

THE DYNAMICS OF PRODUCT INNOVATION AND FIRM COMPETENCES

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This study examines how product innovation contributes to the renewal of the firm through its dynamic and reciprocal relation with the firm's competences. Field research in five high-tech firms of varying age, size, and level of diversification is combined with analysis of existing theory to develop the findings of the study. Based on the notion that new products are created by linking competences relating to technologies and customers, a typology is derived that classifies new product projects based on whether a new product can draw on existing competences, or whether it requires competences the firm does not yet have. Following organizational learning theory, these options are conceptualized as exploitation and exploration. These organizational learning concepts are used to gain a dynamic and path-dependent view of product innovation and firm development, and to reveal the unique nature and challenges of different types of product innovation. Copyright © 2002 John Wiley & Sons, Ltd.

Nothing endures but change—Heraclitus

Ever since Schumpeter's (1942) classic work, the need for organizational innovation and renewal has been recognized, not only to withstand the 'gales of creative destruction,' but also to create them. Organizations need to continuously renew themselves if they are to survive and prosper in dynamic environments. This renewal challenge is even more pronounced in the current business environment characterized by fast changes in customers, technologies, and competition.

Product innovation has been recognized as a primary means of corporate renewal (Dougherty, 1992), and as an 'engine of renewal' (Bowen *et al.*, 1994). At the same time companies have been exhorted to develop more innovative rather than incremental products, and there has been an emphasis on the development and marketing of

innovative products (e.g., *Journal of Product Innovation Management*, 1998). Underlying this strong interest is the notion that 'really new' products are crucial to firm survival in the current fast-changing business environment.

THEORETICAL BACKGROUND

How can product innovations generate organizational renewal? The purpose of this study was to develop a conceptual framework to understand how product innovations contribute to firm renewal. Organizational renewal involves the building and expansion of organizational competences over time, often involving a change in the organization's product market domain (Floyd and Lane, 2000). According to Floyd and Lane (2000: 155), 'a theory of strategic renewal must recognize that maintaining adaptiveness requires both exploiting existing competencies and exploring new ones.' I argue that product innovation drives

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organizational renewal by exploiting and exploring firm competences, and I examine the reciprocal interplay of product innovation with firm competences over time.

My conceptual framework is based on field research and an integration of the scholarly literature regarding product innovation, organizational resources and competences, organizational learning, and path dependency. The product innovation literature has examined the determinants of new product success (cf. Cooper, 1993; Montoya-Weiss and Calantone, 1994, for extensive reviews). These studies consistently showed a positive impact of project–firm synergy (the extent to which the project can draw on existing in-house resources and skills) on new product performance (e.g., Cooper and de Brentani, 1991; Cooper and Kleinschmidt, 1993; Kleinschmidt and Cooper, 1991; Song and Parry, 1997a, 1997b; Zirger and Maidique, 1990). In other words, new products with a closer fit to firm competences tended to be more successful. Despite the contribution of this finding, this literature has only studied the effect of resources on product innovation. New product studies have not considered the reverse direction of the product innovation–competence relation, i.e., the effect that new product projects in turn have on the firm's competences and its trajectory of renewal. These studies therefore provide a limited view on the role that product innovation plays in firm renewal.

Some scholars have examined product innovation from a resource-based perspective. Leonard-Barton (1992) argued that paradoxically core capabilities both enable and impede product innovation, in the latter case becoming core rigidities. She found that core capabilities facilitated the development of projects closely aligned with those capabilities. In contrast, projects lacking alignment with the four dimensions of a firm's core capability (employee knowledge and skills, technical systems, administrative systems, values and norms) were inhibited. Leonard-Barton argued that firms are faced with the dilemma of both utilizing and maintaining their capabilities, and yet avoiding their dysfunctional flip side by renewing and replacing them. Similarly, Dougherty (1995) found that over time 'core incompetences' grow around the firm's core competences. Supporting this insight, Henderson (1993), in her study of the photolithographic alignment equipment industry, found that incumbent firms introducing products

requiring different organizational capabilities were hampered by their store of experience. In a study of the typesetter industry, Tripsas (1997) found that specialized complementary assets supported the success of incumbent firms in developing products based on different generations of technology. Tripsas and Gavetti (2000) found in a historical case study of Polaroid Corporation that managerial beliefs impeded the development of technological capabilities, and consequently Polaroid's commercialization of digital imaging products.

Since the notion of 'dynamic capabilities' (Teece, Pisano, and Shuen, 1997) called attention to the need for renewal of firm competences in changing environments, resource-based scholars have started to focus much more on the dynamic nature of capabilities, asking how capabilities and resources evolve over time (Helfat, 2000). Eisenhardt and Martin (2000) reviewed acquisitions, alliance formation, and product innovation as some organizational activities that serve to renew and reconfigure organizational resources. Eisenhardt and Martin (2000) argued that product development is a dynamic capability of the firm, because of its ability to alter the resource configuration of the firm. Product development is one of the mechanisms by which firms create, integrate, recombine, and shed resources. According to Eisenhardt and Martin (2000), explicating the link between resource-based theory and product innovation will inform resource-based theory and strengthen its empirical grounding. Helfat and Raubitschek (2000) offered another recent work that firmly positions new product activity within the purview of resource-based theory, arguing that organizational capabilities and products co-evolve over time.

This article makes advances in applying resource-based theory to product innovation in several ways. First, it explicates which resources are necessary for product innovation. At this point much resource-based empirical research has used secondary data, and therefore was limited to the proxies of organizational resources present in such data (Silverman, 1999). Second, the article shows how product innovation can serve as a vehicle for the renewal of firm competences/resources. Priem and Butler (2001) suggested there is a great research opportunity to study the accumulation of resources and capabilities. This study articulates the dynamic and reciprocal relation between a firm's product innovation efforts and its

competence use and development. The insight into the reciprocity of the product innovation–competence relation extends resource theory by examining not only how competences are used in product innovation, but how they are built as well, and by examining how one competence can be used to build another. The findings of this study show that developing and marketing new products are activities that can expand the competence base of the firm, which in turn enables further new products.

The discussion of the renewal of firm competences draws on organizational learning concepts. This article shows how new products impact the firm's renewal path by applying March's (1991) distinction between exploitative and explorative modes of learning to the product innovation context. The findings show how product innovation functions as a tool for organizational learning, and thus contributes to firm renewal. In addition to offering the first application of March's distinction to product innovation, this article also presents an additional concept: the notion of a second-order competence, i.e., the competence at explorative learning. The extant resource/competence literature has not yet specified what might be the nature of a competence at adding competences to current stock. Collis (1994) suggested the notion of higher-order or meta-capabilities, which he defined as capabilities of the learning-to-learn type. Building on his notion, I define second-order competences as the ability to identify, evaluate, and incorporate new technological and/or customer competences into the firm. Second-order competences are important because they may help firms to mitigate path dependencies in their development, escaping from the trap laid by their current competences (cf. March's, 1991, 'competency trap'). Adding new competences to the firm's repertoire is important for its continued prosperity in a changing environment (McGrath, 2001). This article suggests that rather than trapping the firm, current competences may be used as leverage points to add new competences, which I refer to as 'competence leveraging.' Anand and Singh (1997) concluded that the redeployment of assets into new businesses is generally a poor strategy. This study suggests that the success of asset redeployment may be contingent on the firm's second-order competences.

This article also draws on the path dependency literature. This literature has mainly focused on technological path dependencies, caused by technological choices that lock the firm in or out

of certain technological trajectories (e.g., Arthur, 1989; Dosi, 1988; Ruttan, 1997; Schilling, 1998). Researchers of the dynamics of technological evolution demonstrated the path-setting effect of dominant designs (Sahal, 1981, 1985; Tegarden *et al.*, 1999). In addition to path dependencies caused by technological choices, this study highlights the path dependencies caused by choices for certain customers. Helfat and Raubitschek (2000) argued that a firm's product history constrains the firm's options for future product sequences. Resource-based theory explicitly acknowledges a firm's history as an antecedent to its current capabilities (Priem and Butler, 2001). My field data demonstrate that product innovation generates path dependencies by its effect on firm competences, which in turn influence the new products the firm is likely to develop and be successful at. The availability of competences relating to some technologies or customers promotes product innovations based on those competences, whereas the lack of competence relating to other technologies or customers leads to the neglect of other innovation possibilities.

The above literature streams are used in this article to develop a framework that depicts the dynamic relationship between product innovation and firm competences, and explains how this interplay over time generates firm renewal. After a description of the methodological procedure, the foundation of the framework is laid by describing the reciprocal linkages between firm competences and the products developed and commercialized by the firm. Drawing on organizational learning theory, new product projects are depicted as serving to further develop existing competences, or as vehicles for the firm to learn new domains of activity. Next, the relationship between new products and firm competences is examined over time to gain a dynamic understanding of how product innovation contributes to firm renewal. Then the framework developed in this article is evaluated in terms of its theoretical and managerial implications. The article concludes with noting the limitations of the present research, and makes suggestions for further research.

METHODS

I conducted a field study using interviews, observations, and documents as data sources from five

high-tech firms that produce physical business-to-business products, varied in terms of age, size, and level of diversification. Research sites were selected to achieve a diverse sample that provides many possibilities for comparison, which enables richer theory development (Glaser and Strauss, 1967; Strauss and Corbin, 1990). I intended to contrast firms that were different in terms of their variety of resources and products, and that were at different stages of development (i.e., start-up vs. mature). Rouse and Daellenbach (1999) called for a rich, detailed investigation of the nature of firm resources through comparative case studies. A multi-site study allows for cross-site comparison and allows the researcher to see idiosyncratic aspects of any one site in perspective (Miles, 1979). The research sites are briefly described in Table 1. Table 2 contains comparative data instances for each case relative to each of the key constructs in the theoretical framework that are developed in this article.

