

THE PROCESS OF TECHNOLOGICAL COMPETENCE LEVERAGING

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Technologies are often amenable to uses for a range of markets, but yet are often underutilized, and consequently not all value is extracted from them. This article presents a longitudinal case study of a firm that successfully applied a fungible technology to products for its served market, but was unable to tap its considerable potential in new markets. The processes of resource allocation and resource transformation inhibited technology leveraging, shaped by the presence of a competence to serve current customers (a customer competence trap) and the lack of a competence to gain access to new customers (a marketing competence gap). Copyright © 2007 John Wiley & Sons, Ltd.

Since the emergence of resource-based theory, a distinction has been made between resources and the services they can provide (Penrose, 1959). It has also been recognized that a particular resource may have a range of potential services; in other words, that resources are fungible (Mahoney and Pandian, 1992; Penrose, 1959; Teece, 1982). In particular, a technological competence, as constituted by a bundle of technological resources, can provide multiple services. One technology can be amenable to many market applications and underlie many products (Danneels, 2002; Hargadon and Sutton, 1997; Patel and Pavitt, 1997; Teece, 1982). Shane (2000) found that one technology invented at MIT was applied by entrepreneurs to make eight different products to serve different markets. Dougherty (1992: 78) mentioned the example of laser technology, which ‘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.’

Despite this potential fungibility, technologies are often not fully utilized, and consequently not all value is extracted from them (Thomke and Kuemmerle, 2002). The classic work by Penrose (1959: 76) emphasized that resources are often not fully used, and that each firm has pools of unused productive services, ‘at any given time the known productive services inherent in a resource do not exhaust the full potential of the resource.’ This point has been supported by several empirical studies. Burgelman (1994: 48) found that ‘the productive potential of a firm’s technological competencies may extend beyond the boundaries set by its product-market strategy at any given time.’ Gambardella and Torrisi (1998) showed the limited scope to which firms applied their fungible electronics technologies in various product markets, while Patel and Pavitt (1997) found that large firms had a broader range of technologies than products. Despite their fungibility, technologies are often not fully leveraged; i.e., they are used only in limited ways. This lack of value extraction means

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missed profits for the firm, and for societal welfare at large it means that many benefits of technological progress are foregone. To understand the reasons for the 'under-leveraging' of technology, one needs to understand the process of technology leveraging. Hence, the research question of this article is: What is the process of technological competence leveraging, and can insight into this process explain why technologies may be under-utilized?

THEORETICAL BACKGROUND

The extraction of additional value from under-utilized resources has been referred to as 'leveraging capabilities'. Miller (2003: 971) stated: 'as learning takes place, a firm is able to apply the capabilities learned and resources earned in one situation to serve a different market or opportunity.' Leveraging involves drawing on an existing competence, while using it as a stepping stone to build a new competence (Danneels, 2002). Technological competence leveraging is a combination of the exploitation of an existing technological competence and the exploration of competences to serve new customers. Honda provides a classic example of technology leveraging, as it applies its technological know-how and production facilities related to combustion engines to cars, lawnmowers, generators, motorcycles, and so on (Nevens, Summe, and Uttal, 1990). As another example, Canon exploits its expertise in optics and lens grinding to serve markets as diverse as photolithography, cameras, and copiers (Nevens *et al.*, 1990). Similarly, Japanese brewers apply their technological competence in fermentation to produce biopharmaceuticals (Lynskey, 2005). Technological competence is constituted by tangible and intangible technically related resources (Mitchell, 1992), such as engineering know-how, manufacturing facilities and know-how, and procedures for quality control (Danneels, 2002).

It is not sufficient for a technology to have many applications; to leverage its technology by applying it to additional markets, a firm must build complementary market-related assets to serve those markets (Gambardella and Torrisi, 1998; Teece, 1982, 1986a, 1986b; Thomke and Kuemmerle, 2002; Tripsas, 1997). Market-related resources include 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 of information between the firm and customers during development and commercialization of the product. Together these market-related resources constitute a 'customer competence'—the ability to serve a particular market (Danneels, 2002). A carmaker leveraging its technological competence in gasoline-powered engines from cars to lawnmowers needs to build understanding of different customers, set up a different distribution channel, establish a new brand reputation, etc.

Even though leveraging technological competence provides incremental profits and avenues for growth and renewal, it seems hard for firms to do so. However, at this time we have only anecdotal evidence of instances of technology leveraging, and only fragmented insights into its process. First, we know that leveraging technology involves the identification of a technological competence as distinct from the products in which it is embodied (Danneels, 2002; Teece, 1982; Wernerfelt, 1984). Prahalad and Hamel (1990) argued that competences are not product-specific; they transcend any particular product. Teece (1982: 45) noted that '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.' Second, we know from prior literature that complementary market-related assets are needed to access new markets (Gambardella and Torrisi, 1998; Teece, 1982, 1986a, 1986b; Thomke and Kuemmerle, 2002; Tripsas, 1997). What is missing in our understanding of the process of technological competence leveraging is the role of resource allocation and transformation. While a technological competence may be identified for possible leveraging across multiple applications, the creation of market-related resources can be highly problematic. The transformation of generic firm resources into specific resources, and subsequently into valuable output, has so far been unproblematic and implicit in resource-based theory (Barney, 2001; Priem and Butler (2001a, 2001b)). Studies of resource allocation have focused on the allocation of rather fungible resources, such as capital budgets (Bower, 1970; Maritan, 2001) or versatile manufacturing facilities (Burgelman, 1991; 1994; 1996). The process subsequent to allocation, transforming the allocated fungible resources

into less fungible ones, has received little attention, although authors noted the effect of resource allocation on strategic renewal (Christensen and Bower, 1996; Noda and Bower, 1996; Noda and Collis, 2001). By and large, resource allocation and transformation have been hidden in a 'process black box' (Priem and Butler, 2001a: 33). Getting a first-hand look at these activities requires a microlevel study that looks inside the firm.

The case study presented below suggests that the allocation of fungible resources and the transformation of these fungible resources into new market-related resources are a function of the first-order customer competence and the second-order marketing competence of a firm. The studied firm (dubbed CHEMAN) struggled to apply a technological competence it had developed (dubbed INERT) to alternative markets. INERT is a technology for making a metal surface inert. Fieldwork done with CHEMAN shows that, despite great promise, INERT's potential outside of its core market stayed largely untapped. While CHEMAN had a strong first-order competence to serve its current customers, this same competence made exploration of alternative customers less attractive. In addition, CHEMAN lacked the second-order marketing

competence necessary to build new customer competences. At CHEMAN, resource allocation and resource transformation were the operative mechanisms by which the presence of customer competence and the lack of marketing competence constrained the exploration of alternative markets.

