UTILIZING USE: THE EFFECT OF CUSTOMER LEARNING AND EVALUATION ON TECHNOLOGY AND INDUSTRY EVOLUTION

Steve Kahl
MIT Sloan School of Management
50 Memorial Drive, E52-511
Cambridge, MA 02142-1347 USA
skahl@mit.edu

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Abstract:

This paper argues that the way customers use a new technology may differ from what producers intended and thereby influences the evolution of that technology and its industry. Customers may interpret the technology differently or may adapt it to their local conditions and requirements, generating variety in how users actually deploy products. Moreover, as customers use new products, they may learn new ways of using the technology, which affects their future purchasing and deployment decisions. This paper argues that incorporating these aspects of demand evolution provides a better explanation of the shifts in competition within an industry than prevailing evolutionary models do. This paper asserts that an industry's shift to cost-based competition depends upon customers converging on a more standardized use of the technology and that the competitive significance of a discontinuous technological change is not determined until its use characteristics are established. A brief discussion of the experience of U.S. manufacturers with manufacturing software from 1954 to 1996 demonstrates the workings of the model. Addressing demand evolution also adds theoretical insight into the study of the co-evolution of an industry's competitive dynamics with firm-level capabilities. By showing how one environmental participant, the customer, evolves in ways that are interrelated to firms innovating, this research argues that the source of competitive advantage lies in the interplay between firms adapting and the environment selecting. Creative and strategic management of how customers understand and use a technology should be an important competitive factor in technology industries.

INTRODUCTION

Scholars have long been drawn to the relationship between technological innovation and industry evolution. A prevailing approach describes this relationship as an evolutionary model of change: technical variety within an industry gives way to a standard, and the industry's competitive dynamics shift from product to process innovation, from product differentiation to cost-based competition (Utterback and Abernathy 1975; Tushman and Anderson 1986; Klepper 1996). Such a focus on efficiency does not lend itself to developing capabilities and acquiring knowledge, so the standard becomes vulnerable to exogenous, discontinuous technical changes (Nelson and Winter 1982; Tushman and Anderson 1986; Henderson and Clark 1990). When these changes occur, new firms replace many of the incumbents.

Empirical studies have demonstrated the evolutionary model at work in a variety of industries (Suarez and Utterback 1995; Klepper 1997). However, there are significant anomalies. In some industries, firms switch back from cost competition to product innovation, leading to a "de-maturity" of the market (Abernathy, Clark and Kantrow 1983). In the camera industry, for example, existing firms introduced significant innovations during the mature phase of the industry that bifurcated the market (Windrum 2005). In other cases, incumbent firms survived technological discontinuities, as NCR did in cash registers (Rosenbloom 2000), Intel did in microprocessors (Burgelman 1994), and Mergenthaler did in typesetting (Tripsas 1997). These anomalies indicate that the evolutionary models have not fully specified the conditions under which competition shifts in an industry and the effects of an exogenous discontinuous change. Prior work has noted that evolutionary models only explain these shifts through supply-side factors

(Afuah 2000), prompting interest in demand-side factors as alternative explanations (Adner and Levinthal 2001; Agarwal and Bayus 2002; Tripsas 2006). This work on the demand-side encourages closer examination of the assumptions evolutionary models make about demand.

Although evolutionary models focus on supply-side factors to explain the shifts in competition, they recognize a role for demand. Customer purchases make innovations and industries viable and customer evaluations of technology affect a firm's incentive to innovate and the industry's profitability (Schumpeter 1934; Nelson and Winter 1982). Evolutionary models make the common economic assumption that individual customer preferences are relatively static[1] (Tripsas 2006). This restricts demand evolution in the models to the entry or exit of new customer segments. More importantly, these models assume that changes in demand and changes in technology are highly correlated. Demand is fragmented during periods of technology variety, such as industry formation or technological discontinuities, and less fragmented during periods of technical standardization. These assumptions are most evident in Klepper's model (1996). Product innovation during the early stages of an industry attracts new customer segments. But, after one period, the model assumes that the new market segment becomes part of the mass market. As firms grow, they shift focus to process innovation which means less product innovation and less entry of new customer segments leading to less demand variation.

[1] There are subtle but important differences in the use of "static". In the extreme, it means that customers do not change their preferences. In a weaker sense, preferences do change, but such changes are exogenous and/or random from the perspective of the evolutionary model. For the argument that I am building, the weaker assumption need only be true.

Lastly, evolutionary models treat discontinuous technical changes as exogenous events that introduce new variety (Tushman and Anderson 1986). In cases where the new technology attracts a new customer segment, these models assume that these customers use the new technology differently than current customers use the old technology. The change comes from the introduction of a new customer segment and a new technology (Christensen and Rosenbloom 1995). If new customers used new technologies the same way old customers did, then the new technologies cannot be discontinuous, by definition.

Research on how customers actually deploy and use a technology challenges these core assumptions. Tripsas (2006) observed that some newspapers extended their use of typesetters beyond the traditional printing of text to include images, showing that customers can *endogenously* change their evaluations of a technology (and thus their preferences) through experiential learning. Yates (2005) observed that insurance customers used the supposedly radical computer similarly to how they had used older tabulating equipment, suggesting that customers need not use radical technologies in new ways. Only after a significant time period and continued use did the insurance companies migrate to more radical uses of the computer. This slow migration to more radical uses of a new technology favored incumbents like IBM who made incremental adjustments to the computer (Kahl and Yates 2005). Such examples show that demand can change endogenously without a supply-side stimulus and that customers can deploy radically new technologies in incremental ways – the evolutionary model's assumptions about how demand evolves as an industry and technology mature are too restrictive.

The technology implementation literature expands the view of the customer as both purchaser and user of the technology. From this perspective, demand evolves not just through compositional changes but also through how customers evaluate and use a technology. Specifying these aspects of demand evolution could clarify the conditions under which industry competition shifts and the effects of disruptive technological changes in a way that can also address the anomalies in the evolutionary models. If customers can change how they value a technology through learning new uses, then firms have an incentive to re-engage in product innovation after technical standardization. And, as the insurance example shows, conservative deployment of radical new technologies can help incumbent firms survive disruptive technological changes.

However, there has been little systematic analysis of demand evolution and its influence on industry competition. The implementation literature focuses on particular implementation instances and does not consider competitive implications (see for example (Oudshoorn and Pinch 2003)). Conversely, the management of technology literature has proposed several demand evolution models that have competitive implications. Adner and Levinthal (2001) describe demand evolution in terms of customers switching from valuing different product features to price as the products satisfy their functional thresholds (or preferences). Like the evolutionary models, this approach assumes that customer thresholds/preferences remain relatively static, but the newspaper example provides evidence that customers do change preferences in meaningful ways that can lead to significant technological changes. Relatedly, Clark (1985) describes a process in which customer understanding and technological development co-evolve as customers and the technology move from an uncertain, generalized understanding of the technology to a more determinate and specified interpretation. Although the developing approach is sympathetic to Clark's focus on customer understanding, there is no *a priori* reason to assume that customer understanding evolves in the manner he described. For instance, even though insurance companies were uncertain about what the computer was, they initially interpreted it in very concrete and specific ways based upon how they used the previous tabulating equipment (Kahl and Yates 2005). Therefore, it is not clear conceptually which mechanisms create variation in how customers understand and use a technology over its lifecycle and how this process influences the competitive dynamics of an industry.

In this paper, I analyze demand evolution's links to technology and industry evolution more systematically. I use frameworks from the marketing literature and empirical evidence from technology implementation research to build a conceptual model of demand evolution: to purchase a technology requires *understanding* and *justification* which introduce variation into customer use. Experiential learning reinforces this initial variation within a customer population. As a result, I argue that demand convergence is not automatic: additional mechanisms are necessary for standardization in use to occur, and only when this happens will the competitive dynamics shift from product to process innovation. In addition, the competitive implications of a technological change are not established until its use is determined. Incremental uses of new technologies can help incumbent firms survive radical technological changes. To demonstrate the model and its implications for industry evolution, the paper considers the historical case of how U.S. manufacturers used manufacturing software from 1954-1996. This paper concludes with a discussion of the theoretical and managerial implications. This analysis implies that the development of firm level-capabilities co-evolves with the selection environment. By showing how one environmental participant, the customer, evolves in ways that are interrelated to firms innovating, this research argues that the source of competitive advantage lies in the interplay between firms adapting and the environment selecting. Creative and strategic management of how customers understand and use a technology should be an important competitive factor in technology industries.

