INNOVATION ADOPTION BY ESTABLISHED FIRMS: UNRESOLVED ISSUES

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This research identified a core set of organizational characteristics influencing innovation adoption: forward and backward integration, size, and product diversity. Some prior work has argued that these factors speed innovation; others have argued that they slow adoption. Our findings indicate that backward and forward integration and product diversity speed innovation. Implications of these findings for both theory development and innovation management in practice are discussed.

INTRODUCTION

The subject of innovation adoption has attracted continuing attention because of the critical role played by innovation in social and economic development (Schumpeter, 1942; Van de Ven, 1986) and in industrial competitiveness (Dosi, 1988; Eisenhardt & Schoonhoven, 1990; Freeman, 1982). Recent work in the area of organizational innovation has helped specify the properties of organizations that enhance or hinder innovation adoption (Damanpour, 1991), the influence of informal boundary-spanning communication on the innovation process (Conway, 1995), the conditions under which dominant designs emerge from innovations (Anderson and Tushman, 1990), and the effects of technological discontinuities on environmental change (Anderson & Tushman, 1997; Tushman & Anderson, 1986).

Despite the range of theoretical and empirical work that has examined the influence of organizational characteristics on innovation, there is still a lack of consensus regarding the role that specific variables play in either helping or hindering innovation adoption (Damanpour, 1991; Kimberly & Evanisko, 1981). As a result, neither researchers nor practitioners have been able to gain much unambiguous guidance from this body of literature. The present study examines four organizational characteristics that have been identified in past

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research as being important to innovation adoption. The four characteristics examined are of interest specifically because there are disagreements about their effects - some prior work has argued that they speed innovation adoption, while other work has argued that they slow the adoption process.

This study first examines how the extent of vertical integration (both backward and forward integration) facilitates or impedes the adoption of a technological innovation. We then discuss how two other organizational boundary variables, organizational size and product diversity, either help or hinder innovation adoption. Our research setting is the personal computer industry, where we examine the adoption of a technological innovation, the 8-bit microprocessor, by personal computer manufacturers operating at the time this product innovation was introduced.

Among all the high-technology industries, the personal computer industry has experienced the most rapid growth in the past two decades. This rapid growth rate is likely to continue in the foreseeable future. In a recent report issued by International Business Machines Corporation, "New Horizons—The Second Decade of the PC," IBM predicts that the personal computer (PC) will become the hub of the home entertainment center, combining television, high-fidelity stereo, video, and games, as well as performing home-based business operations (Tyler, 1993). Furthermore, the growth of the PC industry has been closely tied to the developments of other high-technology industries (e.g., semiconductor, telecommunication, video game). As such, we are convinced that any finding in this study could be generalized to other high-technology industries with relative ease, and a better understanding of the innovation adoption behavior in this industry will help researchers understand the technological innovations in other related industries as well.

Studying the adoption of 8-bit microprocessors by personal computer firms is also interesting owing to the crucial role played by this generation of microprocessors when the entire PC industry was still in the early stage of its life cycle. Unlike the MMX microprocessor recently developed by Intel—whose adoption was almost unanimously viewed as imperative by all PC manufacturers immediately upon its introduction—8-bit microprocessors have followed a relatively slow path of diffusion in the personal computer industry. This fact implies that different types of organizations were more likely to show differing propensities to adopt such an innovation. Understandably, the decision to adopt an innovation when its advantage is not yet obvious tends to be more crucial for the success of winning market competition than if the technological innovation were instantly viewed as superior and necessary by all firms.

Theory

A thorough review of the literature on organizational innovation has convinced us that organizational variables, in comparison with the contextual and individual factors, play a particularly critical role in affecting an organization's propensity to adopt innovation. Damanpour's (1991) extensive meta analysis indicates that the type of organization adopting innovations and their scope seem to serve as more effective moderators of the relationship between organizational innovation and its potential determinants than the type of innovation or the stage of adoption.