METHOD

The INERT (disguised name) technology at CHEMAN (disguised name) provided a rich empirical site in which to study technology leveraging, as the phenomenon was salient there (Strauss, 1987). The research site is CHEMAN, a company that makes components and accessories for chemical analysis (chromatography) instruments. Chromatography is a technique for assessing the chemical composition of gaseous or liquid samples (gas chromatography is referred to as 'GC' and liquid chromatography as 'HPLC'). CHEMAN was founded in 1985, and in 2002 had about 160 employees and \$26 million in annual sales (see Table 1). In many ways, CHEMAN has been a very successful company. It enjoyed sales growth and profitability every year since its founding. Its instrument components, especially those coated with INERT, have been used extensively by NASA for space

Table 1. Key numerical data during the observation period

	1996	1997	1998	1999	2000	2001	2002
CHEMAN annual sales	13,634	15,556	17,552	19,401	21,804	22,808	25,573
# CHEMAN employees	96	119	134	151	150	157	160
Revenue per employee	142.0	130.7	131.0	128.5	145.4	145.3	159.8
% CHEMAN margin (net profit/sales)	14.3	9.9	7.7	11.1	13	11	15
INERT annual sales	342	461	555	801	1025	1084	1251
% INERT annual sales growth rate		34.8	20.4	44.3	28.0	5.8	15.4
INERT net profit ^c				-20	150	145	375
% INERT margin (net profit/sales)				-2.5	14.6	13.4	30.0
Passivation annual sales ^d	342	461	555	801	1025	1041	1201
Corrosion Resistance annual sales	0	0	0	0	0	30	35
Anti-Coking annual sales	0	0	0	0	0	13	15
Ultra-High Vacuum annual sales	0	0	0	0	0	0	0
Total non-passivation annual sales	0	0	0	0	0	43	50
% non-passivation annual sales	0.0	0.0	0.0	0.0	0.0	4.0	4.0
# INERT manufacturing employees	1.5	2	2	2.5	2.5	3	3
# INERT management employees	1	1	1	1	1 ^a	1 ^a	2 ^b

All sales and profit figures are expressed in thousands.

^a INERT Business Development Manager said was actually 0.5.

^b Interviews indicate 0.5 support from manufacturing engineer, so could be 2.5.

^c The INERT Group has operated as a profit/loss product line since 1998. Cost calculations include overhead allocated proportional to sales.

^d About 90% of passivation revenues derive from coating of instrumentation and/or sampling components used for chromatography.

shuttle and space exploration missions. Mainly, its customers are analytical labs in both industry and government that conduct chemical analysis by chromatography.

The research design employed by Burgelman (1994, 1996) served as an exemplar for the current study. Burgelman conducted a longitudinal case study within one corporate setting (Intel Corporation), collecting current and historical interview and archival data during two periods. Data were collected at CHEMAN during two time periods. I had regular contact with informants at the site over a 2-year period in 1996–1998, and again in the period 2002–2004. Henceforth, the first period will be referred to as T1 and the second as T2. I conducted a field study primarily using interviews and internal company documents as data sources.

The interviewees represent everyone involved in INERT (see Table 2). In the first round (T1), 11 interviews were conducted with nine interviewees, in the period 1996–98. The second round of interviews was conducted in 2002–03, with some follow-up by e-mail in 2004. In the second wave (T2), 16 interviews were conducted with 11 interviewees. Five interviewees were interviewed in both the first and second waves of data collection. E-mail exchanges took place throughout the focal study period of 1996–2002. Additional e-mail exchanges with questions of clarification occurred into 2004. 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. Interviews commonly lasted from 45 minutes to 2 hours, and were tape-recorded. The tapes were transcribed verbatim.

Various public documents relating to the company were collected, such as Web page print-outs, product catalogs and collaterals, and press accounts. In addition, the company generously provided access to internal confidential documents, such as annual financial statements, with detailed cost and revenue figures for each product line, product line annual plans, strategic plans, and detailed figures regarding employees (FTE) allocation over the years (see Table 1).

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. 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

Table 2. List of interviews

T1	T2
<i>Repeated interviewees</i>	
Founder and CEO	Founder and CEO
Director of New Products (3 times)	Former Director of New Products/Product Line Manager
INERT Business Development Manager	INERT Business Development Manager (3 times)
Product Line Manager	Product Line Manager
INERT Senior Scientist	INERT Senior Scientist (2 times)
<i>Unique interviewees</i>	
Manufacturing Manager	INERT Manufacturing Engineer (2 times)
R&D Manager	VP of Sales and Marketing (2 times)
Research Scientist	Chief Innovations Officer
Research Chemist	Chief Financial Officer
	Controller
	R&D Manager
9 interviewees—11 interviews	11 interviewees (5 same as in T1)—16 interviews

between data analysis and data collection, represented as: literature review ↔ data analysis ↔ 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.

I was known to be a researcher by participants in the setting, and participants were aware of my research topic. I kept a journal that includes field notes and reflections on the progress of the study. 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 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 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. These conceptual clusters formed the basis of the organization of the findings (see Table 3).

In order to organize my data, the development of two additional tables included in this article was instrumental. Table 4 reflects the key events in the history of INERT at CHEMAN. Table 1 presents the main numerical data regarding CHEMAN and the application of INERT through the focal study period from 1996 to 2002. Both tables were assembled by extracting and matching data from interviews and documents.

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 or third interview. In addition, I made presentations of my findings to the participating firm. The member checks served to revise and hone the findings discussed below.

FINDINGS

The purpose of this study was to develop an understanding of the process of technology leveraging. The findings presented below are based on field research and an integration of the scholarly literature. As discussed, analysis of the data and analysis of the existing literature were interwoven in deriving the findings of the study. Consistent with the method of constant comparison between data and theory used to derive the findings, the following sections will tell the data and theory stories jointly (Orton, 1997).