Triangulation of various types of data collected through different methods can overcome the limitations of one method by counter-balancing the weaknesses of one method with the strengths of another (Jick, 1979). I used various types and sources of data to provide a rich and solid foundation for the theory development. I conducted 34 interviews with organizational members involved

in new product development to assess their perspectives on and experiences with new product development. Some of the reports by interviewees were retrospective (Miller, Cardinal, and Glick, 1997), other reports were contemporary with the activities they described. Interviewees were drawn from multiple functional areas (e.g., R&D, marketing, manufacturing), and from various organizational levels. Data about development processes and projects were compared and integrated across informants. Interviews commonly lasted from 45 minutes to two hours, and were tape-recorded. The tapes were transcribed verbatim, which generated about 1000 pages of transcripts.

I supplemented my interview data with observations of selected activities in the sites, such as daily activities relating to new product development and new product meetings. Observations lasted from one to four hours. I was known to be a researcher by participants in the setting, and participants were aware of my research topic. I had a passive presence and was unobtrusive so as not to interfere with ongoing events and activities. This allowed me to gain first hand exposure to the processes under study, instead of solely relying on interviewee accounts. I kept a journal that includes field notes and reflections on the progress of the study. In addition, I

Table 1. Research sites^a

Firm pseudonym	Areas of activity	Age	Size: # employees/annual sales in \$ million	Level of diversification	Number of interviews/observations conducted
CHEMAN	Components for chemical analysis instruments	12 years	100/15	Several related product lines	8 interviewees 10 interviews 6 observations
ZAP	Amplifiers/metal bonding/engineering solutions	2 years	8/2	3 diverse areas of activity	4 interviewees 6 interviews 4 observations
ULTRASONIC	Non-destructive testing instruments	50 years	200/30	1 area of activity dominates, but is SBU of conglomerate	6 interviewees 7 interviews 2 observations
COMP	Hardware peripherals and network integrator	20 years	12/3	2 related areas of activity	3 interviewees 4 interviews 2 observations
TELECOM	Telecommunications equipment	40 years	1000/150	One area of activity dominates	5 interviewees 7 interviews 6 observations

^a Figures are approximate to protect confidentiality.

Table 2. Comparative data from research sites

Construct (definition)	CHEMAN	ZAP	ULTRASONIC	COMP	TELECOM
Customer competence (ability to serve certain customers)	Sampling kit made in continuous exchange with customers—Analytical lab customers for development of columns for specific compounds	Relations with government/military agencies, understanding of grant procedure—but no relations with commercial customers	Relations with industrial customers (various industries) of nondestructive testing ultrasound instruments, good reputation and brand name	Good relations with local businesses, reputation as computer solution provider	Reputation and relations with customers in wireline telecom market, especially cable TV operators
Technological competence (ability to make a certain product)	INERT technology, which allows for coating of metal with glass—fused silica technology	Metal-forming technology enables contraction of metal without contact—Nonlinear, high-efficiency amplification	Ultrasound diagnostic signal generation and display	Skills in peripheral integration and network integration	RF signal transfer, amplification
Exploitation (developing a product that draws on existing resources)	Added enormous variety of fused silica columns for detection of variety of compounds	Every commercial product involved exploration	Flaw detector with color (as opposed to monochrome) monitor	Hardware for portable video editor built on existing technological competence	New editions of amplifiers for cable TV customers
Exploration (developing a product that requires new resources)	Metal columns required building of INERT process—Developed ability to coat aluminum with INERT	Bicycle frame made through metal forming requires building relationship with bicycle manufacturers	Medical ultrasound diagnostic devices would require building relationship and reputation in medical industry	Portable video editor involves exploration of various potential customers (e.g., military, sports teams, TV stations)	Wireless products require new customer competence—Fiber optic products require new technological competence

(continued overleaf)

Table 2. (Continued)

Construct (definition)	CHEMAN	ZAP	ULTRASONIC	COMP	TELECOM
De-/Re-linking (uncoupling of a product with the competence it embodies)	De-/Re-linked INERT from columns to cylinders	Finding applications for metal-forming technology—for amplification technology	De-linked its customer competence in NDT market, and re-linked it with software development skills to form analysis software	Apply skills in computer hardware and peripherals to video editor	De-link signal amplification from wireline market and apply to wireless market
Path dependency (future stock of resources is constrained by prior stock)	Persistence in pursuing analytical lab markets	Committed to commercialize existing in-house technologies	Stayed in industrial applications of ultrasound (did not enter medical)	Built on existing skills in hardware and peripherals to expand business	Continued to serve only telecom customers—but did expand technology base (e.g., optics)
Marketing competence (ability to develop new customer competences)	Used network of contacts and direct mail to find markets for INERT—self-admitted low marketing competence	Didn't know how to identify and assess potential markets for its technologies	Avoided medical market because would require building new customer knowledge, sales channel, and reputation	Was unable to make significant sales in new markets (only one video editor sold)	Difficulty building relations with phone companies
R&D competence (ability to develop new technological competences)	Incorporated and further developed INERT technology	Developed new type of signal amplification (nonlinear)	Have skills for making medical diagnostic devices	Developed and integrated hardware and software for portable editor	Successfully explored fiber optic technology

gathered organizational documents, such as new product proposals, new product process reviews, product announcements, memos, product catalogs, business plans, annual reports, meeting minutes, press releases, prints of web pages, and business press articles.

I provide a thick description of practitioner perspectives and experiences, while avoiding idiosyncratic findings by conducting a comparative analysis of five firms (ranging from a recent start-up to a mature, diversified firm). My first-hand exposure to the natural setting of new product development allowed me to gain an appreciation of the different types of product innovation from the firm's perspective. I had regular contact with informants at the sites over a 2-year period, which allowed me to track the development of each firm's new product activities over time.

I used the extended case method (Burawoy, 1991) as a guide to data analysis. This methodological approach uses empirical data gathered through case study to reconceptualize and extend theory. This study contributes to the integration of concepts and theories by using the extended case method, which aims to integrate and synthesize existing bodies of work. Burawoy (1991: 26), the developer of this method, made this observation: 'The generation of theory from the ground up was perhaps imperative at the beginning of the sociological enterprise, but with the proliferation of theories reconstruction becomes ever more urgent. Rather than always starting from scratch and developing new theories, we should try to consolidate and develop what we have already produced.' In contrast to the grounded theory approach, the primary focus of the extended case study is not to build *new* theory. The goal of the extended case method is to integrate and extend *existing* theory. The researcher examines the literature relevant to his/her problem area, and employs the empirical data to fill in its gaps, reveal its flaws, elaborate its meaning, and extend its coverage.

The extended case method approach goes through many cycles of confrontation between data and theory, in each iteration directing the analyst to additional data and drawing on additional concepts and theories. The extended case method consists of two 'running exchanges' (Burawoy, 1991: 10–11): between literature review and data analysis, and between data analysis and data collection, represented as: literature review \Leftrightarrow data analysis \Leftrightarrow data collection.

The first running exchange involves the interplay of existing concepts/theories and analysis of empirical data. In the extended case method, intensive analysis of the data and exploration of the scholarly literature occur in conjunction. Data analysis points to relevant concepts and theories in the literature, while simultaneously the literature provides conceptual frameworks to aid in the interpretation of the data. The second running exchange calls for continuously moving back and forth between data collection and analysis. The analysis of initial data (itself informed by the first exchange) suggests additional information to be collected.

The initial data collection at each firm focused on developing an overall understanding of the process of new product development at that firm, using a standard interview guide. In later interviews I asked more specific questions to refine and elaborate themes that emerged from the analysis of earlier interviews, and to check factual data. During all interviews, I encouraged informants to illustrate their statements with specific events and examples from specific projects. Data collection stopped when theoretical saturation was reached (Strauss, 1987), i.e., when additional data resulted in minimal incremental understanding (Lee, 1999).

I thoroughly read interview transcripts, observation notes, and documents looking for themes and patterns (Miles and Huberman, 1994). Critical passages were highlighted and coded, and initial interpretations were recorded in marginal notes. When reading and analyzing transcripts, field notes, documents, and scholarly literature I generated memos. Memos are brief analytical notes, i.e., little pieces of insights that the researcher achieves as he/she proceeds with the analysis (Strauss, 1987). I continuously matched and contrasted memos to refine theoretical understanding (McCracken, 1988), and I systematically compared the emergent theoretical interpretations contained in the memos with the evidence from each case to assess how well or poorly they fit with the case data (Eisenhardt, 1989). This iterative process of constantly comparing emergent theory and data led to additional, often more qualified and refined memos. This approach to theory construction is highly similar to that of Rafaeli and Sutton (1991: 757), who developed their insights by 'an iterative process of traveling back and forth between the data, pertinent

literature, and emerging theory.' As the study progressed, I sorted these memos and grouped them to arrive at conceptual clusters (Berg, 1989). Conceptual clusters are sets of closely related analytic ideas, for instance, 'resources,' 'linking/delinking/relinking,' 'leveraging competence,' 'path dependency,' and 'second-order competence.' These conceptual clusters formed the basis of the organization of the presentation of findings (see Table 2).

