	0.176	4.00***	0.712	0.178	4.00***	0.712	0.179	3.97***
	TimeSinceInnov	-0.018	0.006	-2.98**	-0.018	0.006	-3.16**	-0.018	0.006	-3.08**
	rho	-0.733	0.352		-0.281	0.915		-0.583	0.811	
Model loglikelihood			-405.201			-386.157			-381.716	
Likelihood ratio test (d.f.)			19.34 (8)*			48.02 (10)***			51.99 (12)***	
Increase in Likelihood ratio (d.f.)						38.09 (2)***			8.88 (2)*	

† p < 0.10
* p < 0.05
** p < 0.01
*** p < 0.001

Table 4. Simple Slope Tests for the Effect of Time Since Previous Innovation on Generational Product Innovation at Three Levels of Organizational Size

		1 $OrgSize_L$ (small)	2 $OrgSize_M$ (medium)	3 $OrgSize_H$ (large)
	estimate	0.029	0.073	0.116
$TimeSinceInnov_L$	standard error	0.018	0.016	0.023
	t-statistic	1.59	4.57***	5.15***
	estimate	0.009	0.020	0.032
$TimeSinceInnov_M$	standard error	0.010	0.006	0.008
	t-statistic	0.87	3.23**	4.09***
	estimate	-0.012	-0.032	-0.052
$TimeSinceInnov_H$	standard error	0.013	0.015	0.024
	t-statistic	-0.90	-2.06*	-2.17*

† $p < 0.10$
* $p < 0.05$
** $p < 0.01$
*** $p < 0.001$

L subscript — Low (one standard deviation below the mean)
M subscript — Medium (at the mean)
H subscript — High (one standard deviation above the mean)

Table 5. Probit Estimates for Generational Product Innovation (DOS/Windows)
(N = 1679 organization-months, 49 generational product innovation events)

		1			2			3		
DV	IVs	Coeff.	S. E.	t-statistic	Coeff.	S. E.	t-statistic	Coeff.	S. E.	t-statistic
GenProdInnov	Intercept	-0.715	0.806	-0.89	-1.117	0.831	-1.34	-1.204	0.876	-1.37
	DOS	-0.509	0.309	-1.65†	-0.464	0.316	-1.47	-0.398	0.316	-1.26
	MktSize	0.016	0.190	0.09	0.080	0.196	0.41	0.068	0.208	0.33
	MktConc	-0.552	0.504	-1.09	-0.391	0.516	-0.76	-0.452	0.528	-0.86
	MktInnov	-0.240	0.216	-1.11	-0.174	0.222	-0.78	-0.165	0.223	-0.74
	Age	-0.004	0.002	-2.11*	-0.005	0.002	-2.34*	-0.004	0.002	-1.87†
	TotPrevInnov	-0.033	0.056	-0.58	-0.032	0.058	-0.56	-0.035	0.059	-0.59
	OrgSize	0.238	0.086	2.76**	0.263	0.090	2.91**	0.389	0.124	3.14**
	TimeSinceInnov	0.028	0.009	3.27**	0.029	0.009	3.29**	0.018	0.010	1.81†
	TimeSinceInnovSq	-0.002	0.001	-3.52***	-0.002	0.001	-3.50***	-0.002	0.001	-3.05**
	MktOpp				0.370	0.222	1.67†	0.364	0.224	1.63
	TechOppMP				0.604	0.300	2.01*	0.609	0.307	1.99*
	TechOppOS				0.428	0.239	1.79†	0.400	0.244	1.64
	OrgSize*TimeSinceInnov							0.022	0.010	2.15*
Model loglikelihood			-180.896			-175.437			-172.833	
Likelihood ratio test (d.f.)			67.01 (9)***			77.92 (12)***			83.13 (13)***	
Increase in Likelihood ratio (d.f.)						10.92 (3)*			5.21 (1)*	