The INERT technology

The technology called INERT at CHEMAN provided a great setting to study the process of leveraging technological competence. INERT technology is a process for making a metal surface inert by depositing a very thin layer of a silicon-based (glass-like) coating on it. Various tangible (e.g., oven chamber, oven plumbing/valves/pumps, parts

Table 3. Conceptual framework

Concept (definition)	Conceptual cluster	Key references	Empirical phenomena
Technological competence (ability to make a certain physical product)	Constituted by tangible and intangible technological resources	Danneels (2002)	INERT technology allows for coating of metal with fused silica
Fungibility (amenability of a resource to diverse applications—to provide a range of services)	Generic (highly fungible) vs. specific (low fungibility) resources	Teece (1982); Mahoney and Pandian (1992); Penrose (1959); Shane (2000)	INERT technology can be applied to many distinct products to serve customers in many different industries
Technology leveraging (applying technological competence to new types of customers)	Excess services De-linking and re-linking technological competence	Burgelman (1994); Gambardella and Torrisi (1998); Hamel and Prahalad (1994); Hargadon and Sutton (1997); Miller (2003); Patel and Pavitt (1997); Thomke and Kuemmerle (2002)	Successful leveraging of INERT to make metal GC columns and air sampling canisters
Technology de-linking (uncoupling of a technology from the product in which it is embodied)	View technology in its own right Disembody technology from products Characterize technology—determine fungibility	Danneels (2002); Hamel and Prahalad (1994); Patel and Pavitt (1997); Teece (1982)	De-link INERT from its embodiment in chromatography products Examine material properties of INERT (e.g., electrical resistance, resistance to acids, physical strength)
Technology re-linking (re-coupling of a technology for new market applications)	Reapply technology to products that address new types of customers Build complementary assets	Danneels (2002)	Look at INERT as an anti-coking technology as opposed to a technology for chromatographic passivation Link with benefits in different market applications, e.g., anti-coking in fuel transfer, diesel engines, jet engines 'Shotgun approach' by broad mailing of INERT brochure
Complementary market-related resources (set of resources necessary to address customers for alternative technology applications)	Resources to access alternative markets	Mitchell (1992); Teece (1982, 1986a, 1986b); Tripsas (1997); Thomke and Kuemmerle (2002); Tripsas (1997)	CHEMAN lacked complementary assets to address customers outside of analytical chemistry, e.g., sales force, relationships, customer lists

Table 3. (Continued)

Concept (definition)	Conceptual cluster	Key references	Empirical phenomena
Resource allocation (pinpointing generic resources to be transformed into specific resources)	Assign resources 'Pay attention to' — 'Put effort into' — 'Focus on'	Burgelman (1991, 1994, 1996); Christensen and Bower (1996); Bower (1970); Noda and Bower (1996); Noda and Collis (2001); Maritan (2001)	Senior Scientist and Business Development Manager assigned to INERT INERT Business Development Manager assigned to also manage other product lines Fund patent applications Distraction by entry into liquid chromatography and analytical services Invest in INERT: money and FTE (see Table 1)
Resource transformation (convert generic resources into specific resources)	Conversion of generic (highly fungible) resources into specific resources (limited fungibility)	Maritan (2001); Noda and Bower (1996); Noda and Collis (2001); Thomke and Kuemmerle (2002)	Hire process engineer to supervise and refine INERT processing Devote scientists to conduct material properties testing (characterization) Hire applications engineers to examine applications in particular industries Payment of attorney fees leads to patent De-linking INERT from current customers led to disassociation with revenue streams—INERT became 'orphaned' Current customers formed impetus to apply INERT to chromatography products CHEMAN successfully served analytical lab customers in both industry and government Lack of understanding of customers needs, relationships, sales channel, reputation to serve out-of-laboratory markets
Impetus	Driving force Customer competence forms competency trap through resource allocation mechanism	Bower (1970); Christensen and Bower (1996); Danneels (2003); Levitt and March (1988)	Set-up new sales group Lack of proactive approach to marketing Post hoc discovery of market segments for metal columns in portable instruments and process control Focused on chromatography as if with blinders
Customer competence (ability to serve certain customers)	Ability to serve particular customers based on bundle of market-related resources	Danneels (2002, 2003)	
Second-order marketing competence (ability to develop new customer competences)	Examine potential markets—find new customers/applications Develop new market-related resources to serve new customers	Collis (1994); Danneels (2002)	

Table 4. Key events

1985	CHEMAN is founded
1985–91	CHEMAN grows at rate of 65–174% per year
1987	CHEMAN is introduced to INERT technology
1991–95	INERT is applied to chromatography products (metal columns and air-sampling canisters)
1994	R&D work on application of INERT outside of chromatography starts
1995	HPLC (liquid chromatography columns) are introduced
1996	Brochure is sent out to <i>R&D Magazine</i> mailing list
1997	INERT Group is formed, headed by INERT Business Development Manager
1997	Applied for first process patent (still pending in 2002)
1998	Applied for second process patent (granted in 2002)
1998	CHEMAN's profitability sinks to its lowest level in company history
1998–99	Analytical Services department started and dissolved
2000–01	INERT Business Development Manager is assigned to manage two of the largest product lines (GC Accessories and Air Products) in addition to INERT
2002	INERT Business Development Manager is assigned full time to work as Business Development Manager for INERT

cleaner, reaction vessels) and intangible resources (e.g., knowledge of proper timing, temperatures, and mixture of chemical agents, how to clean parts prior to processing) together constitute the competence to apply the process. The silicon-based coating can be tailored to benefit a variety of applications. This process was initially discovered in the 1930s by a scientist, but it was not until the late 1980s that it was developed and refined for commercial use by CHEMAN. CHEMAN was founded in 1985 as a manufacturer of components, mainly columns and accessories, for chemical analysis (chromatography) instruments.

In 1987 CHEMAN was introduced to the INERT coating technology by one customer, who requested that CHEMAN use it to coat transfer lines used in chromatography systems. After the success of this initial application of INERT, the company applied its newly acquired technological competence to products for chemical analysis, which was CHEMAN's traditional domain. From 1991 to 1995 INERT was applied to develop new chromatography products, in particular metal columns and air sampling canisters.

We came to the idea of INERT actually through chromatography, but realized that it had much potential for other market areas than we were currently selling into. (Director of New Products—T1)

With INERT we deposit a very thin layer of glass on stainless steel. . . . At first when we developed it we were making fairly large diameter tubing with

it. Somebody said, 'Well why can't we do the same process with very small diameter tubing and make capillary columns out of it?' And that's where the development of the metal capillary columns came from. Because we understood chromatography and we understood this metal coating technology and we combined them to make a metal capillary column. (Director of New Products—T1)

Metal columns were found to be of particular value in portable and process control instruments, which require greater ruggedness and temperature tolerance. One particular use of portable instruments is in space exploration, and CHEMAN's metal columns were adopted by NASA for space instrumentation.