CONCEPTUAL MODEL OF DEMAND EVOLUTION

Figure 1 summarizes a model of customers' activities in purchasing and using a technology, showing how aspects of purchasing and deployment generate and retain variation in customer use. The remainder of this section explains this model in greater detail, beginning with purchasing.

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The marketing and economic literatures emphasize two different aspects of purchasing: *understanding* the technology to compare alternatives and *justifying* the purchase, typically expressed as "willingness to pay." Understanding entails categorizing the technology in relation to pre-existing product categories and then comparing alternatives (Urban, Hulland and Weinberg 1993; Zuckerman 1999). The different product categorizations that customers make create variety in how customers interpret the technology (the first branching in Figure 1). Although firms influence which comparisons are made through advertising and design features (Hargadon and Douglas 2001), customers may categorize technologies differently than intended by the firm and from each other. For example, telephone makers initially positioned their product as a replacement for the telegraph, used primarily for business purposes. Urban customers made this comparison, but farmers, who generally did not use telegraphs, interpreted the technology as a means of social interaction (Fischer 1992; Kline 2000).

Justification entails calculating the potential benefit of using the good. Customers have some functions in mind and calculate benefits based on those, but technology-intensive products are typically designed to perform many functions, only some of which a given customer might evaluate. The different functions for which customers calculate benefits also generate variation in customer use (the second branching in figure 1). For example, early adopters of total quality management (TQM) focused on local problems and requirements leading to many different customized adoptions and uses of the product (Westphal, Gulati and Shortell 1997).

After purchase, customers implement the technology to perform a set of functions.[2] Local conditions—pre-existing technology, organizational routines, political structures—influence the customer's actual use (Orlikowski 1993). Barley's (1986) famous CT scanner study, for example, shows two customers deploying the technology to perform the same function in two different ways. To get the technology to function, customers adapt it to local conditions and requirements (Gilfillan 1935; Orlikowski 2000), creating another source of variation (the third branching in Figure 1).

In fact, the technology management literature posits the act of using the technology as a form of experiential learning (Rosenberg 1983; Von Hippel and Tyre 1995). Rosenberg (1983, pp. 123-4) identifies two types of knowledge from learning by using: embodied knowledge in which customers learn more about the relationship

[2] Of course, the customer need not actually use the technology (Lanzolla and Suarez 2006). However, this model assumes that some customers do actually use the technology; otherwise, it is not viable.

between technical characteristics and performance, and disembodied knowledge in which customers learn new uses of the technology that require very little technical changes. Learning by using provides feedback to influence future technical design changes as well as changes in customer service. Thus, traditionally, the focus on learning by using has been its effect on technical development and the producing firms. From the customer perspective, discovering new uses may, in turn, influence the evaluation of subsequent product purchases and deployments, as newspapers did with typesetting and insurance firms did with computers. This variation is shown by the squiggly lines in Figure 1.

Experiential learning is a source of variation, but it is also a mechanism for feedback: different uses (produced by earlier sources of variation) yield different experiential learning, which creates different new uses. To return to the phone example, business customers used the phone to take messages and conduct business transactions while farmers used multiple-party lines to promote social cohesion (Fischer 1992). Experiential learning implies an inherent non-convergence in use. This implication is important methodologically – it is difficult to *a priori* define a customer segment. It is not immediately apparent which use characteristic dominates a given customer segment and which use characteristic differentiates between customer segments. However, standardization in use often occurs. In the TQM case, after an initial period of customized solutions, the market conformed to a more standard use of the product (Westphal, Gulati et al. 1997). Since there is an inherent tendency for non-convergence in use, though, standardization is not automatic.

There are several ways standardization may occur. One is structural: the sources of variation may not be that different (the "space" between the branches in Figure 1 may be small). If customers categorize the product and envision its uses in ways that "overlap" or are "symmetrical" (Adner's (2002) terms to describe the structure of a demand market) , they will interpret and deploy the technology in similar ways. For instance, the interpretation of the phone for social purposes may overlap enough with the interpretation of the phone for business purposes to establish a standardized use. Another is social: even if there are multiple product comparisons or uses, customers may come to a collective understanding that focuses on one. Insurance companies, for example, initially categorized the computer in several ways, comparing it to the human brain, the calculator, and tabulating machines, but actors in the industry then focused on tabulating machine comparisons (Kahl and Yates 2005). Social constructivists describe the "closure of the interpretive flexibility" of a product (Pinch and Bijker 1987) as an inherently social process in which different participants negotiate a collective understanding. There may be other mechanisms for standardization. That others exist beyond structural and social ones is not important here. What is important is that one must exist; standardization in use is not automatic.

THE MODEL'S IMPLICATIONS FOR INDUSTRY EVOLUTION

Evolutionary models argue that a shift in an industry's competitive conditions occurs when the technical standard emerges (Nelson 1995b; Agarwal, Sarkar and Echambadi 2002).[3] Prior to the emergence of a technical standard, the sources of competitive advantage are product differentiation and innovation, and post this point, they switch to efficiency, scale-based resources and knowledge, and process innovation.

[3] Different models provide different explanations as to how this selection occurs; for example, selection of a dominant design (Utterback and Abernathy 1975) or larger firms switching to process innovation (Klepper 1996). Exactly how the technical standard emerges is not significant here. What is important is that technical standardization is the event that triggers the shift in competitive factors within an industry.

Empirically, this shift in competition is marked by a change in the entry/exit patterns of industry participants: industry entry is higher than exit prior to technological standardization, but after, entry is lower and the total number of participants declines. These models explain shifts in the dynamics of competition without explicit consideration of the customer perspective, assuming that the market becomes less fragmented when the technology standard emerges (Utterback 1994; Klepper 1996).

However, the proposed demand model implies that technical standardization can occur without standardization in customer use. Many general-purpose technologies and services have this characteristic. For example, consulting firms often "standardize" product offerings like technology-development methodologies, but customers still customize the offerings. Under these circumstances, demand requirements remain varied and changing which in turn prevent a shift in competitive dynamics from product to process innovation. These demand conditions require firms to continue investment in product differentiation. Only if customers did start deploying the technology to perform similar functions in similar ways—standardize their use—would the source of competitive advantage shift to efficiency and process innovation.

Proposition 1– *An industry's competitive dynamics shifts from product differentiation to cost-based competition only when both the technology and customer use standardize.*

Another feature of the evolutionary model is that the shift to cost-based competition is irrevocable (Agarwal, Sarkar et al. 2002). The technical standard is retained because firms focus on process innovation and on knowledge and resources around the technical standard. Product innovation does continue, but firms only make incremental improvements to the standard (Utterback and Abernathy 1975). To make this claim, these models assume that the standardization in use is also irreversible, but this is only the case under certain conditions. The proposed model shows a propensity toward variation in customer use through local differences in deployment and experiential learning, even after initial use standardization. Only in cases where this additional learning reinforces existing standardized uses will the shift to process innovation remain irreversible. But, in many cases, customer learning does not reinforce the standard. For example, Zbaracki (1998) observed the de-stabilization of TQM when customers learned that the standardized offering's reality did not match its proponents' rhetoric. In these cases where standardization breaks down as customers learn new uses, the industry's competitive dynamics shift back to product differentiation and innovation to meet the new customer needs. Therefore, unlike the evolutionary model, this demand model is not restricted to two stages of industry evolution, but instead allows for multiple periods of standardization and de-standardization (McGahan 2004).

Moreover, evolutionary models treat periodic discontinuous technological changes as exogenous to their models (Tushman and Anderson 1986). The competitive significance of these technological changes comes from the introduction of new skills, knowledge, or customers with which existing firms are not familiar (Tushman and Anderson 1986; Henderson and Clark 1990; Christensen and Rosenbloom 1995). In contrast, the proposed demand evolution model recognizes that there is some persistent variety in how customers deploy a technology. Thus, a technological discontinuity represents *another* variation (albeit one with a new technology), not the *only* new variant, as implied in evolutionary models. The new use of a new technology may overlap with some current uses and be significantly different from others (using Adner's (2002) concept of the structure of demand). As Adner predicts, to the extent that the new use is similar to an existing targeted customer base, the discontinuous technology should not be as disruptive to existing firms.