† $p < 0.10$
* $p < 0.05$
** $p < 0.01$
*** $p < 0.001$

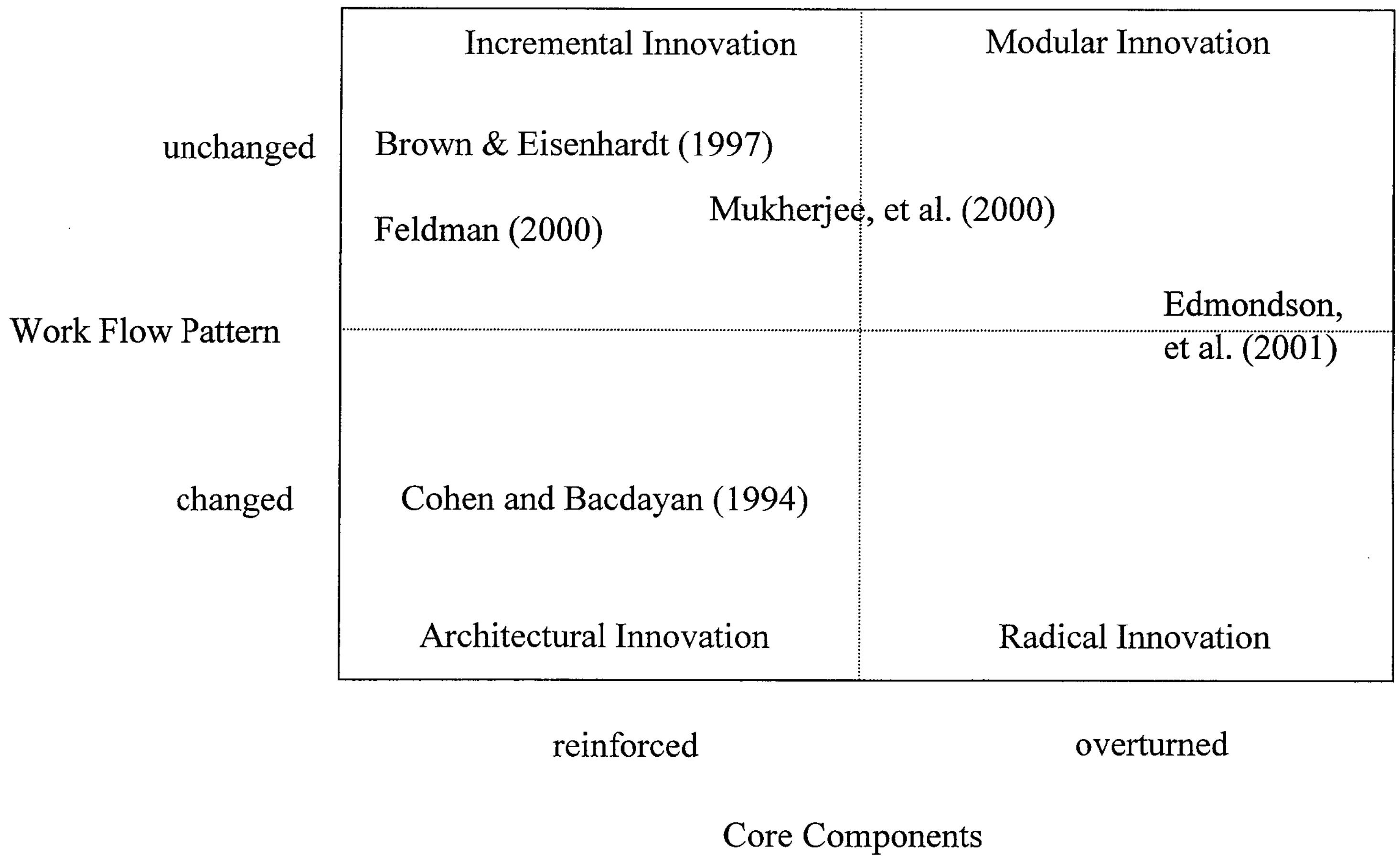
Figure 1. Comparing Perspectives of Inertia from Organizational Ecology

	Structural Inertia[1]	Organizational Momentum[2]	Focal Study
First Law of Motion			
• Body at Rest	X		
• Body in Motion		X	X
Second Law of Motion			
• Mass (Size)	X		X
• Mass (Age)	X		

[1] For structural inertia, the reference study is Hannan and Freeman (1984).

[2] For organizational momentum, the reference studies are Amburgey et al. (1993) and Miller and Friesen (1980).

Figure 2. Innovation of Routines Typology



* Axes and cell labels are retained or extended from the Henderson and Clark (1990) typology.