Among major organizational variables, organizational size has been consistently found to affect innovation adoption in empirical studies (e.g., Kimberly & Evanisko, 1981; Moch & Morse, 1977) although the direction of its effect has been negative in some studies but positive in others (Damanpour, 1989). Teece (1986, 1988) highlights the importance of firm

boundaries—defined by the extent of vertical integration—in determining the economic value of technological innovation. In the meantime, some researchers also link the degree of diversification to organizational innovation by examining the economies of scope (Nayyar & Kazanjian, 1993), the need to gain competitive advantages (Porter, 1980; McCann, 1996), or the difficulty of implementing innovations (Abernathy & Utterback, 1978). As a result, we decided to focus on the effects of backward and forward integration, organizational size, and product diversity in our study of the technological innovation in the personal computer industry.

It is not coincident that all the four major independent variables that we selected are closely related to the broad concept of organizational boundaries. Backward and forward integrations collectively define the boundaries of the operations engaged by an organization; product diversity reflects the horizontal boundaries in terms of the markets targeted; while organizational size measured by the number of employees is an indicator of the breadth of the human boundaries. These measures of organizational boundaries are crucial for studying innovation because, on the one hand, they reflect how strategic resources are allocated within an organization, thereby creating constraints on the ability to try new things, and, on the other hand, they serves as indexes of the level of resource abundance, which makes the costs of innovation more or less affordable for an organization.

Organizational boundaries are determined partly by design and partly by historical evolution. Although most firms inevitably grow bigger as their success continues, managers do have more discretion over other dimensions of organizational boundaries. McCann (1991a), for instance, uses the case of NutraSweet to demonstrate how an innovating company can be designed by "working against boundaries." Studying the net effect of these boundary variables on innovation is even more intriguing as we realize that the same variables may have differing effects on different stages of the innovation process (George, Nunamaker, & Valacich, 1992). Although in this study we do not plan to directly measure the specific effect of these variables on different stages of the innovation process, we do discuss both the positive and negative effects of each variable on the timing of innovation adoption based on the assumption that the same variable may have differing impacts on the initiation and implementation of technological innovation.

Effects of Organizational Boundaries

The source of inputs or the distribution of outputs for the organization may be particularly important in predicting innovation adoption (Porter, 1980, Damanpour, 1991). Whether the firm internally controls the source of supply for its inputs and whether it sells through its own sales force or through distributors can have an important influence on the decision whether or not to adopt the innovation (Rogers, 1983), and how quickly adoption occurs (Mitchell, 1989).

Theorists interested in the boundaries of the organization and innovation have tended to be ideologically split concerning the effects of forward and backward integration on innovation adoption (Dosi, 1982; Pisano, 1990). From an information processing standpoint, internalizing the channels of technological input or product distribution can lower the manufacturing costs and simplify the sequential coordination among different production stages necessary for innovation adoption (Klein, Crawford, & Alchian, 1978). However, utilizing the market rather than internal mechanisms can lower the level of firm specific

assets in the old technology, making it easier for the organization to more quickly adapt to technological innovation (Grossman & Hart, 1986). These factors play different roles in the case of backward integration and forward integration.

Backward Integration

Backward Integration Slows Adoption. At the upstream stage, the ability to control the supply of inputs is one important factor that differentiates organizations and can affect the competitive position of the organization (Harrigan, 1986). In the case of innovation adoption, particularly in technologically intensive industries, internalizing backward stages of the value chain may prove to be disadvantageous since backward integration may require investment in technologies that may be difficult and costly to replace if new innovations come on the market (Malerba, 1985). Integrating backward in the value chain may not be in the long-term interest of the firm if the technology is changing rapidly and there are large fixed investments in the upstream process (Balakrishnan & Wernerfelt, 1986). Because of the investment already made in the older technology, backward integration may lead to a lower likelihood of innovation adoption. This fact might explain why General Motors, which had achieved an exceptionally high degree of backward integration before it switched to the strategy of "global outsourcing," used to have difficulty in competing with Chrysler, a much less backward-integrated automative firm, on launching innovative new models.