In addition, how customers will use the new technology is not determined by the technology itself. Customers may adopt conservative uses that replicate older technologies, as insurance companies did with computers. In these circumstances, to the extent that incumbent firms can adopt the new technology, we would expect them to have a greater chance of survival because they best understand existing use patterns. In the insurance case, an incumbent, IBM, not only successfully transitioned to the computer but also captured significant market share (Kahl and Yates 2005). Conversely, if the new technology generates radical new uses, then we would expect incumbents to have greater difficulty given both the technology and usage change.

Proposition 2– *Ceretis paribus, incumbent firm survival during periods of discontinuous technological change is not impaired unless customer use of the new technology changes from current uses of the existing technology.*

Finally, at a fundamental level, evolutionary models generally suppose that a new technology's entering the market produces uncertainty that decreases over time as the technology standard emerges (Utterback and Abernathy 1975; Nelson and Winter 1982; Clark 1985). Uncertainty increases variation in understanding and deployment because customers are likely to make different categorizations and consider different potential uses. Yet, a new technology need not enter the market with high levels of uncertainty. Consider the introduction of pharmaceutical drugs. Due to regulatory approval and reimbursement constraints, new drugs enter the market with specific uses. Over time, the uses can multiply as the customers learn new applications. For example, Botox was originally approved to be used for treating eye disorders, but during clinical trials it was found to have uses in dermatology. Similarly, baking soda originally was used for baking and cleaning, but today it has expanded to deodorizing and toothpaste. In these cases, variation *increased* over time. Market uncertainty about what the product is and how it is used thus need not be a pre-condition for the introduction and evolution of a technology.

THEORETICAL SCOPE

This model has some assumptions of its own. It assumes, for the sake of explication, that the only sources of variation and standardization are those specified. There are likely others. Customers may purchase based on what other customers purchase, rather than justifying their purchases through product comparisons. For example, later adopters of TQM simply followed a legitimized understanding and use rather than assessing their local needs (Westphal, Gulati et al. 1997). Even in this case, though, the act of deployment and use will produce different experiences, and the feedback loop of experiential learning will still operate. Thus, the scope for this model is not whether customers engage in the specific activities outlined above, but the conditions that determine whether variation in use and experiential learning are possible. One important characteristic associated with learning by using is uncertainty about the technology performance. If customers are certain about the operating characteristics of the technology before deployment, then variation and experiential learning may be irrelevant. Such uncertainty seems to be greatest when there is a high level of what Rosenberg calls “systematic complexity” (1983, pp. 135-6). Sources of “systematic complexity” include technical and design factors, such as complexity, cost of design and breadth of functionality, as well as deployment factors, such as integration with other technologies and organizational process change. Thus, I expect this model to apply to technologies and markets in which there are high levels of "systematic complexity" that creates uncertainty in operational performance in the technology.

APPLICATION – THE MANUFACTURING SOFTWARE MARKET 1954-1996

To demonstrate aspects of the conceptual model, I provide a brief historical discussion of how U.S. manufacturers understood and used manufacturing software from its inception in the early 1950s through the transition to client/server technology in the mid 1990s.[4] Manufacturing software automates the processes associated with planning and controlling product and inventory within the manufacturing process, for example, determining how much inventory is needed to meet projected demand and making changes to product plans as manufacturing conditions change. Today, this software is integrated into a broader suite of functions such as accounting and human resource management in software packages known as enterprise resource planning (ERP).

This software technology fits the scope conditions as it has high levels of "system complexity." Manufacturing software often requires some organizational change and must be integrated with other technologies such as hardware, databases, and communications software to function. Thus, its performance characteristics are not well known prior to implementation. During the time period of this study, manufacturers changed how they used this software several times based on shifting product comparisons, experiential learning, and technological changes. Table 1 provides a summary of these changes in terms of the characteristics of the conceptual model. The shifts to the "standard system" and later to "ERP" represent manufacturers converging to new standardized uses of the software based on these different understandings and

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[4] The study of usage patterns ends in 1996 when the software market began another significant transition to Internet architectures. Although this sacrifices industry data, from a usage perspective there is still uncertainty about how customers use Internet software.

justifications. In addition, different customer segments – large and small manufacturers – emerged. Although the customer segments used the software to perform similar functions, they deployed the software in different ways. Large manufacturers deployed the software within specific departments or at local plants which reinforced decentralized operations, but small manufacturers centralized operations of the software. The variations in the case, in turn, exhibit important aspects of the conceptual model: how local conditions affect the deployment of the technology and how different comparisons and experiences lead to different uses.

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In addition, the variations in customer use and technological change allow for a test of the propositions generated from the conceptual model. Technical standards initially emerged around host-based architectures. After a radical technological change to client/server technology in the late 1980s, the technical standard shifted to distributed architectures. The timings of the two technical standardizations correspond with the standardizations of use to the “standard system” and to “ERP” described in Table 1, enabling a test of the first proposition. Furthermore, one customer segment, large manufacturers, significantly changed its usage of software after the technological change to client/server; whereas, the other segment, small manufacturers, did not, enabling a test of the second proposition.

Method and Data Sources

Historical case studies provide some advantages over cross sectional or even quantitatively focused longitudinal research. Historical analysis is particularly relevant since I am primarily interested in explaining the process of how customer understanding and use changed over time. Unlike typical industry histories which primarily focus on technological and industry development, this analysis incorporates data from both the producer and the customer perspectives. The data that describes how manufacturers used the software is not easily captured by quantitative measures such as sales data. Rather, it is presented in the deployment diagrams and detailed descriptions of how the systems worked found in contemporary presentations at trade and professional association meetings, the trade press, and industry analysis conducted by third parties. Archival records of these presentations, articles, and analyses were the primary source of data on how manufacturers used the software. The discussion of the technical histories draws upon a well established secondary literature (Fisher, McKie and Mancke 1983; Bashe, Johnson, Palmer and Pugh 1986; Campbell-Kelly and Aspray 1996; Campbell-Kelly 2003), supplemented with contemporary industry analyst reports that focus on software specific technology. Software firm histories come from publicly available records such as SEC documents and several firm biographies. For a more complete discussion of the historical record and discussion of data sources, please see (Kahl 2006). Where possible, I supplement historical accounts with data analysis from contemporary sources.

I use the conceptual model described in Figure 1 to structure the historical narrative. This framing of the historical discussion focuses on the salient features of the model: how different product categorizations and local conditions influenced the variations in use, how manufacturers learned and changed their uses over time, and how the evolution of their demand influenced the competitive dynamics of the software industry.

Initial Sources of Variation in Manufacturing's Use of Software

When business computers were introduced in the mid 1950s, pre-packaged applications did not exist. Instead, manufacturers bought computers and developed their own applications. Manufacturers were uncertain about what the new computer was and which applications should be developed (Fisher, McKie et al. 1983). Consequently, manufacturers interpreted the computer by making several product category comparisons – to tabulating machines/other manufacturing equipment as popularized by the consultant John Diebold's vision of a fully automated factory (Diebold 1952) and to the "human brain." These different comparisons focused on different uses: the machine comparison favored deploying the computer to process data to give managers more time to make decisions on their own; whereas, the human comparison favored using the computer to improve human decision making itself. Even though multiple comparisons were made, initially the comparison with tabulating machines was favored for several practical reasons associated with deploying the technology.

General Electric's purchase and implementation of computer applications in 1954 typified this emphasis on data processing (Osborn 1954). Although GE recognized that computers had "Great Brain" like qualities, they initially shied away from computational uses in fear that managers might view computers as replacing them, limiting its effectiveness. They were also concerned about managing the risk of implementing the computer. Rather than "making a drastic jump from present operations to a completely new system controlled by a mechanical brain"(Osborn 1954, p. 101), GE chose to "convert" existing functions to the new machine. To justify the purchase, they calculated the potential cost savings in comparison to tabulating machines. Specifically GE measured benefit in terms of eliminating clerical workers and did not consider operational improvements such as inventory reduction. From a deployment perspective, GE used the computers like tabulating machines and focused on its data processing aspects. Computers were meant to centralize the “routine ‘dog’ work involved in each of these operations” (Osborn 1954, p. 106), but to gain consent GE allowed the department to retain the rights to the data and decision making. The common term to explain this use of applications was “automation,” reflecting the focus on displacing costs, programming repetitive tasks, and separating data processing from decision making.