Figure 3. Component Change Loops for Operating Routines in Organizational Customers

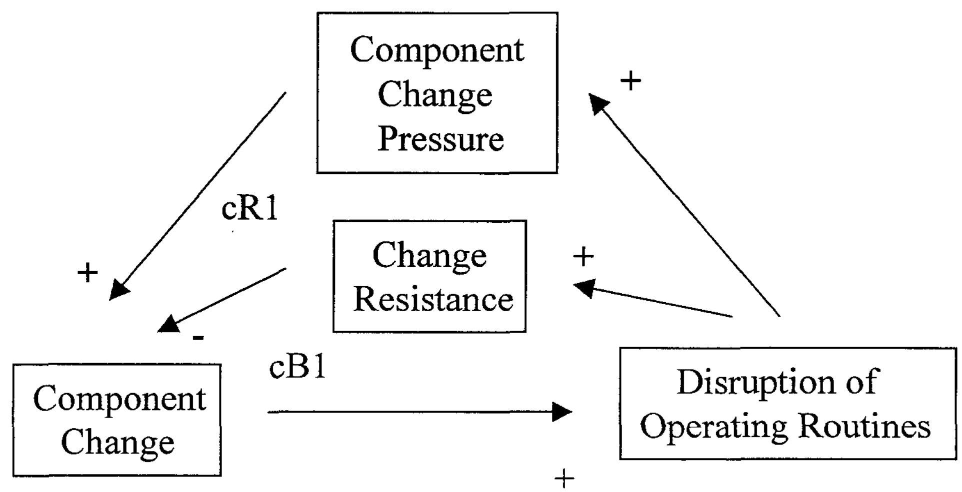


Figure 4. Producer Perspective on Demand for Component Change

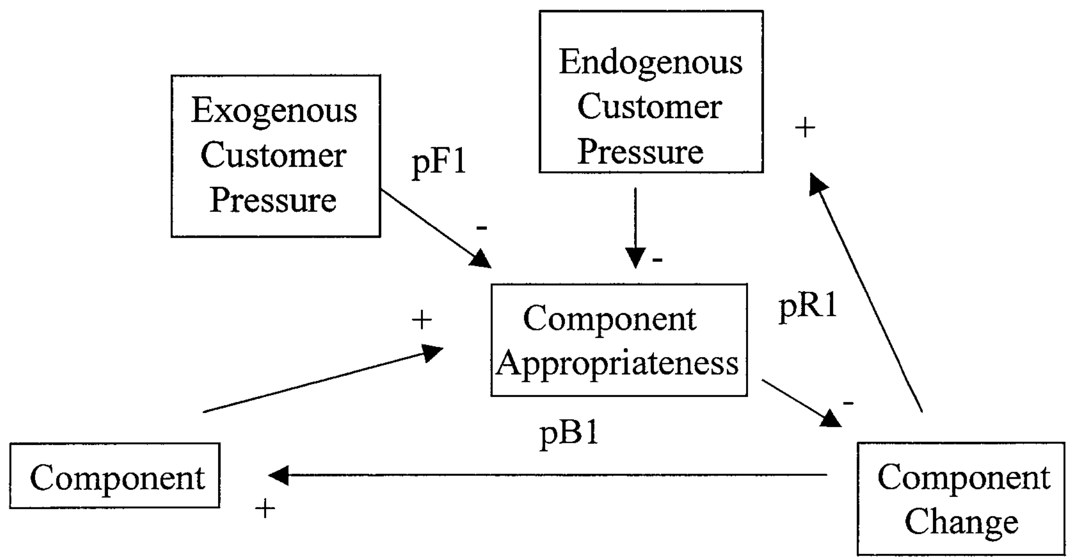