To test the credibility of my interpretations of the data, I subjected my analysis to member checks (Hirschman, 1986; Lincoln and Guba, 1985). I checked my emerging insights on an ongoing basis with my informants, asking for their feedback, sometimes in a second interview. In addition, I made presentations of my findings to the participating firms. The member checks served to revise and hone the findings discussed below. The four members of the committee supervising the dissertation of which the present research was part served as research auditors, helping to establish the dependability and confirmability of the present findings (cf. the recommendations by Lincoln and Guba, 1985).

NEW PRODUCTS AND FIRM COMPETENCES

This section will demonstrate that technologies and customers are key competences in new product development, show the reciprocal relationship between new products and these competences, and present a new product typology that builds on the insights into this relationship. The findings in this section emerged from the interplay of literature, especially on competence/resource-based theory of the firm and organizational learning, and analysis of the data.

Technological and customer competences in product innovation

Product innovation requires the firm to have competences relating to technology and relating to customers, and each of these competences is constituted by a set of resources. The literature has used a plethora of terms (e.g., resources, assets, skills, capabilities, competences) and has apparently not arrived at a consensus regarding the meaning of these terms. For the present analysis the more comprehensive term 'competence' is

used to refer to an ability to accomplish something by using a set of material (e.g., equipment, machinery, mail list) and immaterial resources (e.g., manufacturing know-how, understanding of customer needs). A competence thus has material as well as cognitive components. My usage is consistent with Grant (1991), who defined a capability (he uses this term interchangeably with competence) as the capacity for a set of individual resources (e.g., patents, know-how, brand names, equipment) to perform some task or activity: '... the capabilities of a firm are what it can do as a result of teams of resources working together' (Grant, 1991: 120). I follow the definition of competence formulated by McGrath *et al.* (1995: 254): '... a purposive combination of firm-specific assets (or resources) which enables it to accomplish a given task.' The two key tasks involved in product innovation are to physically make the new product (which is possible when a technological competence is present) and to sell that product to certain customers (which is enabled by the presence of a customer competence). An extensive literature has pointed out that these are the two key tasks in product innovation (e.g., Cooper, 1993; Song and Parry, 1997a), and that the key resources needed to accomplish them can be classified as market-related and technically-related (e.g., Danneels and Kleinschmidt, 2001; Mitchell, 1992; Moorman and Slotegraaf, 1999). Figure 1 presents the reciprocity of firm competences (customer and technology) as well as their constituent tangible and intangible resources, as they were abstracted from informant descriptions of the resources required for various projects. Below I provide a few case examples to illustrate some aspects of these competences.

Customer competence gives the firm the ability to serve certain customers.¹ Customer competence is constituted by such market-related resources as: knowledge of customer needs, preferences, and purchasing procedures, distribution and sales access to customers, customer goodwill or franchise reflected in the reputation of the firm and its brands, and communication channels for exchange

¹ I use the term 'customer competence' in preference to 'market competence' because the former is more specific. 'Market' denotes a broader concept, namely the exchanges of goods and services between customers and suppliers, and the effects on these exchanges of environmental factors such as technology, laws, culture, and competition. In contrast, the term 'customer competence' emphasizes customers as the central element.

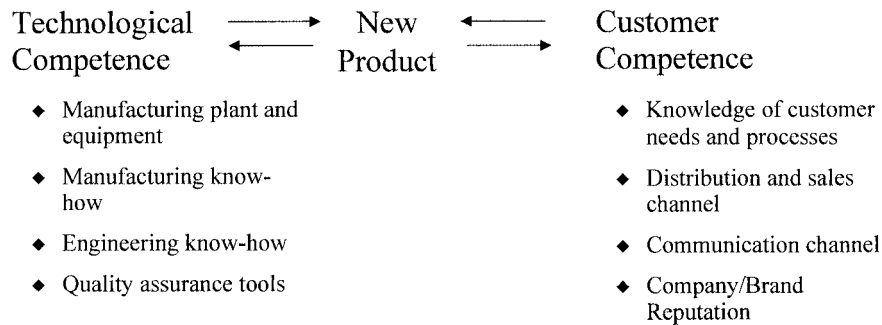


Figure 1. Product innovation as linking of technology and customer competences

of information between the firm and customers during development and commercialization of the product. For instance, at CHEMAN, access to customers and an open channel of communication facilitates development of products:

I rely on my contacts, I call them and say, 'We're thinking about developing a sampling kit. What would you like to see in a sampling kit?' So I find those people, get their ideas, and then make them a product. It's a very synergistic relationship in which we're both talking: 'I'm thinking about doing this sampling kit and I thought of this.' And he says, 'Well you ought to do this.' And I'm like, 'Yeah, and we ought to do that, too.' The next thing you know you've got an idea for a product. (CHEMAN Product Line Manager)

I started talking to the customers we had, saying, 'Why wouldn't you use more of this?' And they said, 'Well, you can't bend it very tightly.' And I said, 'Well, if we pre-bend it and then coat it, you can put it in your system without any stress.' I kept developing a relationship with the instrument manufacturers. (CHEMAN Manufacturing Manager)

In contrast, TELECOM's wireless products are closely aligned with its technological competences, but cannot draw on TELECOM's existing customer competences. The following quote illustrates some aspects of this lack of fit: channels of distribution and sales, the reputation that the company has with customers, and relationships with customers:

Our core competency, what TELECOM is known for, is developing RF amplifiers. We do that for wireline networks that do broad band signal generation. Well, one of the things we're looking at from a diversification standpoint is there's all these wireless networks going up all around the world. And those signals need to be amplified, too. And in a way there's not that much difference. You're

amplifying a signal and instead of connecting it to a piece of cable, you're just shooting it through the air without a wire. That's a booming market. But our sales channels right now just sell to cable companies. We need to have customer relationships. If we went to the cellular show they would say, 'Who the hell is TELECOM?' (TELECOM CEO)

Technological competence gives the firm the ability to design and manufacture a physical product with certain features. Technological competence is constituted by such technically related resources as: design and engineering know-how, product and process design equipment, manufacturing facilities and know-how, and procedures for quality control. These quotes present some dimensions of technological competence:

For example in the case of going from fused silica to metal, that process was much more involved because we had to develop new technology for making the metal columns. It involved developing new manufacturing techniques, developing quality assurance techniques, looking at even how the product is packaged or handled. (CHEMAN Director of New Products)

We have several fiber optic projects in place for this year. And our competency level is coming way up. Hired new engineers for it. We couldn't use the same research people. We needed a new skill. And some capital expenditures. New test equipment, new equipment to handle the fiber. New ways of manufacturing. We have to protect part of the manufacturing area because of the stray laser lights. A lot of safety issues. (TELECOM Marketing Director)

Linking technological and customer competence

Understanding the new product development process requires a simultaneous view of customers

and technology, as argued by Dougherty (1992: 78), '... a product constitutes the integration of markets and technologies, and cannot be understood as one or the other separately. This point is emphasized because both academics and practitioners often refer to technology alone or a market when they speak of products. A product is not a technology nor a set of customers, since, for example laser technology underlies a wide range of products, such as fiber optic networks or cutting tools, which can be marketed to a wide variety of customers, from banks to surgeons.' Ghemawat (1991a) noted that in looking at product innovations, students of marketing have focused on customer base and students of technology on know-how, while these two key strategic resources are intimately connected. Thus, it is necessary to address the impact of both on product innovation simultaneously, rather than considering each separately.

New product development is a process of linking technology and customers (Dougherty, 1992). On the demand side, customers' needs motivate them to seek certain benefits of products. On the supply side, a firm's technologies enable it to provide certain benefits through the attributes of its products. The notion of 'linking' emerged from the contrast of ZAP with the established firms. At ZAP (a recent start-up) technology-customer linkages were not yet established. Contrasting ZAP with established firms and tracking events at ZAP during the study period revealed the construction of the linkages over time. Discussion of technology-customer linking appeared most explicitly in data from this start-up firm. At ZAP making linkages was at the heart of discussions, as observed during meetings and noted in interviews. The linkages were problematic and had to be actively created. In contrast, at the more mature firms linkages had been made, and over time had become taken for granted.

New product development requires bringing together two competences: competence relating to technology and competence relating to customers. This idea is depicted in Figure 1. That two types of competence have to come together in new product development has implications for the types of new products the firm pursues. The ready availability of competence relating to some technologies or customers promotes product innovations based on those competences, whereas the lack of competence relating to other technologies or

customers leads to the neglect of other innovation possibilities.

Penrose (1959: 70) saw resources as pieces of a 'jigsaw puzzle' which a firm combines and recombines to produce outputs. Applied to product innovation this means that new products are the result of various combinations of customer and technological competences of the firm. The skill of the firm at combining and recombining (i.e., delinking and relinking) customer and technological resources could be thought of as its integrative capability (Henderson and Cockburn, 1994). Creating a new product requires making a connection between (potential) customers and (potential) technologies of the firm. I add 'potential' in parentheses, because the firm may or may not have the competences it requires for a new product. In developing a new product, a firm may already have the technology and/or the customer competences needed for it, or it may build these competences. Following March's (1991) organizational learning theory, I label these options exploitation versus exploration. This usage is consistent with Sitkin, Sutcliffe, and Schroeder (1994), who defined exploitation as learning activities involving the use of resources the firm already has, and exploration as learning activities that lead to the addition of new resources. These organizational learning concepts help to understand how organizations use and develop technologies and customers as competences through product innovation. Maidique and Zirger (1985) developed the idea of learning about customers and technologies through product innovation. Following Maidique and Zirger (1985), I view new products as vehicles for organizational learning about technology and customers. Product innovation can serve to exploit existing or to explore new competences. Therefore the arrows in Figure 1 are bidirectional, in order to depict the reciprocity of the relation between product innovation and competences. March (1991, see also Levinthal and March, 1993) argued that organizations engage in two broad kinds of learning activities. They engage in exploitation, the use and further development of existing competences, and they engage in exploration, the pursuit of new competences. The returns from exploitation are short term, near, and clear. Exploitation supports current organizational viability. Exploration involves searching out and developing new competences. Compared to exploitation, returns from exploration are more remote in

time, distant, and uncertain. Knowledge developed through exploration activities results in a greater ability to adapt to changes, and thus supports future viability. In a dynamic environment existing competences may become obsolete, and new competences may be called for. Exploration enhances the adaptation of the organization to a changing environment because it increases the variance of organizational activities (McGrath, 2001).