Based on these interpretations and deployment requirements, accounting applications made a good choice for conversion. Routines in accounting processes like payroll were well established, documented, and audited (Johnson and Kaplan 1987). In addition, the data processing groups responsible for analyzing the benefits as well as managing the new computers typically were included within the finance function (Haigh 2001). In contrast, many of the routines in production planning and inventory control in the mid 1950s were ad-hoc, undocumented, and not well audited (Kahl 2006). These applications were much less likely to be developed. Table 2 shows the frequency of the different applications deployed at large manufacturing establishments from 1954 – 1958. Only 12% of the survey respondents did not deploy any accounting function at all. By comparison, manufacturing applications (highlighted on the table) were implemented less frequently and were more varied across the firms.

A possible alternative explanation of this usage pattern is that technical limitations of the computer did not allow for certain types of applications to be built. The minimal memory, poor data and program management, and no user interfaces of the computer at the time certainly favored applications that managed repetitive data processing such as payroll. These limitations also made it difficult to run multiple applications on the same computer. However, if technological limitations were the only factor, we would expect only data intensive applications to be deployed and only a few applications per computer. Table 3 shows the average number of applications per computer and the average number of different functional areas (defined as manufacturing, Finance, sales, IT, and HR) represented from the applications deployed (from the application data represented in Table 2). Contrary to the predictions of the technology limitations hypothesis, manufacturers deployed on average 8 applications per computer (from 1955-1957), cutting across multiple functions. In addition, manufacturers implemented computationally intensive applications such as engineering computations despite the computational restrictions (See Table 2).

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Changes in Manufacturer's Understanding and Use

In the 1960s, manufacturers began to shift their use of manufacturing applications from processing clerical tasks to supporting managerial decision making (for a summary of this shift, see Table 1, "Standard Systems). They shifted to comparing computer applications to human decision-like qualities.

Specifically in manufacturing, Joseph Orlicky implemented one of the first decision-oriented applications, called material requirements planning or MRP, on an IBM machine at J.I. Case in 1961 (Orlicky 1975). MRP calculated material requirements based upon dependent relationships within a product's configuration, production requirements, and end-product demand. It also provided audited procedures to respond to changes in the production schedule. MRP enabled production planners to do the complex computations to plan and respond to material requirements. This use contrasted with earlier systems that were more oriented toward record keeping. Orlicky, himself, supported the idea that computers and their applications were “human like.” In fact, one of his chapters in a later published books on computers was called “A Machine That Amplifies Man’s Intellect” (Orlicky 1969).

This shift in use resulted in part from incremental technological improvements in the computer, poor initial results from early implementations of the computer applications, and a shift in how manufacturers justified the deployment of computer applications. Incremental technical improvements in disk drives, solid state computers, COBOL programming language, CRT monitors, and hierarchical databases improved data management, computational capability, and user interfaces. These advancements allowed for more data and computational intensive applications like MRP to be developed. Aside from these technical changes, there were increasing concerns about the benefits of using the computers in conservative ways. By the 1960s, consultant surveys of practical computer deployments showed poor financial return (Garrity 1963). Interestingly, these studies blamed poor management skills and the conservative, practical uses customers had created for computers instead of any technical issues. In response, the justification for these applications shifted from cost displacement to quantification of potential operational benefits such as increased inventory turns, reduction in inventory, lower shop labor costs, and lower maintenance expense (Glaser 1967). According to this logic, instead of developing applications that address already well automated systems, manufacturers should consider automating those processes that may have more significant impact on the bottom line. MRP applications, for example, were typically justified not in how many clerical workers they could replace but in how much inventory and production cycle times they could reduce.

Standardization to MRP and a New Customer Segment

At first, only a handful of manufacturers developed MRP solutions. Orlicky estimated that by 1971 there were approximately 150 and by 1975, 700 installations (Orlicky 1975). By 1984, the industry analyst group IDC estimated that approximately 21,000 of this system or its next generation, MRP II had been installed (IDC 1985). Another way to describe this transformation is through how the manufacturers described their applications in the conference proceedings. In the late 1950s and into the 1960s, manufacturers would describe their applications in terms of the specific function it performed, but later the descriptions switched to the conventional use of "MRP." MRP had become the standard system to describe automation of production planning and control. How did this happen?

In the early 1970s, the heavy marketing of the MRP technique by the professional society, American Production and Inventory Control Society (APICS), contributed to this growth. This effort became known as the "MRP Crusade." APICS was founded in 1957 to help educate and promote the production planning profession. During the "crusade," APICS engaged in several important activities to promote MRP and more advance production and planning techniques: they partnered with consultants and educators like Orlicky to conduct seminars on MRP, started a certification program for manufacturing professionals based upon these planning techniques, and published a book series on the topic. Outside of APICS, consulting groups emerged to educate firms about best practices in MRP. Perhaps most notable, Oliver Wight established a software evaluation service in 1973 that advocated a "standard system" approach to MRP. The combination of the "crusade," education, and consulting services legitimatized MRP as the standard manufacturing application.

Also during this time, small manufacturers entered the market representing a new customer segment. The lower price point of the minicomputer introduced in the late 1960s made it more feasible for smaller manufacturers to own and implement their own applications. Smaller manufacturers had functional requirements similar to larger manufacturers, but lacked the resources for highly customized solutions. In many cases, functional personnel took on the additional duties of supporting the new technology and applications, where large manufacturers had several different departments. Small manufacturers tended to centralize operations on the minicomputer, whereas, large manufacturers integrated these systems into their existing mainframe environment, resulting in a heterogeneous hardware environment. Even though the MRP system integrated work tasks, it was deployed locally in large manufacturers, thus reinforcing decentralization. Thus, the main difference between small and large manufacturers was not what functions the MRP solution performed, but in how it was deployed.

From the industry perspective, many firms entered the pre-packaged manufacturing software market in the 1970s. Pre-packaged solutions differed from the earlier developed applications in that the business logic was already pre-programmed. Most of the pre-packaged software vendors incorporated MRP logic espoused by APICS into their solution set. Figure 2 shows the number of industry participants over time, with a substantial increase during the 1970s. The standardization of MRP as well as IBM's decision to unbundle software contributed to this growth. Many different kinds of firms entered the market, including hardware vendors, consulting groups, service bureaus, pure play manufacturing software vendors, other software vendors migrating from other functional/technical areas, and even customers. From a market share perspective, IBM, with its MAPICS and COPICS products, would capture 50% of the market by 1984 (IDC 1984) (See Figure 3). IBM's strength in hardware certainly contributed to its success, but in addition, IBM actively participated in APICS' "MRP Crusade" and hired many of the early thought leaders in MRP – including Joseph Orlicky, George Plossl, and Oliver Wight – into its manufacturing consulting and education groups. This group educated manufacturers on production and control techniques as well as helped develop modules for IBM's manufacturing solutions.

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Acquiring a packaged solution represented a new kind of product purchase for large manufacturers accustomed to developing applications. Manufacturers believed that the best way to purchase software was to understand in advance exactly what the software was supposed to automate. Because no pre-packaged software could perfectly match functional, organizational, and technical requirements, manufacturers faced the new consideration of how much customization of the software should be done. The manufacturer Sundstrand, for example, did extensive analysis trying to determine the optimal trade-off between customization and implementation, coming to the conclusion that less customization was better (Hoyt 1975). Thus, the idea of software automating a defined system persevered even though manufacturers justified and deployed the software differently than they did with the original automation systems in the 1950s.