Backward Integration Speeds Adoption. A contrasting argument has been put forth by other theorists, who argue that by backward integrating the firm can move supply considerations from outside the firm to inside the firm, making it easier for the organization to coordinate operations between internal divisions than between separate organizations (Monteverde & Teece, 1982). Gupta and Toong (1984) note that firms with internal upstream capabilities can potentially gain a vital competitive advantage in understanding and being able to quickly capitalize on new technologies in their own operations. In addition, the common ownership of crucial parts used in both the upstream and current stages of operations reduces institutional barriers and coordination costs (Teece, 1986). These advantages should, in turn, help make the technological innovation more readily understandable internally and speed up adoption of the innovation. For instance, once the strategic decision to enter the PC market was made, the capability to make computer chips in house has allowed IBM to launch its PC speedily even though earlier versions of IBM PC used Intel microprocessors exclusively. IBM's recent decision to make Power PC chips in house may be driven by the advantage brought by backward integration for technological innovation, too.

The arguments given above present reasons why backward integration may either hinder or facilitate innovation adoption. Teece (1986) points out that empirical research needs to examine in more detail the effects of backward integration to sort through the conflicting theoretical arguments. Because the role of backward integration has been argued to have contradictory effects, we pose the effect of backward integration on innovation adoption as a research question (RQ):

RQ-1: What is the effect of backward integration on the rate of innovation adoption?

Forward Integration

At the downstream stage, the use of an in-house distribution channel is another critical variable influencing the adoption of technological innovations (Damanpour, 1989). However, as in the case of backward integration, theorists have remained split regarding the effects of forward integration on innovation adoption. Some have argued that forward integration slows innovation adoption while others have argued that forward integration speeds adoption.

Forward Integration Speeds Adoption. Those arguing that forward integration leads to an increase in the propensity to adopt assert that the presence of an internal distribution channel can offer a major advantage to the organization since the organization maintains control over the introduction of the new technology to their customers (Anderson & Schmittlein, 1984). Additionally, the organization may be better able to train and educate its sales force about the benefits of the new technology and offer specific rewards and incentives targeted toward sales of products with the new technology. Control of the distribution channel can even ensure shelf space for the new product (Aaker, 1992). Finally, the organization may face internal pressure to adopt the new technology more quickly from an internal sales force which hopes to offer products with the newest technology. A good example that demonstrates the benefits of forward integration for innovation is Shaw Industries. As the most innovative and the largest carpet maker in the world, Shaw Industries has been pursuing forward integration by acquiring carpet retailer chains in recent years. In the personal computer industry, Dell Computer, a firm famous for its direct sales strategy, has been very responsive to the industrial clients' new needs by quickly incorporating the most advanced features into its products.

Forward Integration Slows Adoption. Other theorists argue that problems associated with introducing the technological innovation within the organization might more than offset this advantage. Salespeople may not be familiar with the new technology and may be reluctant to adopt it early, especially if it is relatively new and its level of customer acceptance is uncertain (Abernathy & Clark, 1985). As a result, they may resist efforts by other functional areas to introduce a new technology to an existing product, since the characteristics of the product would become more uncertain (Oster, 1982; Nadler & Tushman, 1987). For instance, Apple Computer used to own Computer Land, which was one of the largest computer retailing chains, but eventually decided to sell it off due to the lack of synergy between computer manufacturing and retailing.

Of course, independent distributors may be equally hesitant to accept new products that have unfamiliar technical features. Nonetheless, independent distributors may be more likely to appreciate the potentially lucrative market promised by an advanced technology (Teece, 1986), and may be more willing to accept the risk of offering the product since the product, if unsold, can be returned to the manufacturer. Costs to the independent distributor are minor and may be more than offset by the potential advantage of offering a more advanced technology.

Given these conflicting perspectives, the effect of forward integration on innovation adoption is equivocal. As was the case with backward integration, we present the effects of forward integration as a research question to be examined empirically:

RQ-2: What is the effect of forward integration on the rate of innovation adoption?

Organizational Size

Size Speeds Adoption. Previous research on the effects of organizational size on innovation adoption has generated little consensus on the size-innovation relationship (Damanpour, 1991; Rogers, 1983). One reason is that size correlates with many structural characteristics, such as formalization or decentralization, that tend to have contradictory effects on innovation adoption (Damanpour, 1989; Tornatzky, et al., 1983). However, many have argued that larger size implies a larger pool of resources and a better ability to compete (Meyer & Goes, 1988) and large organizations are more capable of sustaining failures or absorbing the risk in trying new things. Scale economies will typically be greater in larger organizations, which may in turn enhance the feasibility of adoption (Baldridge & Burnham, 1975; Kimberly & Evanisko, 1981; Moch & Morse, 1977). Quick legitimacy may even come from customers' *ex ante* expectations of the market share that would be gained by large firms, as evidenced in the case of the IBM personal computer (Katz & Shapiro, 1985).