Types of product innovation

Simultaneously considering exploitation and exploration of customer and technological competences leads to the matrix of new product types depicted in Figure 2. This typology shows how technologies and customers as firm competences impact new product development and are themselves impacted by new product development, and how these resource dynamics influence what type of new products a firm pursues.²

The two types of competences required for product innovation constitute the two dimensions along which products can be new to the firm: a new product can draw on existing technological competences or require new technological competences, and draw on customer competences that the firm already has or require a new type of customer

competence. Since the degree of newness is continuous, rather than dichotomous, the dimensions are indicated by arrows. In other words, the typology consists of ideal types. In practice, specific innovations are more or less like the ideal types (cf. Doty and Glick, 1994).

In pure exploitation, a firm uses both existing technological and customer competences. In pure exploration, the new product is a tool to build new competences relating to both customers and technologies. There are also two intermediate cases. Both technologies and customers are firm competences that can be leveraged. Leveraging technology (exploiting technology/exploring customers) implies appealing to additional customers through developing products based on an already achieved technological competence, whereas leveraging customer competence (exploiting customer competence/exploring technological competence) involves building additional technological competences to appeal to a greater share of existing customers' needs.

I compared and contrasted the new product projects within and across the sites to gain an understanding of the key characteristics on which these types of projects differ. Table 3 presents an overview of the characteristics of the types of innovation. Judging the viability of a new product has two main dimensions: technological assessment and market assessment. Technological assessment involves judging the technological feasibility of the product (i.e., can the firm produce the physical product with certain features). Market assessment involves judging the market potential of the product (i.e., will the firm be able to sell the product). The following quote shows how both kinds

²I argue that this competence-based typology presents an advance over the classic new product typologies: the Booz, Allen, and Hamilton (1982) typology and the Ansoff (1957, 1965) Growth Vector Matrix, since it provides better insight into the potential for firm renewal through product innovation. The competence-based typology provides a better understanding of the nature of various types of product innovations, their various challenges and requirements, and their implications for firm renewal. A more detailed comparison between these new product typologies is available from the author.

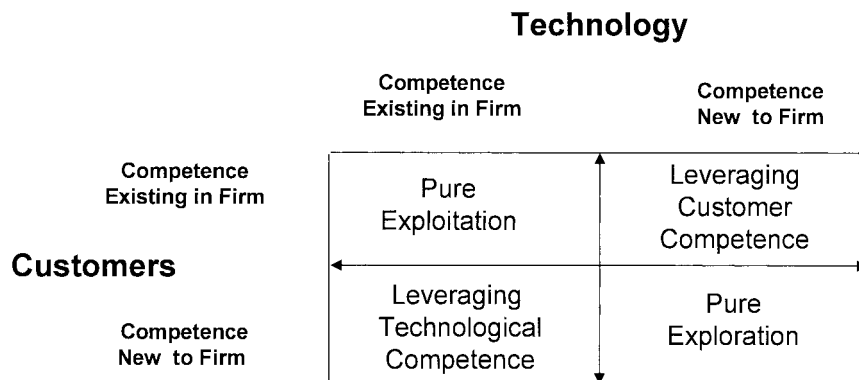


Figure 2. Competence-based new product typology

Table 3. Characteristics of product innovation types

<i>Characteristic</i>	<i>Type</i>			
	Pure exploitation	Customer competence leveraging	Technology competence leveraging	Pure exploration
Market potential assessment	Relatively easy	Relatively easy	Relatively difficult	Difficult
Technological feasibility assessment	Relatively easy	Relatively difficult	Relatively easy	Difficult
Impetus from current customers	Strong	Strong	Weak	Weak
Returns	Relatively certain	Relatively uncertain	Relatively uncertain	Uncertain
Needed scope of market search	Narrow	Narrow	Broad	Broad
Needed scope of technological search	Narrow	Broad	Narrow	Broad
Competence to be acquired	None	Technology	Customers	Technology and customers
Project duration	Short	Medium	Medium	Long

of assessment are facilitated by the firm's competences:

Historical data give you validity. If you're targeting existing customers, it will give you a sense of how attractive the market is. If using your current technology, it will allow you to evaluate the feasibility of the technology that you're going to use in the product. Historical data serve to verify your forecast. If a product line manager says to me, 'I can sell a hundred new flaw detectors because last year I sold 75 of this kind and with this feature I know I can sell 100.' There's a basis for that forecast that I as a manager can live with and feel comfortable about. Yeah, if we had color screens we could sell another 25 percent. Now if he comes to me and says, 'I want to sell something to customers we don't have.' Then how do I believe in his 100 forecast? It has less validity. And not only that, engineering has not produced this product. So that also has less validity. Without either one of those as a basis, you're really flying blind. (ULTRASONIC General Manager)

Judging the market potential is relatively easy if the product exploits existing customer competence. Knowledge about customers facilitates assessment of the market potential for new products. It is much easier to assess the market potential if the new product is aimed at existing customers.

You know, we look at the market. Because we're generally working with products within the

chromatography market, which we have a pretty good feel for. So if someone comes in and says, 'I want to develop this particular product that's going to do this,' we'll ask ourselves how many customers potentially would want it. (CHEMAN Director of New Products)

Similarly, technological assessment is easier within the domain of current technological competence.

I think a lot has to do with whether you've had a lot of experience. For instance, I have been in applications for quite a number of years and I can recognize potential uses because I have a pretty good familiarity with the technologies and can recognize what would work. (ULTRASONIC Engineering Manager)

It is characteristic for exploiting an existing competence that the returns are fairly clear and certain (March, 1991), as in this case of exploiting customer competence:

If we know there's a product that customers are asking for, we're going to go back and develop the product that will solve their problem. And that does make more sense because you know you have a built-in market for that product as soon as you've developed it. (TELECOM Marketing Director)

In contrast, the returns from exploration are unclear, uncertain, and remote in time. The

following quote illustrates explorative learning at COMP. The firm learned a great deal about the potential customers and competitors for a new product it had developed. However, this learning came at high cost and without immediate financial return.

We have been trying to get this portable video editor accepted in the market. It's a computer with a high-end video card and sophisticated graphic software. The hardware part of it was familiar to us. The editing software we were unfamiliar with. And we were going after new customers. We were unfamiliar with the editing process, unfamiliar with how people in that industry think. If you don't already know the market or the technology that you're getting involved with very well, that injects a level of risk. With the video editing project we found out stuff we didn't know. We learned a whole lot more about video production and television stations and editors and so forth. When we started to work with people who really do video editing we started to learn. We heard their objections, started to understand how they operate and so forth. We're also learning now there are others that are producing a portable system. So one thing that I'm learning is that we have to be careful where we extend ourselves. It isn't to say that we can't, but the cost of doing so is much greater. We are paying a big price up front for all of the things that we're learning. We spent so much just to get to the point where we're beginning to understand what we're up against, and we haven't sold a single unit. (Director and Founder of COMP)

Current customers have a strong impetus toward the exploitation of existing customer competence (cf. Christensen, 1997; Christensen and Bower, 1996). The current data support that existing customers form a particularly strong driving force of new product development.

A lot of times it's through our technical service hotline. We have an 800 number that people call in and we get talking to the customers and they say, 'You know it would be nice if you had something that did this.' 'Oh, you need something that does that? Well we'll tell our engineering department here.' They say, 'Hey, that's a good idea. We can sell those things.' We've gotten so many ideas from our technical service hotline. (CHEMAN Manufacturing Manager)

Many of the ideas for our products come from our customers. They'll tell us, 'If you only made this item we would probably buy that.' A lot of times it comes to our door. People say, 'Would you have a column that will do this, this and this?' If there's an application that people ask about often, I'm thinking, 'This is an application I need to run.' And if I can't find a product that we currently have that

works with it, I might go to R&D and say, 'Can you help me develop a product that will do this, this and this?' (CHEMAN Research Chemist)

Exploring new customers, as opposed to exploiting an existing customer competence, requires a proactive approach. It requires building an understanding of the needs of customers that are as yet unidentified.

Because to go into new markets first of all you got to know that market and you've got to know how to address the market. But you got to have application knowledge, too. For example if we wanted to go into the medical area, we wouldn't have any clinical knowledge. If we want to be a real player in that, we would have to develop that. In contrast, something we do have that we can leverage is very strong application knowledge in industrial non-destructive testing. We know the customers. We know how they use the product. We know what they want. (ULTRASONIC Product Manager)

This interviewee from ZAP relates her start-up firm's challenge in exploring customers; the identification and evaluation of different types of potential customers:

It's always a struggle because the electronics that we have, because of its advantages, has so many different areas that it can be applicable to that we have a tendency to want to go after everything. We're looking at aircraft applications, we're looking at space applications, you know, there's still a lot of diverse marketplaces that our electronics fit. And so that's going to be a continual challenge to look at those programs that make the most sense. (ZAP Director of Research)

Once the potential customers have been identified the firm needs to develop a relationship and communication channel with the new customers.