Variation from the Standardized Understanding and Use

Evolutionary models assume that there is no significant variation post standardization. However, in the later part of the 1970s and 1980s, there were important variations in how manufacturers used MRP software. Manufacturers started to integrate heterogeneous technology, expand MRP functionally, incorporate new manufacturing techniques, and modify MRP to support different styles of manufacturing. Table 4 counts the total number of presentations at APICS that focused on these topics, showing the increased interest post-standardization to MRP in the early 1970s. These changes modified how manufacturers purchased software and at a very basic level they questioned the efficacy of the MRP approach. The sources of these changes came from knowledge gained by using the software and several technological and competitive changes. For the purposes of the study, it is important to focus on how experiential learning led to new uses.

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Insert Table 4 Here
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On-going use of MRP applications increased knowledge about scheduling production beyond just calculating the necessary inventory requirements. Through use, it became apparent that without an accurate schedule, MRP was less effective. Production scheduling required additional information about capacity – both human and machine – that previously was not factored in the calculations. At a higher level of planning, MRP required integration with other functions such as finance, human resources, and purchasing (Wight 1981). Using MRP in additional manufacturing verticals identified other limitations of the standard MRP solutions. The standardization of the MRP process occurred in certain types of discrete manufacturing, in particular, make-to-order and make-to-stock production environments (Orlicky 1975). As firms from different manufacturing styles implemented MRP solutions, the limitations of the MRP approach were exposed, further entrenching MRP as addressing only certain manufacturing segments. For example, in aerospace & defense, the production process, although discrete in nature, is run as projects rather than off customer orders. MRP systems are designed to operate off of orders or forecasts and did not have strong project management capabilities.

In addition, the changing competitive landscape encouraged manufacturers to re-evaluate their production planning and execution processes at a more fundamental level. From increased global competition and poor economic conditions, the 1980s initiated a flurry of alternative manufacturing techniques – just in time (JIT), computer integrated manufacturing (CIM), and quality improvement to name a few. Manufacturers considered how current MRP practices related to these new approaches. For example, the JIT concept introduced the notions of continuous improvement, increased customer focus, and localized control to make changes which challenged the central planning and control aspects of the MRP system.

The two most important technological introductions were integration technologies and the personal computer. At each level of the technology stack, new technologies tried to integrate heterogeneous and proprietary technologies: UNIX at the operating system level, TCP/IP and LANs at the communication level, and relational databases at the data level. These technologies stimulated new consulting services called “systems integration." In the mid 1980s, third party consultants such as Andersen Consulting began offering services that helped clients more effectively combine the different hardware, software, and communications technologies to better support the information needs of their client (IDC 1987). An important consequence of these activities was that consultants got much more directly engaged in the purchase decision to help ensure that the software supported the developing architectural standard.

Conversely, the introduction of the PC in the early 1980s continued to decentralize the technology, especially at the work process level. Historically, the user interface, called "green screens", directly integrated with the mainframe or minicomputer and all work processes and data were centrally controlled. However, PCs enabled business users to do their own data analysis outside of a centrally controlled computer as well as outside the control of the information technology staff. With respect to manufacturing, trade magazines began to show how spreadsheets could be used in the manufacturing environment (Johnson 1985). Production planners could download production information into a spreadsheet and do their own contingency planning outside of the system, but if the planner did not upload his altered plan, the existing MRP application would have the wrong information. How manufacturers used the software was changing to include higher levels of management and this localized use created concerns about data integrity and the efficacy of the entire system.

From an industry perspective, software firms responded with continued product development and investment in new service capabilities. Vendors released new software products, called Manufacturing Resource Planning (MRP II), that supported broader functional integration at the planning level and improved production scheduling.

Industry specific variants of the software, in particular in aerospace and defense, were also developed. Vendors also increased their investment in building out services. Historically, software firms provided maintenance, training, and limited implementation support. In the mid 1980s, many software firms added management-type consulting to their implementation services. These changes in services were concentrated in firms that targeted larger manufacturers as small manufacturers tended to use localized third party support. In the small manufacturing market, these firms invested in building out their value-added reseller channel at the local markets.

Thus, contrary to predictions of the evolutionary model, by the late 1980's there was significant variation in how manufacturers evaluated and used manufacturing software. Software firms responded through changes in the product as well as changes in service capabilities.

Technological Discontinuity – Client/Server and an Industry Shakeout

In the late 1980s and early 1990s, client/server architecture emerged as a new way to design, build, and deploy software applications. Client/server took advantage of the integrative technologies to distribute transactional processing across multiple hardware platforms. The previous host-based architectures ran on proprietary operating systems using hierarchical database structures and processed all transactions on a single machine. Client/server required learning new technological skills, such as a new operating system, relational database and communication capabilities, as well as restructuring transaction processing. These characteristics fit the literature's definition of an architectural, competency-destroying change (Tushman and Anderson 1986; Henderson and Clark

1990). By 1987, several new client/server applications entered the market and by the early 1990s, most pre-existing software firms invested heavily to make the transition.

Despite this radical technical change, customers initially did not modify their usage patterns. Studies in 1991 and 1992 indicated that roughly 35-45% of the Fortune 1000 engaged in limited client/server projects, but they were generally concerned about data security and wanted to minimize organizational change (Gantz 1992). However, with the introduction of reengineering soon after these surveys were done, large manufacturers started to significantly change their usage pattern. Management consultants encouraged firms to radically change their business processes to become more cross-functionally integrated (Davenport and Short 1990; Hammer 1990; Hammer and Champy 1993). Although manufacturers had integrated at the planning level with MRP II, reengineering called for integration at the execution and task level. Thus, rather than automate existing processes, reengineering principles argued for complete functional redesign – "Don't Automate, Obliterate" (Hammer 1990).

Reengineering changed how large manufacturers evaluated and used the new client/server software. Rather than change business processes first and then buy a software package, large manufacturers purchased software as they reengineered (Ravikumar 1994). Since consultants were heavily engaged in the broader reengineering effort, they also became much more involved in the selection process. The cross-functional integration also expanded functional and management representation in the purchasing decision. To justify these purchases, manufacturers continued the trend of focusing more on customer value generation, such as, how the software can help reduce customer delivery times and improve product quality and service (Rosati 1992). Thus, the software was used to configure new business processes to help establish competitive advantage, in contrast with the previous use to automate pre-existing functions in order to become more efficient. The switch in terminology captures this change – software shifted being called "systems" that "automate" to "solutions" that "configure." In contrast, smaller manufacturers did not as aggressively adopt reengineering practices and continued to use the new client/server solutions as they did the host-based solutions. Reengineering did not appeal to smaller manufacturers for several reasons: the cost of redesigning processes, the current centralized deployment of integrated solutions (MRP and MRP II) (AMR 1995), and the lack of resources. Thus, because smaller manufacturers were already centralized, these firms did not radically change their usage patterns.

From the industry perspective, evolutionary models would predict that the transition to client/server should be disruptive to the software vendors regardless of the targeted market. The competency-destroying aspects of the new technology applied equally to the same markets. In fact, the transition to client/server was disruptive – 29% of the pre-existing firms left the market between 1987 (introduction of client/server applications) and 1996. However, making the technological change did not seem to be the significant competitive issue. Most of the exiting firms invested to make the technical change and by 1994 most firms had released a client/server version of the software. Figure 4 compares the exit patterns of those vendors who targeted large manufacturers versus those who targeted smaller manufacturers, showing the underlying patterns in use. More vendors who targeted the large manufacturers exited (17 or 57% of all firms) between 1987 and 1996 than those that targeted small manufacturers (13 or

18% of all firms) even though there were more that three times as many of these vendors. Contrary to the evolutionary model's prediction, firm exit depended more on whether the customer's usage pattern changed than on whether firms made the technological transition.

Further analysis of software firms' actions reveals they had trouble identifying the new usage patterns that developed in large manufacturers. Essentially, software firms who targeted large manufactures believed that existing customer evaluation processes and uses would persist through the technological change. Advertising during the technological change emphasized the traditional manufacturing integration found in MRP and MRP II systems as opposed to the new horizontal functional integration. In fact, a third party industry group, Gartner Group, not the software firms, coined the term, enterprise resource planning or ERP in 1992. Vendors began calling the new client/server software by this name to emphasize the horizontal or enterprise integration that it can provide. Software vendors also tried to expand the market by selling lower cost solutions to the less penetrated smaller manufacturing market (Ambrosio 1992). Since this transition, SAP, an incumbent, replaced IBM as the market leader. IBM exited the market in 1994 to concentrate on services. Since then, the market has experienced another significant discontinuity as software and manufacturers switched to Internet architectures.