Size Slows Adoption. To a certain extent, however, larger size may also create bureaucratic barriers, making it more difficult to legitimize a new technology within the organization, in turn hindering innovation adoption (Damanpour, 1989; Dougherty & Hardy, 1996). Hage (1980) examined several empirical studies that tested the relationship between organizational size and innovation and found that the relationship between the two variables was generally negative. The coordination between different subunits of the organization required to adopt the innovation may be more easily achieved in small organizations rather than large organizations (Nord & Tucker, 1987). In addition, it may be important for smaller organizations to differentiate themselves in a highly competitive market by quickly offering the latest technology to customers (Tornatzky & Klein, 1982). This need is reflected in the generally higher R&D productivity of smaller firms (Mansfield, 1968; Tornatzky et al., 1983), implying that such small firms would be more likely to be among the first to adopt innovations.

Because the effect of size is somewhat indeterminate, we pose its effect as a research question:

RQ-3: What is the effect of size on the rate of innovation adoption?

Product Diversity

Product Diversity Slows Adoption. Several theorists have argued that an organization with several types of products, each with somewhat different requirements, may find adopting a technology to be particularly difficult (Abernathy & Utterback, 1978). A diverse set of products represents many different constituencies of users with different expectations about the type of products the firm is supplying. Feedback received from a diverse set of customers (concerning whether or not the contemplated new products are desirable) may provide inconsistent or even confusing signals to the organization (von Hippel, 1986). From a different perspective, Hitt, Hoskisson, and Ireland (1990) have examined the effects of acquisitions (which typically increase product diversity) on risk-taking and innovation, finding that managers engaged in acquisitions become more risk-adverse and thus less committed to encouraging innovation. Firms with many products and many customers,

each with different needs, may potentially face heightened external resistance to innovation adoption.

Product Diversity Speeds Adoption. Other theorists have argued that organizations with more diverse products will be likely to adopt an innovation more quickly. Transaction cost economists note that an important motive for diversifying is to exploit firm-specific assets in other markets (Markides, 1992; Montgomery & Wernerfelt, 1988; Teece, 1982). Product diversity can often reflect an organization's desire to pursue a competitive strategy that relies on being early to the market with new products (Miles & Snow, 1978). Porter (1980), for example, points out that firms need to make basic choices between differentiation and efficiency in the strategy they pursue. He goes on to note that greater efficiency is usually obtained when a firm concentrates on a relatively narrow range of products, while firms pursuing a differentiation strategy often attempt to be more innovative, and an innovation-driven strategy is typically associated with a broader product line. From the transaction cost perspective, the tradeoff between efficiency and innovation identified by Porter seems to reside in the choice between economies of scale versus scope. Nayyar and Kazanjian (1993) argue that economies of scope are a major benefit of diversification and can lead to greater levels of innovation.

Given these conflicting arguments regarding the effects of product diversity, we pose the effect of product diversity on innovation adoption as a research question:

RQ-4: What is the effect of product diversity on the rate of innovation adoption?

METHODS

Data

Our specific research setting involves the adoption of the 8-bit microprocessor by personal computer firms. The data for this study spanned the 15-year period from 1972 to 1986 and was coded from a wide variety of archival sources. Since 1972, Datapro Research Corporation has published the Directory of Suppliers, which is the most complete listing of companies in the data-processing business. This listing, updated annually, identifies the establishing date, number of employees, major distribution channels, and the major product groups of firms in the hardware and software businesses. In Datapro's other annual publications, Directory of Small Computers and Who's Who in Microcomputing, detailed information about each firm's computer products, as well as the major types of customers is also provided.