It's a learning experience for us to try to market into a totally new market area. And I don't know whether we're doing a good job or not because we really don't have a lot of previous experience with it. We've tried some other routes and we're attending some trade shows we never went to before. We've rented mailing lists that we've never rented before. And hopefully we're targeting the right people. (CHEMAN Director of New Products)

I couldn't just knock on [disguised] Air Force Base's gate and say, 'Is there anyone in here that needs a coating for this application?' So you have to establish contacts and build rapport with people

in different industries. (CHEMAN Manufacturing Manager)

Exploring customers requires a deliberate effort at seeking input from new kinds of customers, and it is not clear which customers to seek that input from. Exploring customers requires building relationships with new customers and developing knowledge about those customers. The company cannot draw on existing relationships with customers.

If we develop a product that doesn't fit into the chromatography business, we need to upfront have a much better plan in terms of marketing. What customers should we be trying to reach? How are we going to reach them? At what trade shows would we display this product line? What magazines would we want to advertise this product in that we're not advertising in now? So there's a lot more involved in it. Typically you can't sell it through the normal channels. We can't sell through our sales people because they're not going to be visiting the customers that want this new product. We can't sell it through the distribution chains that we sell through because typically they're serving laboratories. If we develop a product that really goes outside the laboratory, there's no way for us to market that with our standard techniques. Whereas in the past every product we developed really fit into the laboratory setting. If the product is not designed for a laboratory, you have to find some new way of marketing that. (CHEMAN Director of New Products)

I also observed the process of exploring customers in a meeting with COMP. The meeting was intended to evaluate alternative markets for a new product in development at COMP. The participants made statements such as:

Slowly our market is getting defined. We're trying to find customers groups with the highest interest. ... We don't know who we are competing against. ... We don't know what to shoot at, it's like target practice in a very dark room. (COMP Managers)

Leveraging firm competences through product innovation

Figure 3 summarizes the main innovation activities in each quadrant of the product innovation matrix. The central idea of the matrix is again 'linking,' building on the premise that new product development is in essence about making linkages between technological and customer competences.

Pure exploitation involves making new linkages among existing competences. In contrast, leveraging involves drawing on an existing competence, while using it as a stepping stone to build a new competence. Hamel and Prahalad (1994) recommended leveraging core competence as a faster and less risky way for the firm to grow and renew itself. They argued that in order to leverage core competences, managers need to escape a product-centric view of their firm, and examine the capabilities on which their products are based. According to Hamel and Prahalad (1994: 227) '... in defining core competencies, managers must work very hard to abstract away from the particular product configuration in which the competence is currently embedded, and imagine how the competence might be applied in new product areas.' Hamel and Prahalad (1994) argued that products embody competences, but competences are not product-specific. In other words, core competences transcend any particular product. One product may embody several competences, and one competence may underlie many products. Teece (1982: 45) argued that

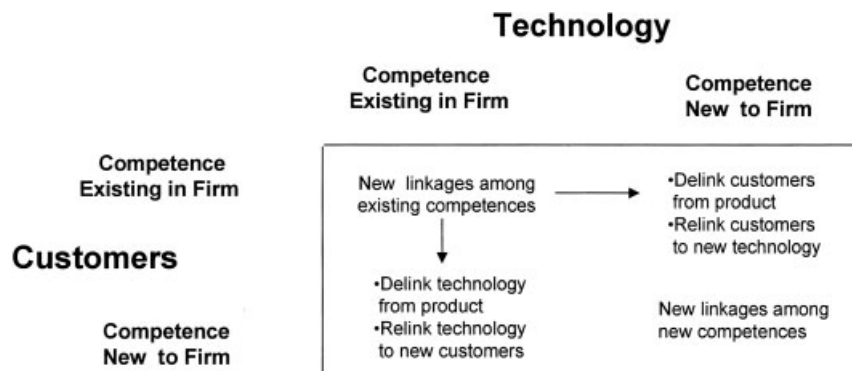


Figure 3. Linking activities by type

'... a firm's capability lies upstream from the end product—it lies in a generalizable capability which might well find a variety of final product applications.' Building on these insights, I argue that leveraging-type new products involve abstracting away from the particular product in which the competence is currently embedded, identifying the competence in its own right (termed 'delinking'), and subsequently linking that existing competence with a new competence (termed 'relinking') to form a new product.

Projects that leverage customer competence can draw on existing customer competence, but require building a new technological competence. The knowledge and access that a company has to its customers facilitates development of these types of products:

Sometimes we'll look at products that our customers are buying that may not exactly be chromatography but are closely related. Like chemical standards [compounds used to calibrate measurement equipment], that's not really chromatography, but they're used by chromatographers. We also got involved in sample preparation products, which again are not chromatography per se, but are a related product. Most of our product expansion has been in products that are in some way related to chromatography as opposed to something totally different in a new market area. You know, targeted at the same customer basically. ... Because we feel we have a better handle on that, plus we have a much better way of reaching those customers because they already make up our customer base. We have our mail lists, for example, that we mail literature to. Those names are already on our mailing lists. So it makes more sense than to try to get out to a totally new area and try to market to customers we don't really understand or have much data on. (CHEMAN Director of New Products)

ULTRASONIC provides another example of leveraging customer competence:

Our customers made us aware of the opportunity to develop and sell software. In some cases the software was developed at customer request. The customer would say, 'Can you provide me with a way of doing this?' Like in particular with my product, I had a DOS based program that allowed a customer to generate reports. We had a guy here who was kind of proficient with DOS and he developed that. When we developed it for a few customers at their request we recognized that this is something that could be used. And we started selling it. So over a period of time we just learned

that this stuff had value. (ULTRASONIC Product Line Manager)

As is generally the case with products that exploit current customer competence, existing customers provide a strong impetus for projects that leverage customer competence. Many of these types of products come about as the firm reacts to requests from customers to provide them with additional products.

Our customers asked us if we also offered chemical standards. So we decided that that was a good business to be in because of that. (CHEMAN Director of New Products)

Similar to the pursuit of products that leverage customer competence, product innovations that leverage technological competence involve two major activities. The first is abstracting away from products to the technological competence that is embedded in the products ('delinking'). All of the informants had difficulty distinguishing products from technologies, and very often answered the question to identify the company's technologies with enumerating its product lines. The following is a typical response:

I guess I'm not really sure what you're asking, because I could just give you a rundown of the different product lines we have here. (CHEMAN Manufacturing Manager)

Technological competence is thus not obvious; it is hard to identify. This points to the tacitness (Teece, 1982) of technology as an organizational competence. Decoupling the linkage between the technology and the product involves stepping back from the current product, and identifying what technological competence(s) is (are) embedded in it. The second activity in leveraging technology, 'relinking,' involves recoupling the technological competence with a customer competence the firm does not yet have.

Both the leveraging options build on the notion that resources provide productive services that may serve a variety of uses in the firm (Mahoney and Pandian, 1992). In other words, competences have a certain degree of fungibility: they are capable of multiple uses (Teece, 1982). The resource perspective has emphasized that resources are often not fully used, and that each firm has pools of unused productive services (Penrose, 1959). Penrose (1959) argued that the possibility of extracting

more services out of current resources presents renewal opportunities to firms. Internal inducements to expansion arise from the presence of underutilized resources within the firm, 'the original incentive to a great deal of innovation can be found in a firm's desire to use its existing resources more efficiently' (Penrose, 1959: 84). In the present framework, technological and customer competences, in various combinations, provide the potential for many products. The next section argues that many of these new product options may not be pursued at a given time.

PATH DEPENDENCIES IN COMPETENCE DEVELOPMENT

Essential in the resource-based view of the firm is its dynamic perspective; how the firm evolves and grows over time through its deployment and accumulation of resources. According to Lewin, Long, and Carroll (1999: 538), 'the cumulative effect of exploitation and exploration adaptations is reflected in the firm's legacy.' Product innovation is a key firm activity through which these resource dynamics take place (Eisenhardt and Martin, 2000; Helfat and Raubitschek, 2000). In this section, I will examine the consequences of the link between resources and product innovation for the direction of firm renewal. Itami (1987) argued that business activities are both inputs and outputs to the firm's assets; they both use and create them. Dougherty (1995) argued that internal ventures and a firm's competences are mutually constitutive, since each contributes to and builds on the other. Similarly, product development is both input and output to the firm's competences: it both draws on and creates competences (cf. the reciprocity depicted in Figure 1). The matrix in Figure 2 offers insight into the resource dynamics through product innovation over time.