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DISCUSSION

The history of how manufacturers used manufacturing software illustrates the proposed model of demand evolution and its influences on the competitive dynamics of the industry. In the 1960s and 1970s, manufacturers shifted their categorization of computers and applications from tabulating machines to the human brain and their justification from eliminating overhead to improving operational efficiency. This shift coincided with a change in how manufacturers used software, as they began to consider applications like MRP that could help improve decision making to reduce inventory. Manufacturers thus began to standardize their use of computer technology. As they continued to work with the software, manufacturers learned new uses for and limitations of the MRP approach, and customized their own usage accordingly. By the time the disruptive shift to client/server architecture arrived in the early 1990s, there was variety in how manufacturers used the software, especially between the highly centralized approach in small manufacturers and the decentralized deployments in the large manufacturers. Thus, the change toward reengineered, centralized applications was radical for large manufacturers but not for small manufacturers. As a result, during the transition to client/server software firm exit depended more upon whether the use patterns of the targeted customer segment changed than on making the technological transition.

There are some important limitations to this case and method. Even though there were two periods of technical and use standardization, there is limited support of proposition 1. In fact, during the standardization to MRP in the early 1970s, entry into the market actually increased, but this may be the result of IBM's decision to unbundle software from hardware sales which made it more profitable to enter the market. The short technology cycles between technological disruptions and the quick onset of variation after standardization to MRP also make it difficult to empirically determine if the industry shifted from product to process innovation. There is evidence that process innovation did increase after the introduction of client/server as firms invested in object-oriented development techniques, but they also invested heavily in Internet technologies in anticipation of the transition to Internet architectures. Thus, additional empirical work is necessary.

A potential response to this argument could be that the demand-side processes described still remain exogenous to the original evolutionary model. However, the use of the technology itself and the subsequent learning that takes place are not independent from the technological development. Customers do not fully control how they use a technology because they do not control the technical design. And, producers do not fully control how customers use the technology because they do not control how customers deploy it. Customer use sits in the intersection between demand-side and supply-side factors. As a result, the implication of this analysis is not to replace supply-side arguments with a demand-side explanation, but to integrate the two perspectives (Mowery and Rosenberg 1979). The *interplay* between customers figuring out what a new technology is and how they may use it on the one hand, and producers developing and marketing new technologies, on the other, shapes the direction of technology change and an industry's competitive dynamics.

With respect to this interplay, the manufacturing case expands the notion of "the market" beyond the customer-producer exchange to include such market mediators as industry associations, industry analysts and consultants. This work joins the sociologically-informed approach that recognizes the role of institutions in industry evolution. Where previous research has focused on the institutions' role in legitimizing new kinds of firms (Aldrich and Fiol 1994) or in standardizing technology (Van de Ven and Garud 1989; Nelson 1995a; Rosenkopf and Tushman 1998), this work shows how institutions influence the evolution of the selection environment. The institutions that were important here differ from the kinds of organizations that have been involved in the technical standardization and governmental lobbying described in previous work. They include organizations that represent customer interests, such as trade and professional associations, and customer-facing mediators, such as consultants and industry analysts. These mediators influence which product comparisons and performance criteria customers converge upon to form a collective understanding of the product. In this case, the manufacturing industry association APICS helped establish MRP as the standard for production management through its MRP Crusade and its professional certification program.

Recognizing these participants as mediators should also caution us against overly "socially contextualizing" the interplay between customers and producers. Incorporating other market participants does make the social context of market transactions more explicit and encourages an analysis of the social embeddedness of these exchanges (Granovetter 1985). This work follows in this tradition, but recognizes that the customer-producer interface is also structured (Zuckerman 1999).[5] In the case, these participants mediated the relationship between the customer and producer through their influence on how the customer categorized the software and justified its purchase. Their position and role in this structure also changed over time: in the 1950s, market mediators educated and advised the customers, but by the 1980s and 1990s, they were more directly involved in the purchasing decision itself, writing requirements and helping customers short-list and

[5] What Ruth Schwartz Cowan (1987) calls the "consumption junction."

negotiate with vendors. Thus, not only did the manufacturers' understanding and uses of the software change over time, but so also did the structure through which they purchased and used the software. These structural changes and the social context in which they were embedded shaped the competitive conditions and innovation incentives that software firms faced.

Details of the case also suggest some conditions under which customers develop radical new uses when faced with a new technology. In the 1950s, large manufacturers developed conservative applications with the new computer technology; in the 1990s, they developed radical processes and applications with the new client/server technology. Why did manufacturers so eagerly embrace change in the later period? One possible explanation is that the concept of reengineering simply did not exist in the 1950s. Yet, the groups responsible for documenting business processes and helping with technology deployments in the 1950s, the so-called "systems men," advocated redesigning business processes and building totally integrated systems (Haigh 2001). Their arguments were strikingly similar to what prophets of reengineering said in the early 1990s.

Rather, the key difference was the nature of categorizations the manufacturers made. In an effort to understand the computer and its application in the 1950s, manufacturers focused on the *similarities* between the computer and machines or people. Computer applications were to "grind out" reports just as manufacturing equipment ground out products, or they had "human-like" qualities. The emphasis on similarities encouraged manufacturers to use computer applications to perform the same kinds of tasks as the tabulating machine. When early tabulator-like uses did not generate the expected returns, the alternate comparison of computer applications to the brain, suggesting use for computational and decision-making purposes, provided an attractive alternative. The combination of these two comparisons and uses helped sustain the computer as a viable technology.

In contrast, during the introduction of client/server technology, large manufacturers did not make multiple product comparisons but focused on the *differences* between client/server and the host-based MRP applications. Prior to the introduction of client/server, manufacturers were learning about the limitations of MRP applications: in its applicability to other manufacturing sectors, in its effectiveness at developing accurate and reliable plans and in how it related to other approaches to solve manufacturing problems. The comparisons of client/server applications with MRP then focused on these exposed limitations. Focusing on how client/server was different from the now-less-attractive benefits of MRP established the new technology's image. Recognition of differences, in conjunction with consultants pushing for reengineering, led to radical changes in large manufacturers' use of software.

This insight—that the number and nature of product comparisons influence whether customers initially adopt radical uses of a new technology—addresses a weakness in the research on learning's role in industry evolution. Traditional work focuses on how the learning is accomplished (e.g., experiential, exploitative, or exploratory) while ignoring what is actually learned. Evolutionary models have an inherent belief that experiential learning is incremental and cumulative and therefore makes it difficult for firms to learn something radically different (Nelson and Winter 1982). In the case of manufacturing software, though, experiential learning identified the limits of the current applications, such that when something new was encountered, manufacturers could understand the differences. A radical new use came out of incremental experiential learning. Cumulative learning does not necessarily imply path dependencies, because if the customers are learning differences, then this knowledge can generate a new path.

IMPLICATIONS AND CONCLUSION

The demand evolution model described here is a dynamic framework that identifies the sources of variation in demand and explains how demand can change over time independent of supply-side stimuli. Explicitly analyzing demand evolution exposes restrictive assumptions within the standard evolutionary model while explaining the shifts in industry competition. Cost-based competition depends upon customers converging to a standardized use, and the competitive significance of a technical discontinuity is unknown until its use characteristics are established. This extended analysis of demand offers theoretical and managerial insights into the co-evolution of industry-level selection and firm-level adaptation.

Historically, explanations of firm evolution in the organizational literature and the sources of competitive advantage in the strategy literature have been divided between two explanations: those that argue that heterogeneous firms with different levels of capabilities must *adapt* to changing environment conditions (Peteraf 1993; Scott 1995; Teece, Pisano and Shuen 1997) and those that argue that environmental conditions *select* new types of firms (Hannan and Freeman 1977). By showing how one environmental participant, the customer, evolves in ways that are interrelated to firms innovating, this research argues that the source of competitive advantage lies in the *interplay* between firms adapting and the environment selecting. A firm's innovative activities affect how customers evaluate and use a technology, but customers also change expectations based upon continued use of the technology, affecting the firm's activities. Environmental selection and firm-level adaptation co-evolve.