In contrast to their environment in Earth-based stable laboratories, space instruments are subjected to extreme vibration and shocks. To be suitable for space probe conditions the column needs to be sturdy and shockproof. Recent developments in column technology have led to metal capillary columns that are appropriate for space science. (NASA Publication (1998)—quote is paraphrased to protect confidentiality)

CHEMAN also applied INERT to develop a new product line of air canisters that are used to take samples for air monitoring and testing, which are still analytical chemistry applications. However, as the next section discusses, the move outside of the core market of analytical chemistry was problematic.

The unfulfilled promise of INERT

I did extensive fieldwork with CHEMAN during the period 1996–98, hereafter referred to as T1. At that time, I was struck by the challenges CHEMAN faced in commercializing the INERT technology, even though many diverse applications were being discovered for it. In the first data collection period (T1), recognition of the ‘limitless’ possibilities of INERT was widespread among CHEMAN employees. They had high hopes on how the technology would transform the company and lead to growth. The following comments were typical:

We have gotten into a technology that was originally used to develop our metal columns, it's called INERT. I see that branching out into something totally unrelated to chromatography. That's where I see CHEMAN has a lot of promise to grow. Not just in chromatography. You could coat parts for instruments; you could coat parts for NASA, for the automotive industry. And there are applications that we don't even know about yet. It's a coating surface. So the potential uses are limitless. (Research Chemist—T1)

In the short term, most of the customers we are addressing are in analytical gas chromatography. Lab guys. They have instruments in the lab to run analyses. Now we're finding that INERT has some very nice properties for the aerospace industry, for jet engines, for diesel engines, for automotive parts, for petroleum refining. I don't doubt that five years from now applications of INERT will be bigger than anything we're currently doing. Now we realize the potential. (R&D Manager—T1)

It was recognized that the development of INERT had been lackluster, and that more attention needed to be devoted to it. Plans were made for investment in INERT, and great expectations of growth were commonplace.

It didn't fit with our customer base. I mean—it does. It has applications in chromatography. But the application in chromatography may be 1 percent of the total applications. And we had no way of reaching the other 99 percent. That's probably why INERT has not been as successful as we thought it would be. We realize now that INERT could easily, if marketed properly, surpass any of the chromatography products we offer because the potential market is so much larger. At least some test trials have shown that it is working in the aerospace industry, if only we use this technology to coat afterburner rings in jet aircraft that could be a tremendous market for us. INERT doesn't

even represent 1 percent of our total sales, whereas in five years from now chromatography may only represent 1 percent of our total sales. (Director of New Products—T1)

Probably in '99 we're going to bring in more applications people to generate data on INERT and develop new products. We're going to have a researcher on the process to make it better. We're going to develop INERT II and III [means new generations of the technology]. 1999 is going to be just a revolutionary year for us. Direct sales will probably break one and a half million next year, based on customers in the new market areas. So we're hoping for 100 percent increase from '98 to '99.' (INERT Business Development Manager—T1)

However, in the second round of data collection in 2002–04 (T2) very little had been done to leverage the INERT technology outside of CHEMAN's core market, in spite of the enthusiasm of my informants in earlier years. In the interviews conducted at T2, the respondents were still talking about the potential of INERT.

I think CHEMAN is realizing its potential. A lot of times people call it our sleeping giant. I think if we put resources into it, we could really make some new paths for CHEMAN, you know, take us in directions that we are not involved in. (Product Line Manager—T2)

INERT was applied to create two very successful new product lines (metal chromatography columns and air-sampling canisters) serving the traditional chromatography market of CHEMAN. However, despite expectations, the technology had not expanded into commercial products outside of the company's traditional scope of chromatography equipment. Applications outside of chromatography had been explored, but were in an experimental stage, as they were at T1, and had led to few commercial sales. At T2, respondents felt that the promise of INERT had not been fulfilled.

I don't think INERT has really lived up to the potential we thought it had, mainly because we haven't really applied the effort to it. ... I think the same potential is still there. We are doing very well with INERT within the chromatography marketplace. (Product Line Manager/Former Director of New Products—T2)

For those four years after you left, nothing changed. And just the last year we've decided to reinvest and look at what potential exists with this technology. (INERT Business Development Manager—T2)

The movement of INERT into applications outside of analytical chemistry, CHEMAN's traditional field, was very slow. At the close of the study period, most of the revenues from INERT came from coating pathways for chemical analysis instruments, which is closely aligned with CHEMAN's traditional business in chromatography. Table 1 reveals that most of the revenue generated by the INERT Group, throughout the study period, derives from passivation of components used for chromatography.¹ Even at the end of T2, sales outside of the chromatography field constituted only 4 percent of revenues of the INERT Group.

In the following sections, the case of INERT will be analyzed in a thematic order, rather than a chronological order. However, a chronological account of key events in the history of INERT is presented in Table 4.

The process of technological competence leveraging: de-linking and re-linking

Technology leveraging involves two distinct steps: de-linking and re-linking. Penrose (1959: 25) stated that 'resources consist of a bundle of potential services and can ... be defined independently of their use.' De-linking involves viewing technology in its own right, as distinct from its embodiment in products; and re-linking involves applying the technology to new products that address new customers (Danneels, 2002). Figure 1 depicts the process of technology leveraging as consisting of two steps: de-linking and re-linking.

¹ 'Passivation' means the application of INERT to surfaces which are absorptive or cause catalytic breakdown of compounds to be analyzed (*INERT Product Line Plan—1996*). 'Chromatographic passivation' means the passivation of metal surfaces used for chromatography, in particular of components for sampling and transfer of liquid or gas samples.

De-linking involves abstracting away from the particular product in which the competence is currently embedded and identifying the competence in its own right. 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. Hamel and Prahalad (1994) argued that in order to leverage 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.' CHEMAN 'imagined' the application of INERT in areas outside analytical chemistry by learning about new applications in two ways. First, the network of scientists and R&D chemists in which CHEMAN was embedded played a great role in de-linking and therefore broadening the scope of potential opportunities to apply INERT.