Penrose (1959) argued that resources are the foundation for firm renewal, and that the accumulation of company resources impacts what direction of development is likely and possible for the firm. According to Penrose, the direction of innovation in a firm is not random, but is closely related to the nature of existing resources and the type and range of productive services they can render. This assertion is supported by this quote from CHEMAN:

We would never go into the aerospace industry unless there was some relationship in there before. We wouldn't start selling guidance systems or navigational equipment, or something like that. (CHEMAN Director of New Products)

ULTRASONIC provides another example of how existing competences narrow the scope of potential future firm renewal:

You are stuck with some kind of existing sales force. You have to take into consideration what you own, what you can do. Well I have a sales force that trumps around in the NDT [non-destructive testing] marketplace. So, yes, they can sell in the NDT marketplace. If I'm going to sell to medical customers, say if I had to go sell to dentists, I couldn't do that. I don't have the marketing and sales force capacity to do that. So I would have to reinvent the company. That would make another company. If you're not leveraging something, you're probably not even doing the right thing. Why would I go to a market that I know nothing about? You know, I don't have any sales force. I don't have any marketing knowledge and I don't have any product. Well why in the hell would I go there? (ULTRASONIC General Manager)

Technological and customer competences form stepping stones for the development of additional competences. The portrayal of the dynamic relationship between product innovation and competences builds on the 'dynamic capabilities approach' formulated by Teece *et al.* (1997). The term 'dynamic' refers to the renewal of competences to address changing environments. The dynamic capabilities approach emphasizes that firms face path dependencies as they develop their competences over time. Teece *et al.* (1997: 515) argued that '... choices about domains of competence are influenced by past choices. At any given point in time, firms must follow a certain trajectory or path of competence development. This path not only defines what choices are open to the firm today, but it also puts bounds around what its internal repertoire is likely to be in the future. Thus, firms, at various points in time, make long-term, quasi-irreversible commitments to certain domains of competence.' The stock of resources commits the firm to a certain domain of activity (Dierickx and Cool, 1989; Ghemawat, 1991b). The accumulation of resources (i.e., its flow, Dierickx and Cool, 1989) is path dependent as it depends on current stock, which itself results from prior accumulation (Collis, 1991).

The competence-based new product typology developed here allows insight into the role new products play both as a cause and consequence of path dependencies. Helfat and Raubitschek (2000) argued that a firm's product history constrains the firm's options for future product sequences. The

present data suggest that the reciprocal interplay between products and competences accounts for these path dependencies. Figure 4 illustrates the trajectory of renewal through product innovation at one of the research sites. New products serve as vehicles for exploring new competences, new

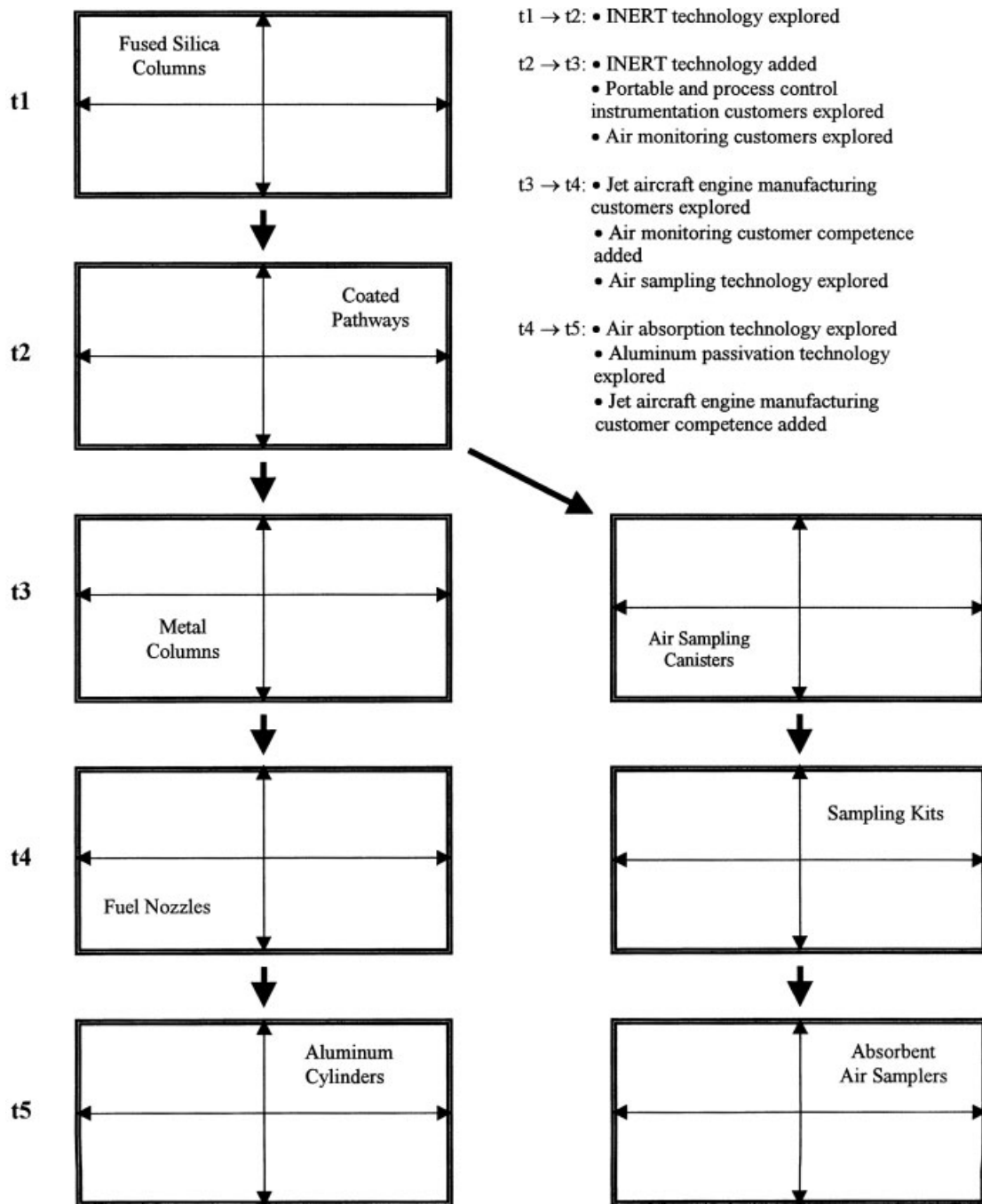


Figure 4. Competence exploration and exploitation at CHEMAN

competences are added to the firm's repertoire, and subsequently serve as a foundation for further products. Between t_2 and t_3 , a parallel trajectory of firm development branches off, leading CHEMAN into air sampling markets and technologies. The trajectory illustrates that new product choices at a given time depend on prior choices in product development, and the effect of these choices on company competences.

And it may be that our success with INERT gets us involved in other businesses. For example, if INERT was successful in the aerospace industry, we may start to look at other products within the aerospace industry that we could make and develop. Because if we served the aerospace industry, we could develop other products for them. (CHEMAN Director of New Products)

Most prior research on path dependencies has focused on technological selection (e.g., Arthur, 1989; Dosi, 1988; Ruttan, 1997; Schilling, 1998). The current findings highlight the role of path dependencies in customer selection. In the prior quote from CHEMAN, for instance, the competency to serve the aerospace industry makes further focus on this industry likely. The path dependency of competence use and accumulation through product development is clearly illustrated in this quote from ULTRASONIC:

More often than not we're taking new technology and addressing existing customers. But it sometimes then allows us to address new customers. For instance, there's some ultrasonic tests that require a considerable amount of judgment on the part of the ultrasonic inspector. We are developing software that will take some of the subjectivity out of the test, which would enable us to address customers that we're currently not marketing to. So there's an example of taking a new technology, the software, and selling it to new customers. . . . The one that comes to mind is an automotive application for which we are developing software that takes the subjectivity out of inspection of spot welds. And that's becoming more and more of an issue because of safety and crash tests that all these welds are, in fact, sound or good welds. We can ultrasonically inspect the weld. But that takes a skilled ultrasonic technician, which is expensive, and the auto industry would like to save money. They would like us to develop for them essentially a go, no-go gauge so that they can very quickly test these things and not have a skilled person. We're developing software that will take the information from the instrument and analyze it and turn a light green or red. If we could get to that point that would open

the door to automotive customers. In the past the automotive industry hasn't done ultrasonic testing of the welds at all. They were taking every 10th door off the assembly line and chiseled it apart and visually looked at every weld. We presented a method which allowed them 100 percent inspection of every single weld on every single door, and they didn't destroy it. So it opened up a new customer for us because they were never doing ultrasonics before. (ULTRASONIC Product Line Manager)

According to Teece *et al.* (1997: 515), 'Deciding, under significant uncertainty about future states of the world, which long-term paths to commit to and when to change paths is the central strategic problem confronting the firm.' The next section will examine the role of second-order competences in firm efforts to change paths.

SECOND-ORDER COMPETENCES

Collis (1994) suggested the notion of higher-order or meta-capabilities, which he defined as capabilities of the learning-to-learn type. Applying his notion to the present context of competence acquisition and use, I define a second-order competence as the competence to acquire first-order competences. In the present conceptual framework one could think of technological and customer competences as first-order competences. They involve the tangible and intangible resources needed for producing a particular product or addressing a certain group of customers. Second-order competences then sit at a higher level; they are not specific to a certain domain of knowledge and skill, but rather refer to the ability to learn new domains. Second-order competences can then be thought of as the ability to identify, evaluate, and incorporate new technological and/or customer competences into the firm, i.e., a competence at explorative learning by exploring new markets or exploring new technology.