Much of the paper has focused on this effect at the industry-level, but this insight can be applied to the analysis of the development of firm-level capabilities. The capabilities view of the firm recognizes the need for firms to develop new capabilities in ever changing environments (Teece, Pisano et al. 1997). This literature has presumed that the locus of this renewal lies inside the firm and that in technology-intensive industries product innovation is a primary source of this renewal (Dougherty 1992; Helfat and Raubitschek 2000; Danneels 2002). This research suggests that the locus of organizational renewal need not lie inside the firm and that other innovative activities within the firm can build differentiating capabilities without product innovation.

To identify customers as users is to recognize that, like producers, customers have capabilities in relation to deploying and using a technology. Also like producers, customers' capabilities are dynamic–they learn about the technology and develop new uses for it. A potentially interesting implication is that firms do not have to internally develop innovation capabilities but can instead leverage customer capabilities by encouraging them to develop new uses for their technologies. Research in user-led innovation has shown that a special group of users, called "lead users," are a valuable source of product innovation for firms (Von Hippel 2005). In this study, IBM used elements of this strategy by hiring several "lead users" of early MRP applications to educate other customers and to develop its own product. Developing strategies and design elements that encourage users to develop new uses and then feeding that information back into the firm may be a way for firms to renew their capabilities. For example, opting to send information back to Microsoft when a program crashes gives Microsoft information about how customers are using its software. Further integration of the user-based innovation literature should provide some additional insight. For instance, it is still not clear how customers develop capabilities through using the technology beyond "lead users" who have special incentive to do so (Von Hippel 1986). Understanding the rate of learning within a customer population and the broad incentive structure to reveal current uses can help us understand the conditions under which not dynamically renewing product innovation capabilities within a firm makes strategic sense.

In addition, functional areas outside of product development and design, such as marketing, finance, and services, influence how customers use technology. How a customer must pay for a product over the lifetime of its contract and how a customer receives service influence how she uses and thinks about it (Rosenberg 1983). These kinds of customer-facing capabilities have traditionally been viewed as complements to product development and design. There is an implicit primacy given to products; these customer-facing capabilities are supposed to support product innovation. But, firms can differentiate themselves without directly engaging in product innovation; innovating in services can help generate new customer uses. Thus, there are other sources of innovation beyond the development and production of new technologies that can renew firm capabilities and affect industry evolution (Cusumano, Kahl and Suarez 2006).

At the conceptual level, this research implies that we need to change how we think about the competitive significance of change within a firm and an industry. We have traditionally measured the significance of change in terms of the magnitude of its difference, with the assumption that radically different change is hard to understand and manage. However, recognizing that the same change can be discontinuous from a producer perspective but continuous from a customer perspective suggests that the significance of change comes not from the magnitude of the difference, but from how we manage the relationship between change and continuity among firms and their customers.

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Tables

Table 1: Summary of Changes in Evaluation and Use; 1954-1996

	"Practical Approach" 1950's – early 1960's	"Standard System" Late 1960's – 1980's	ERP 1990's
Evaluation			
Justification	Displace Clerical workers and tabulating machines	Operational Cost Containment (e.g., reduce inventory)	Competitive Advantage (e.g., improve customer service and quality)
Categorization	Tabulating equipment, human brain	Computational	Computational
Actual Use			
Functions	Department level functions, accounting pervasive	MRP, MRP II – vertical functional integration	ERP – horizontal functional integration
How Deploy	Divisional data processing centralized	Early push for centralization but became more decentralized	Centralization with some local processing autonomy
Processing	Automating – Batch oriented	Automating, Shifting to on-line, real time	Configuration; dynamic and process oriented
Users	Data processing / business users	IT / business users, managers	IT / business users, solutions for executives

Table 2: Top Applications Deployed at Manufacturing Sites 1954-1958

Application	1954		1955		1956		1957		1958		Total	
	#	% all	#	% all	#	% all	#	% all	#	% all	#	% all
Payroll	2	67%	38	84%	43	73%	59	72%	5	38%	147	73%
Labor Distribution	2	67%	26	58%	26	44%	42	51%	6	46%	102	50%
Cost Accounting	2	67%	31	69%	21	36%	33	40%	1	8%	88	44%
Engineering Computations	2	67%	18	40%	22	37%	34	41%	4	31%	80	40%
Employee Benefits	2	67%	20	44%	20	34%	28	34%	5	38%	75	37%
Material Production Requirements	1	33%	17	38%	17	29%	27	33%	4	31%	66	33%
Inventory Control	1	33%	15	33%	18	31%	27	33%	3	23%	64	32%
Sales Revenue Analysis	2	67%	9	20%	14	24%	30	37%	2	15%	57	28%
Production/Planning	1	33%	14	31%	13	22%	23	28%	1	8%	52	26%
Finished Stock Inventory	1	33%	10	22%	11	19%	27	33%	2	15%	51	25%
Sales/Revenue Accounting	1	33%	8	18%	13	22%	27	33%	1	8%	50	25%
Special Analysis: Planning & Control	1	33%	12	27%	11	19%	22	27%	2	15%	48	24%
Design Problems	1	33%	9	20%	12	20%	20	24%	3	23%	45	22%
Raw Material and Stores Inventory	2	67%	9	20%	11	19%	20	24%	1	8%	43	21%
Economic Research	1	33%	9	20%	13	22%	18	22%	2	15%	43	21%
Customer Billing	1	33%	8	18%	8	14%	21	26%	3	23%	41	20%
Operations Analysis	1	33%	7	16%	6	10%	21	26%	3	23%	38	19%
General Accounting	2	67%	14	31%	7	12%	14	17%	1	8%	38	19%
Personnel Records	2	67%	14	31%	5	8%	15	18%	1	8%	37	18%
Planning/Budgeting	2	67%	13	29%	6	10%	15	18%	1	8%	37	18%
Financial/Operating Reports	1	33%	12	27%	8	14%	14	17%	0	0%	35	17%
Purchase Planning & Control	2	67%	5	11%	8	14%	16	20%	0	0%	31	15%
Accounts Payable	2	67%	8	18%	8	14%	9	11%	2	15%	29	14%
Customer Billing	2	67%	6	13%	6	10%	8	10%	2	15%	24	12%
Machine Loading Scheduling	0	0%	5	11%	6	10%	11	13%	0	0%	22	11%
Accounts Receivable	0	0%	2	4%	6	10%	11	13%	1	8%	20	10%
Economic Research	2	67%	7	16%	3	5%	4	5%	3	23%	19	9%
Total All Implementations	3		45		59		82		13		202	

Source: Controllership Surveys, 1954-1958 (see Kahl, 2006)

Table 3: Installation Statistics from Controllership Surveys 1954-1958

	Total Installations	Unique Firms	Avg # App	Avg # functions	# with IBM 650
1954	3	3	14.3	5	1
1955	45	31	8.6	3.6	30
1956	59	44	6.4	3.0	35
1957	82	57	7.7	3.4	47
1958*	13	10	5	2.7	8

* Survey completed in year 1958, so incomplete for the year

Source: Controllership Surveys, 1954-1958 (see Kahl, 2006)

Table 4: Article count for selected topics in APICS Annual Conference Proceedings, Selected Years 1962-1989

	1962	1965	1968	1971	1974	1977	1980	1983	1986	1989
Master Production Scheduling	1	0	0	4	2	16	16	13	14	13
Function Interface	0	1	0	1	0	12	22	29	17	34
JIT	0	0	0	0	0	0	1	13	32	11
CIM	0	0	0	0	2	0	2	10	16	11
Vertical Expansion	2	1	0	0	0	6	5	5	6	15
All Articles for the year	26	19	16	29	38	66	131	188	188	173

Source: APICS Proceedings 1962 – 1989 (See Kahl, 2006)