Dependent Variable

The dependent variable is the timing of the adoption of the 8-bit microprocessor by individual personal computer firms, measured by the number of months elapsed since the 8-bit microprocessor was first available before a firm adopted it. The Directory of Small Computers lists the type of microprocessor used by each personal computer manufacturer and the date of its first shipment, which is the operational definition of the adoption date in this study. This source is also supplemented by the data coded from IEEE Computer, which has reported all new products in the data-processing industry every month sine 1966. Together, these two publications provide fairly complete information about the timing of adoption of the 8-bit microprocessor by existing organizations.

Independent variables

Backward Integration. Defined as the capacity to fabricate microprocessors. Operationalized as a dummy variable for each year of the study, coded 1 if the organization has the capacity to produce microprocessors.

Forward Integration. Defined as the extent to which the firm is forward integrated into distribution. Operationalized using two dummy variables: "Direct" which indicates whether the firm has its own in-house distribution channel and "Retailer" which indicates whether retailers or independent distributors are used.

Size. Operationalized as the log of the number of employees.

Product Diversity. Operationalized as the number of different products the firm produces.

Control Variables

Number of Firms Already Adopting. Katz and Shapiro (1985) found that there are many innovations for which an adopter's utility increases with the number of other adopters. Soon after the innovation is introduced, technical and commercial features of the innovation are not well established and are not clearly understood. As more firms adopt the innovation, adoption costs tend to decline, economies of scale appear more attainable, suppliers are more willing to invest in complementary parts, and distributors find it more attractive to carry the new items (Farrell & Saloner, 1985). The fact that a large number of organizations have adopted a new technology can help legitimize its use and facilitate the adoption of the innovation by others (Abrahamson, 1991).

Once legitimacy concerns are overcome and the innovation proves to be successful, the propensity of an individual firm to adopt the innovation increases as the number of adopting organizations increases. Assuming that the innovation proves successful, most organizations will eventually adopt the innovation. We therefore predict a curvilinear effect of diffusion on adoption. Initially, when few organizations have adopted, the number of adopters will have a negligible effect on adoption. However, as the number of adopters increases, we would expect that the propensity to adopt would increase at an increasing rate, leading to a bandwagon effect (Abrahamson, 1991). The number of adopters should affect the adoption rate of existing organizations in an exponential manner: as more adopt, the likelihood of adoption increases even further. We add a quadratic term for the number of firms adopting to control for any curvilinear relationship.

Growth of Total Market Demand. A dynamic relationship between new product demand and product or process innovation has been repeatedly observed by the past researchers (Bayus, 1995). Other things being equal, rapid growth in market demand for personal computers should motivate firms to adopt the 8-bit microprocessor. In the personal computer industry, we suspect most firms would not respond to a single year's market growth but would be more interested in longer-term trends. We therefore calculate the average rate of growth in the personal computer market demand for the previous two years and use this average as the rate of market growth.

The Adoption of a 16-bit Microprocessor. During the period of our study the 16-bit microprocessor was also introduced. Firms may leapfrog the 8-bit device and first introduce

TABLE 1
Basic Statistics and Zero-Order Correlations of Independent Variables

Variable	Mean	S.D.	1	2	3	4	5	6	7	8	9
1. Backward Integrated	.07	.26	-	n.s.	n.s.	n.s.	n.s.	**	n.s.	n.s.	n.s.
2. In-house Distribution	.50	.50	.06	-	***	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
3. Retailer	.46	.50	.08	-.43	-	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
4. Size^	4.59	1.32	.14	-.15	.00	-	n.s.	n.s.	n.s.	n.s.	**
5. Product Diversity	1.85	1.20	.09	.10	-.21	.21	-	n.s.	n.s.	n.s.	n.s.
6. # Adopters	105	23	-.32	.08	.06	-.13	-.24	-	***	n.s.	n.s.
7. Demand Growth (%)	136	233	.11	-.10	.06	.23	-.14	-.44	-	n.s.	n.s.
8. 16-bit Adoption	.03	.17	-.05	.00	-.16	.14	.18	.17	-.08	-	n.s.
9. Ownership	.91	.29	-.15	.18	-.06	-.37	-.15	.09	.12	.06	-

Notes: ^Firm size is operationalized as the logarithm of the total number of employees;
n.s. Not significant;
*$p < .05$;
**$p < .01$;
***$p < .001$.

models with the 16-bit device. For firms which have adopted the 16-bit microprocessor, subsequent adoption of the older, 8-bit technology would be less likely.