I presented this notion to several informants. With some informants the notion did not resonate, or they showed little comprehension of it in follow-up questions and answers. This may be due to the high level of abstraction of the concept. With a few informants however, the idea of second-order competence did resonate, and they were able to elaborate on it and apply it. This TELECOM manager gave the following interpretation of the notion:

Pick a case. There's not a major defense company in this country that did not see the need to diversify into commercial applications. Not one defense company didn't make the point that 'we're going to diversify into commercial markets.' Now why is it that many failed? They failed because they had no marketing savvy, because they couldn't figure out how to get to these new customers, who could they possibly be, where are they, how do we reach them? And then when we reach them, what do we do with them? That is that ability to actually develop those relationships and do all that. (TELECOM New Business Development Manager)

Anand and Singh (1997: 106–107) interpreted the competences of defense firms in a very similar vein as the above informant: 'As a result of doing business with the government for long periods of time, specialized contractors have learned to operate in this environment. On the other hand, they have not accumulated any skills for marketing their product to any other kind of customers.' In other words, defense firms have a first-order competence that enables them to serve the defense market, but because they lack a second-order marketing competence they have difficulties serving other customers.

A second-order competence in identifying and acquiring new customer competences could be considered a marketing competence proper, operating at a higher level than a market or customer competence. This second-order marketing competence is akin to Day's (1994) characterization of marketing capability as consisting of market sensing and customer linking. Similarly, a second-order technological competence could be seen as an R&D competence proper. Both notions are supported by the TELECOM manager in a member-check interview:

So one is the R&D competence, the ability to harness technology to do new and exciting things. And the fact is, a lot of companies don't have a true R&D capability. That other competency that you mentioned is usually not thought of as a competency, but I really believe it is, and that's the ability to develop knowledge of customers, build relationships, gain access to them. The ability to actually identify who the customers are, how to get to them, what do you do when you get to them. How the hell do we reach them once we decide to go after them, in terms of channels to market. That's a major challenge, because what we're talking about is going through doors that we've never been through, facing faces that we've never faced and meeting people and developing relationships

on untested ground. It's time consuming, it's capital intensive, and requires a whole skill set. For me that is what I consider to be marketing skills. That's something that people underestimate, fail to invest in, fail to understand how long it takes, fail to understand the subtlety involved. (TELECOM New Business Development Manager)

The notion of second-order competences also corresponds with suggestions in the literature that firms vary in the extent to which they are good at accessing new markets or incorporating new technologies. For instance, Meyer and Utterback (1995: 302) noted that 'for technology-based firms, it is more difficult to learn about new markets than it is to learn about new technologies.' In other words, the absence of second-order competences may constrain the renewal options that firms pursue, for instance the lack of marketing competence in a technology-focused firm may inhibit renewal through expanding customer bases. On the other hand, second-order competences may mitigate the effect of path dependencies; i.e., marketing competence serves to overcome the history of serving particular customers and R&D competence serves to overcome the history of prior technological resources. In the firms studied here, evidence suggests that the lack of marketing competence restricted renewal, as firms were hampered by their inability to add customer competences. As Table 2 shows, marketing competence was less prevalent in these firms than R&D competence. Building a new customer competence involves identifying new customers, developing knowledge about those customers, and gaining access to them through sales and distribution channels. The following quotes from CHEMAN suggest that lack of second-order marketing competence impedes the exploration of new markets:

The marketing side of CHEMAN is probably the weakest point of the company. We're much more of a technology company than we are of a marketing company. Plus, in the past all of our products were always marketed to the same group of customers. If you go after new types of customers, and you don't have a very strong marketing side to the company, you can flounder. I mean we've had INERT [a technology to put a glass coating on steel] since I've been with the company. We've had that product for 8 years. And for the first 7 of those years we didn't know what to do with it. . . . Probably the biggest customers are people who are not existing customers. And finding those people is a lot more difficult. So there's a lot more prospecting work involved. So there's a lot more

burden on marketing. (CHEMAN Director of New Products)

It doesn't seem like we do market research to come up with the ideas for new products, I wouldn't say that we do a lot of that in marketing here. Our marketing focus is more in advertisements and making company publications. There really isn't a focus in marketing for trying to find new fields. Probably we should do more of that. (CHEMAN Research Chemist)

ZAP had used military grants to build its technological competences, but had to build customer competence in its efforts to commercialize its technology.

It's difficult to identify a customer in our area. There's no real mechanism for going out and finding a customer list, send out brochures to them and direct market. It's not very clear at all how we could do that. How do you identify who your customers are? What mechanisms are there that you can use to go out and find your customer and market yourself to that customer? Those are difficult questions. Our solution has been to market through existing, well-recognized companies that already have a customer base and sell through them. But we have no idea who they're selling to. It could be anybody from Sony to the University of Wisconsin. (ZAP Research Director)

ULTRASONIC informants explained their company's decision not to leverage its ultrasonic (i.e., technological) competence into the medical market by arguing that they would have difficulty adding a new customer competence to serve this market. At the same time they emphasized their company had the R&D skills to make medical diagnostic instruments.

We don't make medical ultrasonic instruments, like they use in ultrasonic scanning of pregnancy. The medical side of the business is a different world than the industrial. Their distribution channels are much different. We just don't have the sales and marketing distribution channels that we would need to be in that area. We use a lot of manufacturer's reps. None of them would be particularly suited to address the medical business because they just don't live in that world. You know, those guys are out calling on petro-chemical facilities or on steel mills. They're just not equipped to call on hospitals and doctors. You'd be looking at probably developing a whole different sales force than what we currently have. And that's not an easy thing to undertake. I think we certainly have the capability of designing the equipment. We have the engineering and the technical expertise if we decided to

get into that market, which we have elected not to. (ULTRASONIC Product Manager)

If we were selling medical instruments, we would have to sell to thousands of hospitals. We have no marketing capability. We have no customers that are hospitals or doctors. We don't sell to any of those people. . . . I think we probably have the talent in this building to build a medical instrument. We have the ability to do that, but then what the hell would we do with it? We have zero marketing skills. We don't even know if it's a good product or not. There's no one in here that could tell the engineers what to build because there's no knowledge about the customers. (ULTRASONIC General Manager)

In contrast, ULTRASONIC comfortably pursued an automotive application of its ultrasound technological competence, even though they had not dealt with automotive customers before. ULTRASONIC could serve customers in the automotive industry without building a new customer competence:

Using the software to go after the automotive industry might require calling on new places, but it would not require new distribution. We would train our sales people and expect them to be able to handle this. We'll train them in the use of the software. It might be a whole new customer that they've never called on before, but it's not like branching out into another industry. . . . Yeah, it's using existing distribution channels. So it's not the same as creating a whole new distribution channel like we would need for using the ultrasound in the medical applications. That's one of the barriers to entry that keeps us out of the medical field. It's a whole different distribution system. It's a whole different way of selling to a whole different group of customers. (ULTRASONIC Product Line Manager)

In sum, this study has distinguished three types of competences: first-order competences (customer and technological competences), integrative competences (the ability to combine first-order competences), and second-order competences (the ability to build new first-order competences). This distinction is akin to the distinction Henderson and Cockburn (1994) made between integrative (or architectural) and component competences. They define component competences as skills, assets, knowledge, etc. that have specific application in particular activities of the firm. The notions of customer and technological competences advanced here have a similarly localized and specific character as they allow the firm to serve a specific

customer base or implement a specific technology. According to Henderson and Cockburn (1994), integrative competences reflect the ability of the firm to integrate its various component competences *and* to develop new component competences. In contrast to Henderson and Cockburn, I consider the ability of the firm to develop *new* competences as distinct, referring to it as a second-order competence.³

DISCUSSION

This study examined how new product development can serve as a vehicle for organizational renewal. I argued that product innovation activities not only draw on, but also serve to develop firm competences, and thus contribute to firm renewal over time. This is particularly important in the current dynamic environment, which requires firms to renew their competences in order to survive and prosper (Cooper and Smith, 1992). Environmental changes make previously acquired competences obsolete, and call for new competences to be built, i.e., competences have to be continuously renewed in the face of change. Product innovation is one potential avenue for such renewal.

My analysis of new products as interconnected through their reciprocal relationships with the firm's competences yields a view of firms as portfolios of competences, rather than as portfolios of products, giving a better perspective on the firm's innovative abilities and renewal prospects (cf. Wernerfelt, 1984). There is growing recognition of project interrelatedness in the literature on product platforms (Meyer and Utterback, 1993)

and design modularity (Nobeoka and Cusumano, 1997). This prior research has provided tools for leveraging technological competences that underlie products. However, it emphasized the opportunities for leveraging these competences among highly related product families, e.g., through sharing components among car models in the research by Nobeoka and Cusumano (1997). This study emphasized the challenge of building new customer competences in more extreme cases of technology leveraging. For instance, a car maker leveraging its technological competence in gasoline-powered engines from cars to lawn mowers is faced with the challenges of understanding different customers, setting up a different distribution channel, establishing brand reputation, etc. This study further developed the notion of leveraging competences, and elucidated the challenges and limitations of competence leveraging. Leveraging competences through new product development consists of de-linking competences from current products, and re-linking of current competences to new products. Marino (1996) presented a tool for identifying competences (de-linking) and evaluating alternative applications. Full exploitation of one competence requires other competences to be present or built. For instance, to leverage its technology by applying it to additional markets a firm must build competences to serve those additional markets. It is not enough to have a technology that has many applications. Full exploitation of the technology in all possible applications would require a wide range of customer competences.