Figure 5. Component Change Loop for Operating Routines in Producers

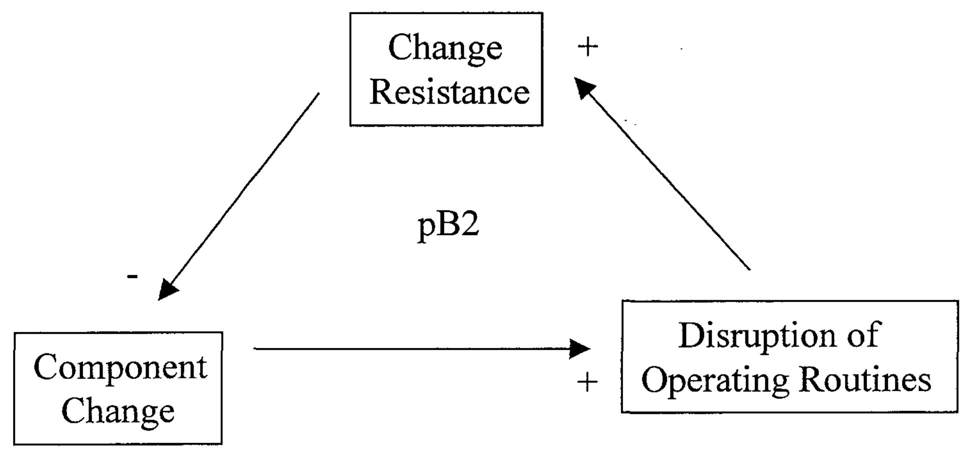


Figure 6. Component Change Loops for Modification Routines in Producers

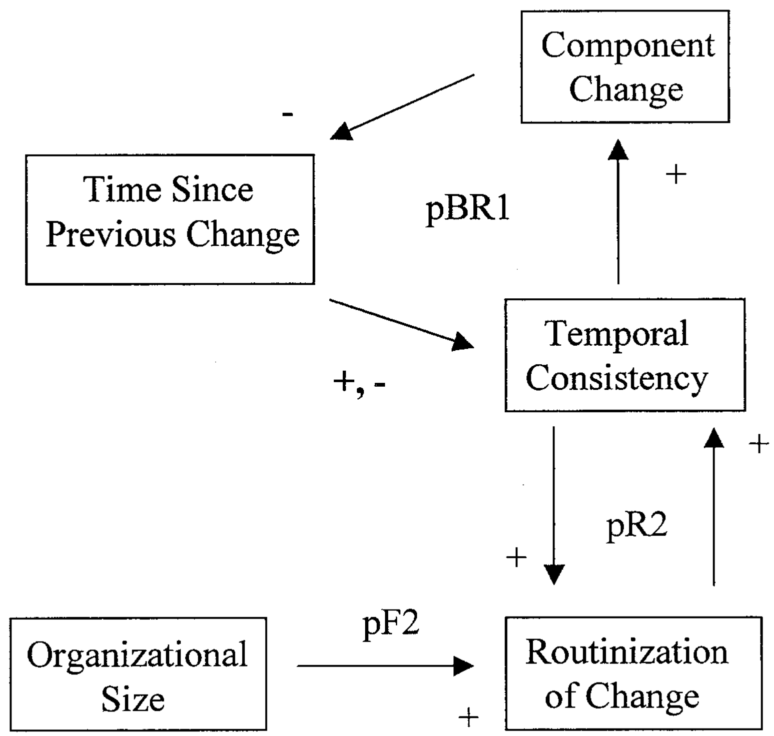


Figure 7. Summary of Loops for Producers