Type of Ownership. Although most personal computer firms are independent, some are subsidiaries or divisions of large companies that are also engaged in noncomputer or even nonelectronics businesses. McCann (1991b) found that young, independent, technology-based ventures tend to seek product breakthroughs via internal innovation by means of research and development. However, inasmuch as external adoption is concerned, it is likely that independent firms are not subject to the bureaucratic constraints of a corporate authority in making their decisions, and therefore should be able to adopt the 8-bit microprocessor more quickly. We used a dummy variable that was coded as "1" if a firm was independent.

A correlation matrix of all independent variables is presented in Table 1. Most correlations are not statistically significant. Among the significant ones, the signs of coefficients confirm the conventional wisdom in this industry. For instance, the total number of adopters is negatively correlated with the growth rate, implying a level-off of market growth when the market is approaching saturation. Likewise, those firms with in-house distribution are less likely to use retailers to sell their products.

Analysis

We used the accelerated event-history model to test the effects of covariates. This method was also used by Mitchell (1989) to examine the timing of entry by industry incumbents into emerging industrial subfields. In the past three decades, loglinear analyses have been widely used by researchers of innovations owing to the curvilinear patterns of diffusion for most innovations (Calantone, di Benedetto, & Meloche, 1988). The dependent variable in

TABLE 2
Adoption of 8-Bit Microprocessors by Existing Firms[a]
Accelerated Event Time Model

	Beta			
Variable	*Non-standardized*	*Standardized*	*Chi-square*	*Signficance*
Backward Integrated	-0.77	-.037	8.77	**
In-house distribution	-.122	-.060	6.02	*
Retailer	-.054	-.022	2.50	
Size	.013	.036	2.26	
Product diversity	-.012	-.031	3.95	*
# Adopters	.041	1.48	366	***
# Adopters^2	-.00013	-.77	100	***
Demand Growth	-.00013	-.028	4.88	*
16-bit Adoption	.099	.027	4.86	*
Ownership	.086	.041	5.18	*
Intercept	1.91	4.10	280	***
Scale	.041			
Weibull Log Likelihood	32.94			

Notes: [a]$n = 67$. Negative coefficients represent shortened time to adopt, while positive coefficients represent longer time to adopt;
*$p < .05$;
**$p < .01$;
***$p < .001$.

our data analysis is the logarithm of the waiting time before a personal computer manufacturer adopted the 8-bit microprocessor. This model may be expressed as the following equation:

$$\text{Log } W_i = b_0 + BX + e_i$$

where $\mathbf{W_i}$ is the length of waiting before firm $\boldsymbol{i}$ adopted the 8-bit microprocessor, $\mathbf{b_0}$ is the intercept of the regression model, and $\boldsymbol{B}$ is the vector of coefficients for the vector of covariates $\boldsymbol{X}$. This model permits a straightforward interpretation of the timing of innovation adoption by individual firms. Intuitively, the waiting time $\mathbf{W_i}$ is an *inverse* measure of the adoption rate.

Unlike conventional regression models, the underlying distribution of the accelerated event-history model is assumed to be drastically skewed rather than semi-symmetrical due to the existence of many right-censored cases—some personal computer firms may have never adopted 8-bit microprocessors as of the cut-off time. As a result, *chi-squares* rather than t values are used for testing the significance of the beta coefficients, and a synthetic *Weibull* log likelihood value in lieu of the F value is used as an indicator of the overall significance of the regression model.

RESULTS

Results are presented in Table 2. For the ease of comparing the net effects of different variables, we have listed both the standardized and non-standardized values in this table.

In general, the results of the analysis confirm that vertical organizational boundaries of personal computer manufacturers did have significant effects on the timing of innovation adoption. As shown in Table 2, the capacity to fabricate microprocessors reduces the time to adopt, indicating that backward integration speeds up innovation adoption. To gauge the effect of forward integration we used two separate measures. The use of an in-house distribution channel, which represented complete forward integration into the sales and distribution function, had a significant effect on reducing the time it took for the firm to adopt the innovation. The use of independent retailers, which represented a lack of forward integration, showed no significant effect.