So many people knew so many other people with traditional inertness problems of metal. ... We had a contact at a university who worked with the Air Force. They have difficulty with their fuels coking and clogging their fuel nozzles. So we started working with them. (Manufacturing Manager—T1)

Some of that came in sort of sideways through our chromatography contacts that had contacts elsewhere. For example, we were working with a professor. He was looking at INERT in terms of chromatographic properties, but through his contacts at the Air Force he also said, 'Well this may have some advantage for jet engines.' They were having a problem with coking of jet engines. We said, 'Let's INERT these nozzles to see whether we can

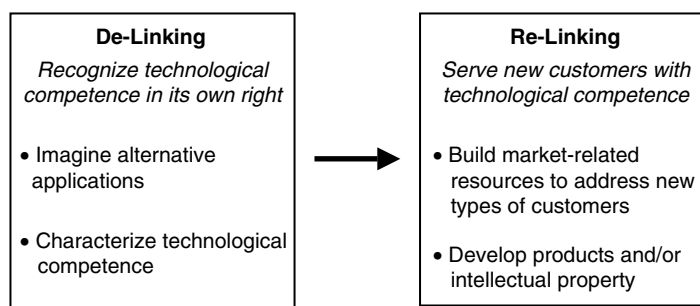


Figure 1. Technological competence leveraging

eliminate the coking problem.’ And it seemed to do that. So that got us into a whole new vein basically of looking at INERT as an anti-coking technology as opposed to a chromatographic technology for chromatographic passivation. ... That was the first indication that INERT might have some utilization outside of chromatography.’ (Director of New Products—T1)

The second way that CHEMAN learned that its new technological competence could be applied to many areas, was through deliberate search. In 1996, as a tool for identifying potential applications, CHEMAN developed a brochure that described the INERT technology, and mailed it out to a broad variety of potentially interested technologists.

And then we said, ‘Wow, if this professor is interested, maybe there are a lot of other people interested in this technology.’ We started brainstorming ways of trying to find markets for INERT. We decided the best thing was a shotgun approach to marketing. We said, ‘Well, how are we going to reach these people that might use INERT?’ We decided research people would most likely at least be interested in playing with INERT. So how do you reach research people? Well, we purchased a list of names of subscribers to *Research and Development Magazine*, which are researchers that are doing anything from aerospace engineering to food engineering, and mailed them a brochure that explained it. ... We put together a brochure that said, ‘We have this wonderful technology, INERT, and it can be used for many different things. Do you have any use for this? If you do, contact us and we’ll work with you to develop products.’ If you look at the brochure, it’s very simple, easy reading. There are maybe six pages with a lot of pictures and ideas of how the product can be used. (Director of New Products—T1)

We did sort of a fishing expedition and that brought back interests of markets we never even knew existed. Like [aircraft engine manufacturer] called us and said ‘Will it protect pistons?’ Then we had other companies that were doing fuel injections for airplane engines, I mean stuff that we never would have thought of. ... That is when we realized the potential to dabble into some other markets. (Product Line Manager—T2)

CHEMAN identified a variety of applications through mailing a brochure about INERT to a broad list of people interest in R&D, which resulted in inquiries from manufacturers in fields as diverse as dental braces, pharmaceutical inhalers, semiconductor process equipment, and aircraft engines.

The brochure generated interest from customers in a wide variety of industries, all of whom saw a potential application of the technology. This quote gives an overview of the variety of different customers who expressed an interest in INERT after learning about it through the brochure:

We’ve gotten a very wide variety of calls. For example, in the aerospace industry they want to coat afterburner rings in jet aircraft. As the fuel burns, carbon is deposited on the afterburner rings, which requires servicing the engine. They have to tear the engine apart, clean the ring off, and put it back together again. Putting this coating on the ring causes much less of the deposit to be formed, which means the aircraft can go much longer without this maintenance. We would never have suspected anything like that. Then somebody wanted to use the process to coat dental braces, because the acid in your mouth reacts with metal. They can’t make braces out of stainless steel. They have to use alloys that are fairly expensive. This coating on the steel makes it less prone to attack by acids. Another example is soldering guns for making printed circuit boards. Solder tends to stick to stainless steel, so they have to constantly replace the tips. Somebody felt that maybe if we could put this coating on the tips for the soldering irons, that the solder wouldn’t stick. So I mean there are a wide variety of applications that we could never in our wildest imaginations have come up with. (Director of New Products—T1)

De-linking also involves technology characterization, in order to determine the fungibility of the technology. The examination of the technology per se, in this case of the material characteristics of INERT treated metals, moved CHEMAN from understanding INERT as a product to a technology that is embedded in products. Interviewees reported on the ongoing efforts to characterize the properties of the INERT coating. The initial R&D work on application of INERT outside of chromatography started in 1994.

We felt the technology would work universally and then customers started sending stuff to us and we realized that the process requires a lot of tweaking to make it work between one metal and another. It’s not a simple thing that you just put this metal in instead of that metal and have it work. ... We still need to work on the technology itself. When we started new applications, we found that the technology needs to be refined. Right now we are looking for a couple of engineers to help us perfect the technology and allow us to utilize the technology in a wide variety of applications. (Director of New Products—T1)

Work on the characterization of INERT and the pursuit of non-chromatography applications began in earnest with the formation of the INERT Group in 1997, headed by the INERT Business Development Manager. However, at T2 this characterization work had progressed little:

We still don't know what the maximum temperatures are, or what the resistance to different levels of acids is. We know some of that on a very elementary level, but not on the level that we need to become a coatings business and play in the semiconductor industry or coat a reaction vessel for a processing plant. When does it work, is there a limit on the size, when does the coating become brittle or things like that. (VP of Sales and Marketing—T2)

One of the things that we really need to do is to find out its characteristics. What is it good for, what is it not good for, what are its limits. We really need to find that out because customers will ask 'How does it work for this, how does it work for that?' We don't know. And now we're sort of characterizing it and finding out its limits and capacities and seeing where it can be used. ... I bet we're just scratching the surface. I mean from a materials research perspective, there is a ton of work that needs to be done. (Product Line Manager—T2)

The plan of the newly formed INERT Group mentioned as goals:

To fully measure all properties the INERT layer has as a passivation layer for stainless steel surfaces. ... To begin getting the INERT treatment recognized as an option for passivation of stainless steel parts and piping in the non-chromatography industry ... Start working on transfer of this technology to the non-chromatographic market. (INERT Product Line Plan—1996)

Technology characterization is necessary in de-linking, whether the commercialization of the technology happens through product development or intellectual property. For either route to commercialization, the functionalities of the technology have to be understood before they can be linked with benefits in different market applications.

We don't know how to even present it to the distribution channel, because we don't know how it's better than what they are currently selling to make it worth their while to even take our call. So I think we know the questions to ask, we just need to do enough homework so that we have at least a rudimentary background of enough technical data to be taken seriously in the field. (VP of Sales and Marketing—T2)

Similarly, technology characterization is a condition for obtaining patent protection, because it is necessary to show the functionality of the technology in the domain that the patent is applied for.