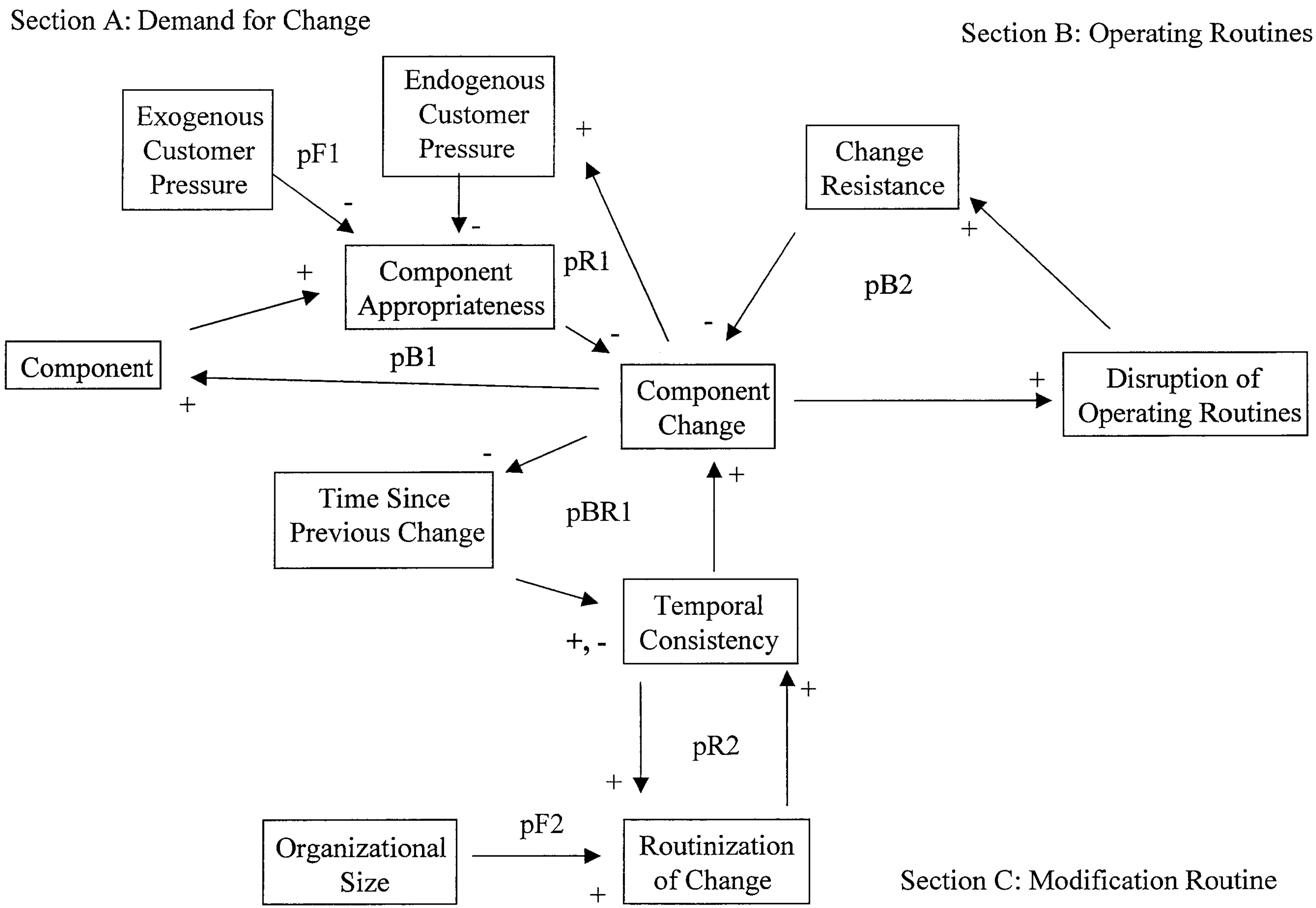


Figure 8. Empirical Model

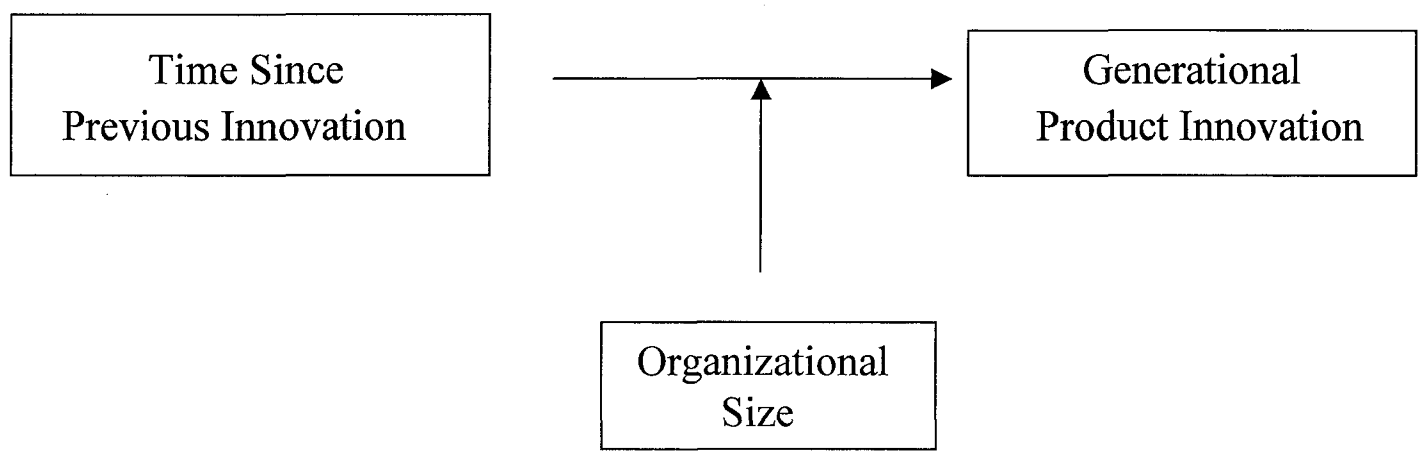


Figure 9. Expected Relationship for Hypothesis 1

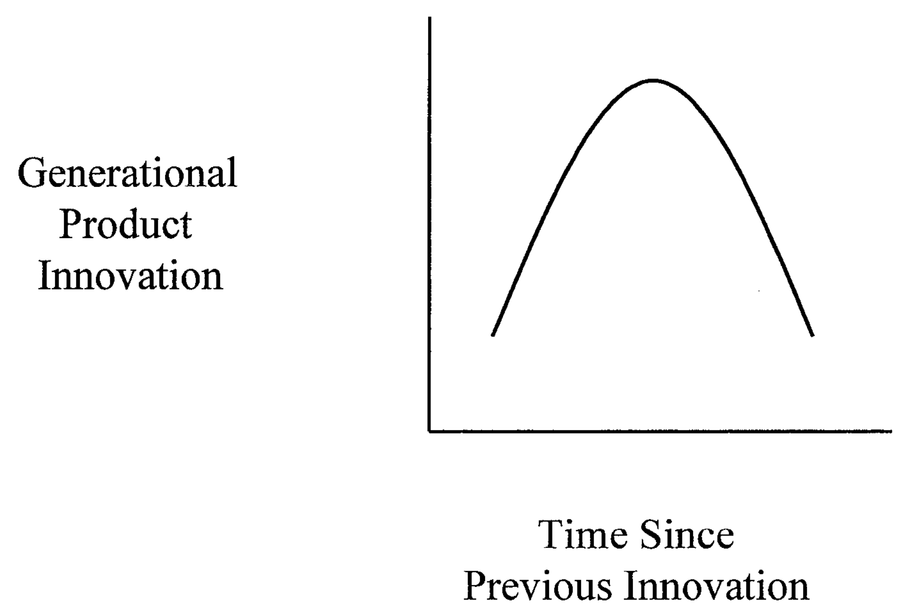
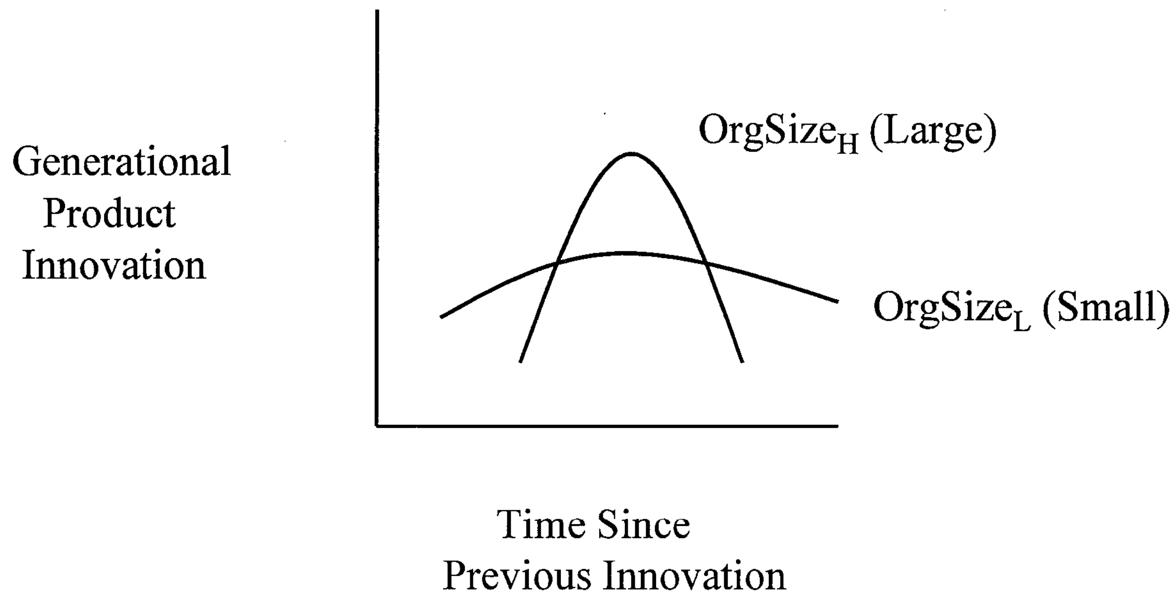


Figure 10. Expected Relationship for Hypothesis 2



† This figure illustrates the prediction that as organizational size increases, the likelihood of generational product innovation (a) increases within a narrowing range of time since previous innovation and (b) decreases outside that range.