Our third research question focused on the effect of size on the speed of adoption. As indicated in Table 2, size had no significant effect on the timing of adoption. Our final research question concerned the effect of product diversity on the timing of adoption. Results in Table 2 indicate that firms with greater product diversity tended to adopt the 8-bit microprocessor more quickly, offering empirical evidence that organizations with broader product lines were more likely to adopt innovations.

The effects of the control variables were generally consistent with our predictions. The growth rate of market demand seemed to encourage personal computer firms to adopt the 8-bit microprocessor, thereby reducing the waiting time. Prior adoption of the 16-bit technology was found to slow down the adoption of 8-bit microprocessor, suggesting a certain degree of competition between these two different generations of technology. Ownership form (whether independent or a subsidiary of a larger organization) indicated that independent firms were slower than subsidiaries in adopting the 8-bit technology. We discuss this counterintuitive finding in the Discussion section. Finally, both the main effect of the number of adopters and the quadratic effect were significant, with the quadratic parameter showing an acceleration in adoption as more firms adopt.

DISCUSSION

The past two decades of research on innovation have produced several competing theories that attempt to clarify the role that specific variables play in either helping or hindering innovation adoption. Our study began by identifying a core set of organizational antecedents to innovation adoption over which there has been disagreement: forward and backward integration, organizational size, and product diversity. Theorists have differed on the predicted effects of these organizational boundary characteristics, arguing that they encourage or discourage adoption.

Our empirical results indicated that backward integration, forward integration and product diversity all speeded the adoption process, while organizational size had no discernible effect. Turning first to the findings for vertical integration, the extent to which the organization had internalized both upstream activities (by backward integrating into microprocessor fabrication) and downstream activities (by forward integrating into distribution channels) had a positive effect on how quickly the innovation was adopted. Our findings support the views of Teece and others (Klein, Crawford, & Alchian, 1978; Monteverde and Teece, 1982; Teece, 1986) that internalizing the channels of technological input and product distribution can simplify coordination across sequential stages of organizational activities, in turn permitting adoption to take place more quickly. By backward and forward integrating, personal computer firms are better able to coordinate operations between internal divisions than between separate organizations.

But backward and forward integrations are not simply two sides of a symmetric process. Backward integration provides a better understanding of the technology as it is being developed and an opportunity for organizations to quickly capitalize on new technologies in their own operations. Forward integration makes the functions of sales and distribution part of the organization, creating internal pressure on the organization to adopt the new technology in hopes of being able to offer leading-edge products. Additionally, organizations with internal distribution channels may feel they can better control the introduction of the resulting product after the innovation had been adopted, thus also encouraging adoption. Through this process of internalization, managers of more fully integrated organizations may feel that they have a better understanding of both the development of the technology and the demands of customers.

Although we found no significant effect of size on innovation adoption, the diversity of products produced by the organization was found to speed up adoption. As argued earlier, firms usually make a choice between innovation and efficiency in selecting a basis for their competitive strategies (Porter, 1980). Organizations that concentrate on a narrower range of products appear to opt for a strategy that stresses efficiency considerations. Conversely, as Montgomery and Wernerfelt (1988) note, firms pursuing a differentiation strategy attempt to move into many new markets as quickly as possible. This also seems similar to the strategic behavior underlying the "prospector" strategy as identified by Miles and Snow (1978). Miles and Snow note that prospector firms rely on being both early to the market and in several markets simultaneously, describing prospector firms as being both innovative and competing in many product areas.