If you apply for a patent like for corrosion resistance, you have to show data that INERT has corrosion-resistant properties. We didn't have the data to apply for the patent, so in the last couple of years we've been gathering more data to allow us to apply for those patents. (Product Line Manager/Former Director of New Products—T2)

While the de-linking step of technology leveraging was less problematic, CHEMAN had trouble with the re-linking step of technology leveraging. Re-linking involves building the market-related resources necessary to serve new kinds of customers, and developing either physical products or intellectual property. CHEMAN had two non-mutually exclusive options for profiting from its INERT technology (Ford and Ryan, 1981; Kollmer and Dowling, 2004). The first option was to use the technology to develop products internally; the second was to license the technology to other manufacturers. Several authors have pointed out that to extract value from technological competence, complementary assets must be present (Teece, 1986a, 1986b; Tripsas, 1997). Danneels (2002: 1102–1103) referred to the bundle of resources necessary to serve a particular group of customers as a 'customer competence,' which '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 of information between the firm and customers.' Depending on the mode of commercialization of the technology, the customers may be users or licensees, buying respectively physical products or intellectual property, but in both cases some degree of these complementary market-related resources (Mitchell, 1992) are necessary. For instance, in both instances a deep understanding of customer needs is necessary to understand how the technology satisfies those needs, and what value customers would place on satisfying those needs. As another example, while licensing would require a smaller sales force, the sales activities involved in gaining access to potential licensees and negotiating licensing contracts with them need to be performed.

Following the recognition of the INERT competence as separate from its current products, CHEMAN sought to re-link their INERT technology to customers outside of its core market of analytical chemistry. However, various complementary assets to address customers outside of analytical chemistry were absent, in particular, company reputation, relationships and channels of communication with customers, and sales and distribution channels.

We can't sell through our sales people because they're not visiting the customers that want this new product. We can't sell it through the distribution that we sell through because typically they're serving laboratories. If we develop a product that goes outside the laboratory, there's no way for us to market that with our standard techniques. In the past every product we developed fit into the laboratory setting. If the product is not designed for a laboratory, you have to find some new way of marketing that. (Director of New Products—T1)

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.' (Manufacturing Manager—T1)

When we go meet with firms in the [disguised] industry, they've never heard of us before and they've never heard of our coating before. They go 'who is CHEMAN, never heard of them, what's this coating, how do we know it's not crazy Eddy trying to sell us things.' (Founder and CEO—T2)

Our current domestic sales force doesn't have that level of comfort that they are able to go outside of a chromatography lab and sell the product. None of them do. (INERT Business Development Manager—T2)

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. (Director of New Products—T1)

The following section shows that the re-linking step requires the allocation of significant generic resources to be transformed into market-related resources.

Resource allocation and resource transformation

Despite the fact that INERT had been de-linked from its embodiment in chromatography products and its potential for alternative applications had been recognized, the accumulation of complementary assets to commercialize INERT was lackluster and intermittent. The CHEMAN case points to the role of resource allocation and transformation as impediments.

The creation of complementary assets requires resource allocation and transformation. Resource allocation involves pinpointing generic resources to be transformed into specific resources (Maritan, 2001; Noda and Bower, 1996; Noda and Collis, 2001). Generic resources are general-purpose resources, with a high degree of fungibility (Teece, 1986a). Financial resources have the highest degree of fungibility; i.e., they can be assigned to the highest variety of uses. Employee time is also a relatively fungible resource, albeit that the productivity of that time will depend on its use within the domain of expertise of the employee. Specific resources are specialized to the performance of a particular task. Resource transformation is the conversion of generic (highly fungible) resources into specific resources (limited fungibility).

The leveraging of INERT required the allocation and transformation of a variety of generic resources into specific resources. For instance, human resources were converted into resources for technology competence and customer competence, mainly via the INERT Senior Scientist and the INERT Business Development Manager, respectively.

Patents are an example of specific resources. CHEMAN was reluctant to allocate resources to obtain and defend patents relating to INERT, as evidenced in an action item mentioned in a document and a statement made by the CEO:

Seek a lower-cost patent attorney than our current one. (Planning Document—2002)

Well, the patent protection will help us, but the patent is something the company has to defend. We have to fight somebody and claim they are infringing. . . . We just didn't have the expertise, the people, the understanding in-house, or the resources to really make it happen. . . . It takes a lot of legal resources; it takes a lot of resources away from your core issues. (Founder and CEO—T2)

Consequently, it was not until 1997, 10 years after it first starting refining INERT, that CHEMAN applied for its first process patent (which was still pending in 2002). In 1998, CHEMAN applied for a second process patent (which was granted in 2002).

Even though the potential of INERT was repeatedly and widely recognized at CHEMAN, the allocation of resources (in particular, human resources) in pursuit of this potential was intermittent and tentative. Consequently, the development of complementary resources, in particular, knowledge about and relationships with potential customers, was very slow. This occurred early in the study period (mid-1990s), as well as later (late 1990s). The following quotes illustrate the early lack of resource allocation.

Strides really slowed down and not a lot was done from '95 to '97. There was no dedication to it. It was buried within another department. It was barely keeping its head above water. (INERT Business Development Manager—T1)

It's a matter of having the person to follow-up. Like when we tried to send out direct mail pieces to solicit leads to then follow-up on. But when we did that, we got inundated with so many things. We were shooting ourselves in the foot by not being able to follow-up. (VP of Sales and Marketing—T2)

I was stretched thin. I was a product line manager. I was also manufacturing manager. I was also departmental supervisor. So there wasn't a lot of time. In the first six months I was struggling with the other products that I was supporting. There were not enough resources available within myself or within CHEMAN. ... Just needed the time to do it. ... The only thing that kept it going was superhuman efforts by everybody involved. (INERT Business Development Manager—T1)

In the late 1990s, stagnating company performance prompted a refocus on the core business, exacerbating the lack of resources for INERT. In 1998, CHEMAN's profitability sunk to its lowest level in company history (see Table 1), and in 2000 a decision was made to assign responsibility for the largest product lines (GC Accessories and Air Products) to the INERT Business Development Manager, in addition to his responsibility for INERT. Since he had formerly managed both of these two traditional product lines, he was considered the best person to pull these core products out of their slump.