Figure 11. Time Since Previous Innovation for Generational Product Innovation Events

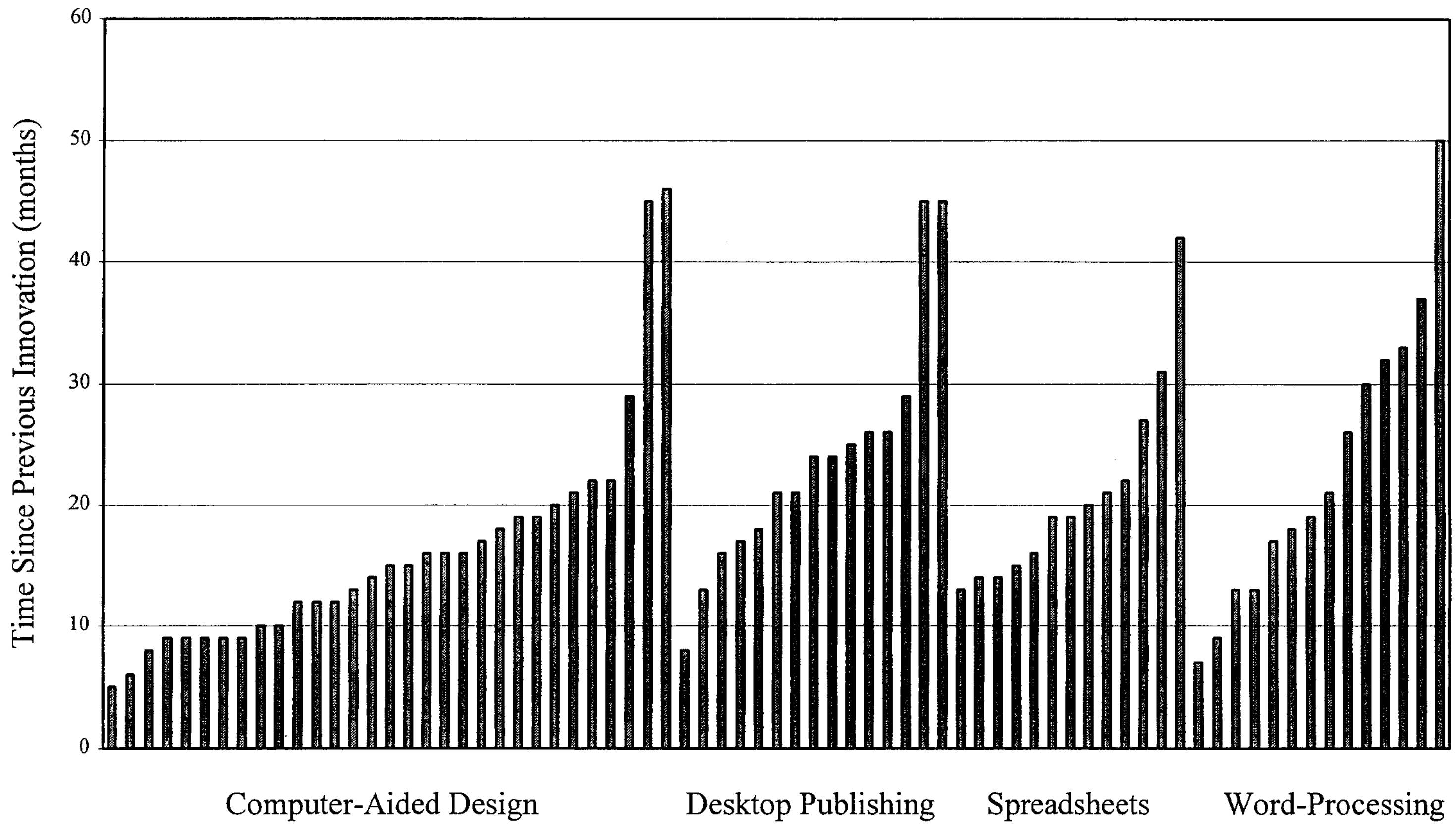


Figure 12. Effect of Time Since Previous Innovation on Generational Product Innovation