In addition, this research distinguishes first-order from second-order competences. New product researchers have found that marketing and technological capabilities must be present for effective new product development. However, these researchers have not specified what enables a firm to add new competences through product innovation. According to Markides and Williamson (1994: 164), '... simply exploiting existing strategic assets will not create long-term competitive advantage. In a dynamic world, only firms who are able to continually build new strategic assets faster and cheaper than their competitors will earn superior returns over the long term.' Second-order competences enable a company to renew itself through building new first-order competences (or strategic assets, in the terminology used by Markides and Williamson). Some companies may have excellent first-order competences (e.g., they know their

³ Some authors have conceived of new product development as a competence in itself. For instance, Subramaniam and Venkatraman (2001) examined the antecedents of transnational new product development capability. Millson and Wilemon (2002) developed a measure of new product process development proficiency. I argue that new product development is a core organizational process in which various firm resources and competences are brought to bear. New product development consists of a set of activities at which firms can be more or less skilled, such as the activities enumerated in the stage-gate framework (e.g., idea generation, screening, business analysis, prototype development, concept testing, launch, cf. Cooper, 1993). In these activities, firm resources and competences need to be brought together. Therefore new product capability relies on the firm's integrative capability, its ability to combine resources and competences (Henderson and Cockburn, 1994). To the extent that the product under development is explorative, second-order competences will also be needed. I owe special thanks to the reviewers for dialogue on this issue.

customers very well and have great relations with them, and they deeply master their technologies), but may falter when faced with the renewal challenge. The presence of second-order competences may explain the relative success of firms in the face of environmental change.

MANAGERIAL IMPLICATIONS

The typology of new products developed here contributes to the examination of opportunities for renewal. It can serve as a tool for portfolio analysis and the generation of new portfolio options, by identifying competences and specifying their potential links to products (for an extensive overview of extant product portfolio tools, see Edgett, Kleinschmidt, and Cooper, 1998). This framework has called specific attention to the resources and competences underlying products, both those that are implicitly embodied in current products, and those that need to be acquired. Existing products can be placed within the typology, and give insight into the nature and direction of the firm's new product initiatives. For competitive comparison, the firm may also gauge the portfolios of its current or potential competitors. Insight into the number and size of various initiatives will help the firm establish timelines and resource requirements for its set of initiatives. By repeating this analysis, the firm will gain insight into how its new product projects evolve over time, and how they are affecting the firm's stock of resources, in effect generating the renewal of the firm.

When examining the renewal potential of a particular new product, managers can classify it in the typology by assessing its degree of fit with the firm's existing competences, and their constituent resources. Managers should examine which resources are already in place, and which need to be built. This exercise will yield the extent to which the project involves customer or technological exploration. Next, managers should evaluate whether their firm possesses the necessary second-order competences to succeed at this level of exploration. In other words, does their firm have the R&D competence required by a technological exploration project, or the marketing competence necessary for customer exploration?

I argued that both technologies and customers are firm competences that can be leveraged to build

new firm competences. Being able to further leverage its technologies and customers through product development means that a firm is able to extract more value out of its competences. In addition, leveraging is an attractive option for firms seeking to diversify through product innovation. It is an easier, faster, and lower risk means for a firm to renew itself than pure exploration. It follows the advice to stick to core competences, while using those core competences as stepping stones to develop new competences. An honest assessment of the firm's second-order competences gives insight into which type of leveraging the firm is most likely to be successful at. Firms with great R&D competence are best suited to expand by offering new technologies to their existing customer base, whereas firms with strong marketing skills might better leverage their technology to different markets.

Second-order competences are not static. Just as a firm can increase its first-order competences, it can develop and nurture its second-order competences. An organization that wants to cultivate its marketing competence may develop its skills in such areas as: assessing the potential of new markets, building relationships in new markets, setting up new distribution and sales channels, leveraging brand/company reputation to new markets, researching new competitors and new customers, developing new advertising or promotion strategies, and developing new pricing strategies. Building an R&D competence would involve building skills in such areas as: setting up new types of manufacturing facilities and operations, scanning for promising new technologies, assessing the feasibility of new technologies, building networks of contacts with research centers, and recruiting engineers in new technical areas.

Understanding the nature of various types of product innovations allows a better insight into the specific challenges associated with different types, and gives guidance as to the best suited management approaches. Conventional approaches to new product development, while appropriate for exploitative innovation, may be inappropriate, even detrimental, when applied to explorative innovation. Approaches suitable to different product innovation types differ in several ways. I briefly discuss how they may be different in terms of managing customer input into innovation, the selection criteria applied to innovation projects, and the evaluation of new product success.

This study provided further support for the prior finding that customers have a strong impetus in a firm's product development (cf. Christensen, 1997; Christensen and Bower, 1996; Utterback, 1994). Customers play an active role in a firm's competence development through their influence on the new products a firm pursues. When managers seek to develop additional customer competences through product innovation, they need to deliberately seek input from *new* customers and evaluate which resources are needed to address those customers.

Another important issue in this research involves how new product decision-makers select new product projects to pursue, and whether selection approaches are (or should be) different for different types of innovations. Most likely, innovations outside of the core business of the firm need to be sheltered in order to prosper, as they take longer to develop and do not have a clearly defined and measurable market. If the same criteria were applied to explorative innovation projects as to exploitative projects, it is likely that most of the latter would never be pursued. The findings from this research provide some guidance as to which standards are appropriate for each type of innovation. For exploitative projects, firms can use their technological and market knowledge to make accurate projections about the technological feasibility and the market success of the new product. For such projects, traditional financial measures, such as Net Present Value, are appropriate. For explorative projects, however, more strategic or visionary criteria are appropriate. Focal questions may be: 'Do we want to be in that market? Is this the right technological direction for the company? Can we leverage our resources to make these strategic moves?'

My research also contributes to the debate on how to define and measure new product success or performance. Griffin and Page (1993, 1996) showed that practitioners and academics recognize that there are many possible measures of new product success, each of which may be appropriate for different types of projects and firms. The learning perspective on new product development presented in this article elaborates the rationale for the use of different measures. Criteria for evaluating explorative projects should be different from those for exploitative projects. At a more strategic level, the framework presented above explicates how firm renewal objectives translate into

project-level objectives. It expands the time horizon for evaluating success and emphasizes the interdependence of project outcomes. Maidique and Zirger (1985: 311) found that the knowledge gained from failed products was often instrumental in achieving subsequent successes: 'New products strongly influence the performance of their successors, and in turn are a function of the victories and defeats of their predecessors.' The measures of success used in most new product research view the project in isolation; its potential benefits for later projects are not taken into account. Evaluators should not just look at the achievement of product-specific objectives (e.g., sales, market share), but also at how a new product builds new competences and serves as a tool for exploring new customers and new technologies. For instance, a product that failed when judged on short-term financial measures may have contributed knowledge about the feasibility of a new technology or the attractiveness of a new market. This knowledge may in turn prevent future failure and increase the chance of future successes. Different types of new products thus need to be assessed by different standards, for some products a measure of successful exploration (what was learned?) should be used. Successful exploration occurred when the learning activity added a new competence for the firm, whether or not that new competence was yet profitably applied to any product. Measures of organizational learning may be more appropriate for explorative projects than financial measures of product performance.

LIMITATIONS AND FURTHER RESEARCH

The findings in this study are based on an in-depth study of five firms. Obviously, I could not establish that the findings are generalizable to all firms producing high-tech industrial products, or whether they generalize to consumer products or services. The researched firms could have idiosyncratic characteristics that impacted their product innovation and renewal efforts. However, the findings presented above have a strong intuitive and conceptual appeal, and are amenable to quantitative verification. Future research could measure firms' product innovation portfolios and examine

the determinants (i.e., organizational and environmental characteristics) and the performance outcomes of those portfolios. Extension of the framework to consumer goods or services would require additional field studies to examine the dynamics of resources and new products in those contexts.

The current study did not explicitly consider the role of alliances and acquisitions in gaining access to competences for new product development. I focused on internal development of competences. However, further research could extend the framework to inter-company new product development. This research could focus on the crucial role of inter-company learning: how are resources required for product innovation transferred or combined across companies? For instance, Lane and Lubatkin (1998) studied the mutual learning of alliance partners. Rothaermel (2001) showed how incumbents in the pharmaceutical industry access biotechnological competences for new product development by engaging in strategic alliances with biotech firms.

Acquisitions are another dynamic capability, in addition to product development and alliance formation (Eisenhardt and Martin, 2000). Karim and Mitchell (2000) examined acquisitions activity as a mechanism by which firms change their mix of resources. They distinguished acquisitions that deepen a firm's existing resource base from acquisitions that extend the firm into areas that require substantially different resources. This distinction is analogous to the exploitation–exploration modes of organizational learning and renewal offered in this article. Anand and Singh (1997) examined firm diversification out of a declining industry (defense) by way of acquisition. A more general theory of firm competence development would incorporate product development and mergers and acquisitions as alternative routes to firm renewal.

Recent work (Szulanski, 1996; Galunic and Rodan, 1998; Subramaniam and Venkatraman, 2001) has examined the facilitators and impediments of intrafirm resource recombinations. One of the key tenets of this article is that for viable new products to be developed technological competence and customer competence have to come together. This raises several questions for future research. Do they have to come together in the same mind, i.e., should they be cognitively represented in the same mind for this connection to occur? Inside the firm, who knows which technological and customer competences the firm has?

Does linking require an in-depth understanding of the competences, or just an awareness of their existence? Research addressing these questions could benefit from prior work in the integration of Marketing and R&D (cf. von Hippel, 1994). Madhavan and Grover (1998) viewed new product development as knowledge management. Future research could examine the organizational mechanisms and structures that facilitate the storage and transfer of knowledge learned through product development.

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