[INERT Business Development Manager] was taken out of that role and was diluted by giving him product line management responsibilities for other product lines as well. It just wasn't getting the resources. (Product Line Manager—T2)

When we had a reshuffling of product managers a couple of years ago, [INERT Business Development Manager] also took on the responsibility for our biggest product line, and for another very rapidly growing product. So we gave him the responsibility for all three of those businesses. Unfortunately because of that, he couldn't spend enough time on just INERT. (Product Line Manager/Former Director of New Products—T2)

Over the last four years, all of us were invested into gas chromatography and nobody was running the coatings division. [INERT Senior Scientist] did a lot of work with coatings, but for gas chromatography. Myself, I was divested to working in our gas chromatography accessories line and nobody was responsible for growing this business. (INERT Business Development Manager—T2)

Also, research attention to INERT was diluted. The scientist was assigned to work on the main product lines in addition to his research to characterize INERT.

At the time, I was researching new columns and trying to do INERT research at the same time. They weren't things that go together. (INERT Senior Scientist—T2)

It just took time for CHEMAN to apply resources to it. We always kept saying, 'This is going to be big, this is going to be big.' And then [INERT Senior Scientist] was really the only scientist that was focusing on it, but he was doing a bunch of other things as well. (Product Line Manager—T2)

Table 1 shows that the sales growth rate of INERT from 1996 to 2000 had been high (between 20.4% and 44.3%), while it declined substantially following this personnel reassignment in 2001 and 2002. Despite the very high and increasing margin of INERT at the end of the study period (the end of T2), the struggle for resources continued:

Our team is going to put together a business development plan this year to look at these different market areas. The idea was originally to hire somebody to do this. But in our strategic planning meetings it was said that it doesn't have to be a full time job, somebody can do it in addition to their regular job. They were making that same mistake. We brought up during that meeting that if we do not

have a focused resource for that, we're going to get spread thin. Of course, you can tell a person to do it part time and they're going to make sure they get their regular job done first. And only when they have spare time they would (pause) ... who has spare time? (INERT Business Development Manager—T2)

The decision was to give [INERT Business Development Manager] responsibility for several product lines, because he had the expertise to manage the product lines. We didn't have a true understanding of how much effort he would need to manage the other businesses, how much of his time would be taken away from the INERT product line. It took us a year or two to realize that INERT wasn't growing the way that we expected it to grow and asked why that was. And we looked at it and said that [INERT Business Development Manager] was trying to juggle too many things at one time, and decided to take some of those other responsibilities away from him, so he could focus his full attention on INERT. (Product Line Manager/Former Director of New Products—T2)

The literature has recognized the importance of slack resources to firm innovation (Bourgeois, 1981; Nohria and Gulati, 1996). Presence of financial slack, a generic resource, enables the investment in less generic resources, such as personnel and capital equipment. Burgelman (1991) emphasized the necessity of slack resources for autonomous strategic initiatives to become incorporated into corporate strategy. O'Brien (2003) found that financial slack, in particular that generated by debt financing, helps firms to pursue innovation through R&D. Debt serves as a buffer that allows continuity in financial slack, such that uninterrupted investments in innovation can be made in spite of cash flow volatility (O'Brien, 2003).

The sporadic allocation of resources to INERT was the result of two financial policies at CHEMAN: to avoid debt and to maintain stable profit margins. CHEMAN's capital structure policy was to avoid taking on debt, preferring instead self-financing:

We fund it all in cash flow, so we're doing okay. We save money. Again, we're privately held, so we've always put the money back into our business. We have debt, but we have relatively low debt, compared to a lot of companies. (Founder and CEO—T2)

Consequently, financial slack fluctuated at CHEMAN, and this led to piecemeal and discontinuous investment in INERT:

When we're having record profitability you're going to see spending. And you're going to see less risk aversion. You ask for a \$10,000 piece of equipment right now and you're in trouble, but next quarter, if you're hitting your numbers and profitability is good, you ask for that \$10,000 piece of equipment, you're going to get it. (INERT Business Development Manager—T2)

Because of self-financing, the company was very dependent on its fluctuating profits to invest in new opportunities. As can be seen from Table 1, efficiency in human resources (revenue per employee) and profitability (margin) dropped in the years (1997–99) preceding the reassignment of the INERT Business Development Manager (in 2000). So the profitability and efficiency of CHEMAN can be said to have a close, albeit lagged, relationship with investment in INERT.

In 2000, 2001 we were looking at bringing the profitability up to 15 percent corporate-wide. It had slipped. We had a lot of hires, revenues didn't jump company-wide in response to the extra salary we had. So at that point it was considered, well we're not losing anything by having all this work concentrated on a few. Our profitability will jump. ... At the same time it was felt 'these people can handle it, what's suffering?' (INERT Business Development Manager—T2)

The non-debt policy was exacerbated by another financial policy, to maintain a 15 percent profit margin every year, which made investments even more dependent on cash flows:

(Chief Financial Officer—T2): Now there's a budgetary constraint that may be what you're picking up on. And that is we strive every year to budget a 15 percent operating profit. (Me): It seems that the 15 percent rule has put a very strict cap on new employee hiring. (Chief Financial Officer—T2): Not strict enough. ... I believe that you should become more efficient as revenues grow, you should be able to do more things with the resources you already have.

Profitability exceeding 15 percent for the year 2000 can be achieved if we increase our sales without additional costs to our payroll. Our challenge for 2000 is to grow with the people resources we currently have. ... The budget for payroll will be exactly the same as this year. ... We must make do with the people we have and put them in the places absolutely necessary to create growth and profitability for the year 2000. (Planning Document—1999)

Customer competence trap

The disconnect between the recognition of 'limitless' opportunities in INERT and reluctant allocation of resources to pursue these opportunities suggests that mere opportunity recognition is not sufficient for resource allocation to occur. Rather, the allocation of resources to opportunities and their subsequent transformation depend on the presence of impetus, a driving force (Bower, 1970). Current customers and the revenue stream they generate have a strong impetus toward the allocation of resources to technological development (Christensen and Bower, 1996). The initial development of INERT was generated by the impetus of current customers, since the technology was used for products serving those customers:

Right now we work with our air-monitoring group, our GC accessories, HPLC, and we do a lot of paths for them. . . . So we're an intermediate in a lot of CHEMAN's products, but now we want to focus on outside customers. (INERT Business Development Manager—T1)

However, in its efforts to branch out to other markets, INERT was de-linked from current customers and was no longer associated with revenue streams, and hence the technological competence in INERT became 'orphaned.' In other words, since the applications of INERT outside chromatography had no revenue attached to them, the impetus for their pursuit was weak.