Several control variables were also found to be critical predictors of innovation adoption, including the rate of market growth, the number of adopters and its square term, and the adoption of the next generation of technology. An unexpected result emerged from one of our control variables which merits additional discussion. Our finding that independent firms were slower than subsidiaries of large firms to adopt the 8-bit microprocessor is contrary to conclusions reached by some prior research (Tronatzky et al., 1983). One possible explanation for this result is that independent firms may be more uneasy about the risk of early adoption since there is no parent company to shield their operations or help absorb potential losses resulting from adoption that occurs too early. Indeed, a study of 1,600 innovations in UK found that firms that are technically autonomous seem to be more successful with process innovations that allow them to achieve cost savings and economies of scale (Calantone, di Benedetto, & Meloche, 1988). This might be the reason why they are less excited about new product innovations that tend to require large initial investments but promise little certainty on market demands. Thus, they may be more likely to wait until they have either collected adequate data about the technology or are sure the market demand is sustainable before committing resources to the new technology.

Theoretical and Practical Implications

Our findings suggest that the transaction costs argument in Williamson's (1987, 1996) market failure framework may not only apply to the efficiency of organizational operations but also have some relevance to an organization's innovativeness. Traditionally, researchers tend to hypothesize that vertical integration would reduce the transaction costs and thereby increase the production and distribution efficiency (Teece, 1988). Based on this vein of thinking, innovation could even be hindered by vertical integration due to the increased sunk costs or lock-in of the production/distribution procedure. Our findings, however,

suggest that innovation and efficiency need not be antitheses to each other, as both forward and backward integrations are found to speed innovation adoption at least in the case of the personal computer industry.

We submit that Williamson's transaction costs theory could be enriched by taking account of the core technology used in each industry. In an industry where constant innovation has become essential for the survival of each organization, vertical integration may even bring about additional synergy between old and new products rather than hinder the adoption of innovations. This fact is also evidenced by our finding that product diversity has sped the innovation adoption, implying that the diversion of resources may not be a severe problem for such a high-technology industry. Nevertheless, for a conventional industry such as automotive manufacturing, we suspect the opposite would be true.

The implications of our empirical findings for practitioners are even more obvious. As we found out, the size of an organization does not seem to have any significant effect on the timing of innovation adoption. Independent firms, which are usually believed to be more nimble in moving into a new market, are not necessarily early adopters of a technological innovation in this industry. In other words, there is no evidence indicating that strategists in such industries ought to be particularly wary of potential entries of small, independent firms. Large firms or their subsidiaries could step in swiftly and join the competition as soon as they see sufficient market demand for a new generation of products, as reflected by the effect of the demand growth rate in our data analysis.

Limitations and Future Directions. This study presents an attempt to examine and test some contradictory arguments from theories of innovation adoption. The dependent variable here is neither whether or not an organization has adopted an innovation at a certain time nor how many innovations have been adopted by an organization. In the former case the dynamic nature of the innovation adoption behavior would be left unexplained; in the latter, the idiosyncratic reasons for adopting different innovations might be obscured. Instead, the time until adoption was used as the dependent variable, which is really a inverse measure of "how soon" an organization adopts a technological innovation. By examining the dynamics of the process we can better understand and describe the variables which influence patterns of innovation adoption over time.

A clear limitation of this study is its single-industry setting. The adoption of the specific innovation examined here, the 8-bit microprocessor, has some characteristics that make it unique. Organizational boundaries may influence not only product innovation but also process innovation. For instance, high product diversity could facilitate process improvement innovations as learnings are applied across product lines, thus lowering production and per unit costs, thereby making products more competitive in a market (McCann, 1996). The other critical issue worthy of further study might be the emergence of "virtual" organizations, which rely on advanced information technologies to create forward, backward, or sideway linkages, thereby altering the very definition of "vertical integration."

One potentially critical variable that was not examined in this study is the background of the firm's founders. Because entrepreneurship has had a significant influence in the personal computer industry, the founders' technical and educational backgrounds may have a major influence on the propensity to innovate. It is likely that the backgrounds of founders not only influence the organization's functional form and strategy but also predispose the organizations to adopt certain technological innovations.

In addition, the attractiveness of a technological innovation for an organization may depend on the specific niche that the organization has selected. It is likely that some firms

decided not to quickly adopt a new-generation microprocessor simply because they had chosen to compete as market followers. Alternatively, of course, there may be first-mover benefits to early adoption of what later becomes an industry standard (Farrel & Saloner, 1985). Given the central role played by technological innovation in high-technology firms, future research should examine the relationship between technological innovation and the competitive strategy employed by a firm.

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