Figures

Figure 1: Conceptual Model of Customer Purchase and Use

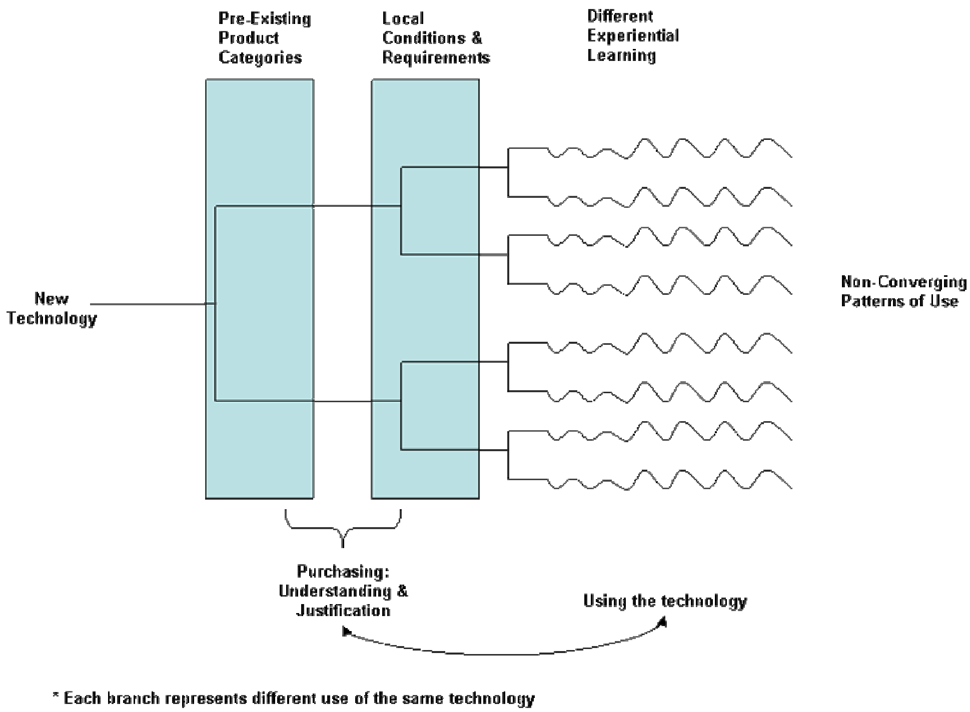
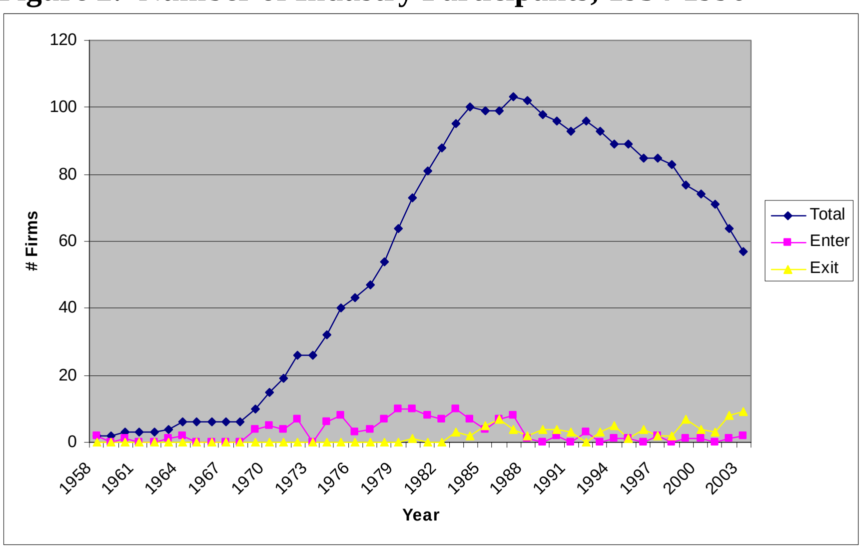
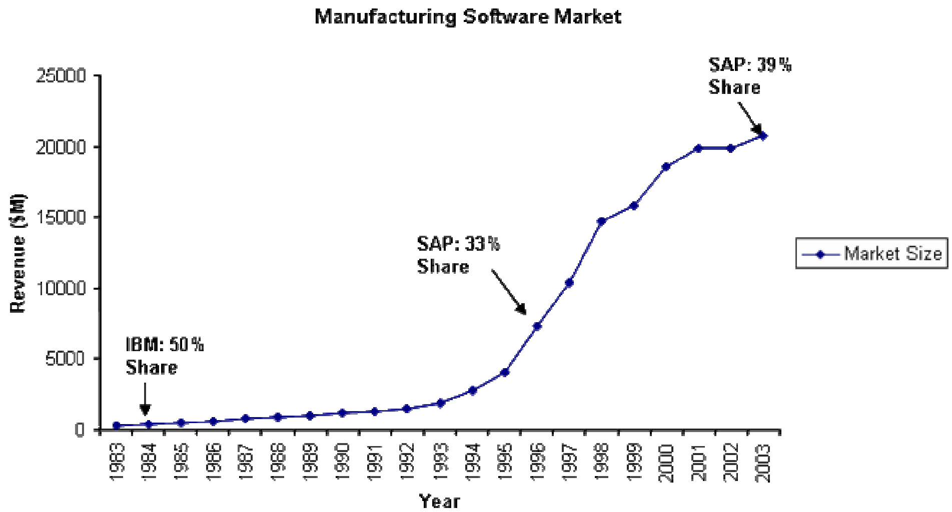


Figure 2: Number of Industry Participants; 1954-1996



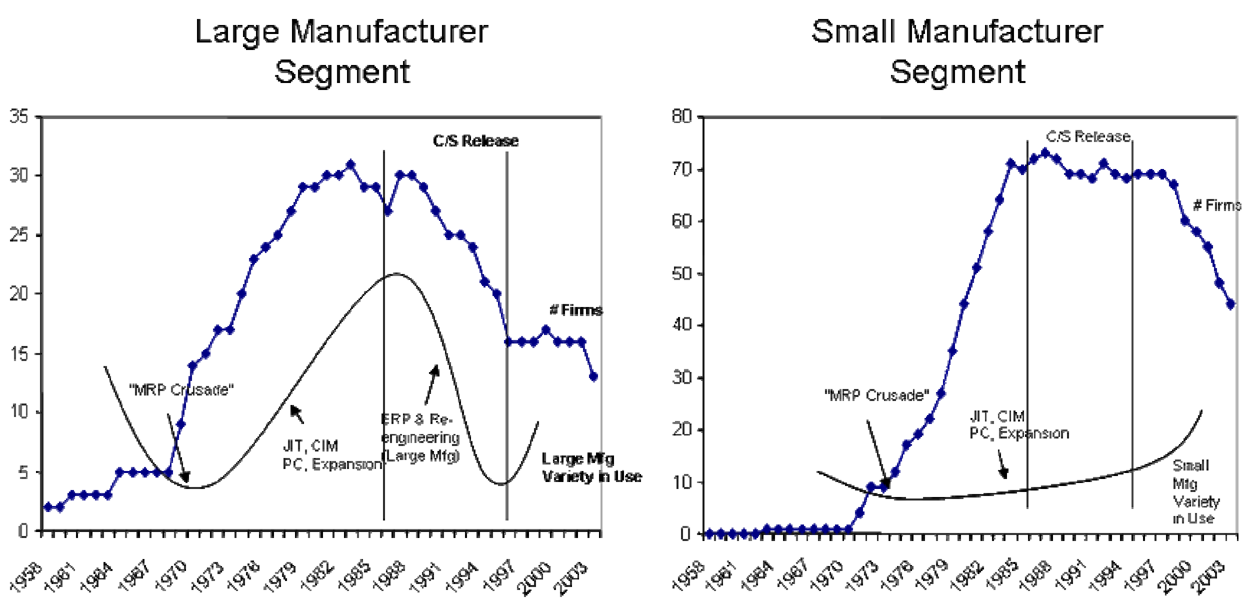
Source: IDC reports (1984 – 2003), AMR Reports (1994 – 2003), SEC Documents; See (Kahl, 2006) for full discussion of data. This data does not include all industry participants.

Figure 3: Manufacturing Market/ERP Market Size, 1983-2003



Source: IDC reports 1983-1993 (some years only includes independent software vendors; AMR 1994-2003 (ERP numbers, extends beyond manufacturing)

Figure 4: Changes in Use mapped to Industry Changes, 1954-1996, 1958-2003



Source: (Kahl, 2006)