Noda and Bower (1996) and Noda and Collis (2001) found that operational results of new businesses had a large impact on subsequent commitment of resources to those initiatives, leading to iterative escalation or de-escalation of commitment. Similarly, CHEMAN made resource allocations to INERT proportional to its revenue:

There are only so many different things that you can invest in and those same people, like [INERT Senior Scientist] and [INERT Business Development Manager] who know the most about INERT are also critical in running the other product lines that are generating more revenue. It's hard to take them off those revenue-generating lines. Say it's 2 percent versus 35 percent of our business. Let me think, which are you going to invest in? (INERT Senior Scientist—T2)

Resources were allocated based on immediate returns, in effect favoring the exploitation of the current customer competence vs. the development

of competences to serve different customers. CHEMAN managers stated that the INERT technology had to prove its potential in these alternative applications before investment in pursuing them was made:

Where is the revenue coming from? INERT as a whole is going to get 1 percent of the total time and effort dedicated to it, compared to the traditional moneymakers. (VP of Sales and Marketing—T2)

We have a plan where as the revenue grows, we will also grow the division, hire more people, expand our workspace, build a new building. That's all in the plan, but right now we're trying to make do with what we have. Let's face it, what's the INERT Group's revenue right now for the year, 1.3 million dollars and we're a 25 million dollar company. So we're a drop in the bucket and we can only expect a proportional investment. As we show promise and grow, the investment will improve. (INERT Senior Scientist—T2)

We never had somebody come to us with an order in hand, so we would be investing in a fishing expedition. (Founder and CEO—T2)

This gave rise to a Catch-22: resources were not allocated to the opportunity to leverage INERT until it generated revenue, but the opportunity did not generate revenue because insufficient resources were allocated to pursuing it.

In 2000, there were some weaknesses in our eight product line managers. We narrowed it down to four that were able to lead the group for each of the product lines. . . . The executive team felt that we only had four that we were able to perform that function properly. And amongst those four, all the product lines were split. And I was considered to have a small product line based on its revenue number. That was the justification—if you look at INERT in terms of just the revenue number, and not the potential, it looks small. They felt I could take on more product lines. (INERT Business Development Manager—T2)

Levitt and March (1988) described a competency trap as the self-reinforcing exploitation of a current competence that makes the exploration of new competences unattractive (see also March, 1991; Levinthal and March, 1993). Firms accumulate experience in those domains of activity in which they have competence, further enhancing this competence, and concurrently locking themselves out of other domains. The case of CHEMAN points to resource allocation and transformation as the mechanisms by which competences

become traps. CHEMAN had a strong customer competence in serving the analytical laboratory market, which made exploration of non-analytical markets relatively unattractive:

The people involved in the INERT technology are also involved in chromatography and are important contributors in those areas. If I completely move them out of the organization, I have a hole. ... If I just pull them out and say, 'Okay, you guys are the INERT Group' there would be a lot of damage done in the programs already going on. (Founder and CEO—T1)

The company looked internally to its core business, which was gas chromatography. In '98, our priorities got switched to making columns and more GC accessories. I think we only grew modestly the prior year as a company. The coatings group had grown 44 percent, but because of the knowledge that we had in manufacturing and product line management, we were tasked into different things. Different things took priority. Myself, instead of marketing one product line, which was coatings, I was brought into GC Accessories and Air. GC Accessories is our largest product line. (INERT Business Development Manager—T2)

Customer competence and resource allocation are intertwined and reciprocal. Resources are allocated to serve customers that the firm can already serve, and consequently the competence to serve those customers becomes ever stronger, in effect creating a competency trap (Danneels, 2003; Levinthal and March, 1993).

In the chromatography business we have so many resources and so much expertise internally; we have very little internal resources and expertise in INERT technology. Unless you conscientiously make the decision to bring in more people with metal passivation expertise, it's just going to happen slowly. (Product Line Manager/Formal Director of New Products—T2)

Finally, at the end of the study period, in 2002, the INERT Business Development Manager was assigned full time to work as Business Development Manager for INERT. However, when asked whether they still felt pressure from the company in terms of justifying their resource allocation, the core members of the INERT Group said:

(INERT Business Development Manager—T2): Not since we've been hitting projections. (Me): Projections meaning revenue projections? (INERT Business Development Manager—T2): Yeah.

(INERT Senior Scientist—T2): Revenue growth and profit ... as long as you keep hitting your numbers.

Marketing competence gap

CHEMAN had operated under a 'market-driven' philosophy, as it was put by several informants and documents, trying to supply everything that chromatographers need. In this philosophy, the relationships with current customers formed the impetus for resource allocation and transformation. In contrast, the commercialization of INERT was described as a technology-driven effort, identifying and delivering the benefits of INERT to any market.

Our products are primarily market driven with some being technology driven. [The list of technology-driven products mentions INERT tubing.] (1991–92 Strategic Plan)

A company can be a market-driven company or a technology-driven company. CHEMAN by nature is a market-driven company. This product [INERT] is technology-driven and there is a conflict internally. (Founder and CEO—T2)

Some people felt we shouldn't even go outside the chromatography market. Basically the vision of the company is to be the best chromatography supplier in the world. INERT doesn't fit into that if it's pursuing market areas that are not chromatography. ... INERT is pursuing coating technologies to supply any market where it could be used, and so it becomes a technology-driven business. As opposed to a market-driven business like CHEMAN, which looks to supply anything the chromatographer needs. (Product Line Manager/Formal Director of New Products—T2)

When interviewees reflected on the promise of INERT, they understood that the full exploitation of INERT would require CHEMAN to address new customers. Building a new customer competence involves developing knowledge about new customers and gaining access to them through sales and distribution channels.

Finding a market that will benefit from your material and be willing to buy ... It was a challenge trying to find a market area. We attended the trade shows to at least get a feel for it, and then we asked [customers who responded to the brochure] to get a better understanding. (INERT Business Development Manager—T1)

In contrast to its strong customer competence, reflected in its ability to serve its particular group of customers well (in analytical chemistry), CHEMAN lacked a second-order marketing competence. A second-order competence is a competence to build new first-order competences (Collis, 1994). Danneels (2002) defined a second-order marketing competence as the ability of a firm to build new market-related resources, enabling it to address new markets. It includes 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. In this sense, a marketing competence is a competence to build new customer competences (cf. Collis, 1994).

The ongoing investment in INERT was driven by CHEMAN's customer competence, as INERT was initially applied to products serving its chromatography customers.

If we didn't have the initial interest in the chromatography world, we wouldn't have been able to justify putting more money into it, because we were a chromatography company dyed-in-the-wool when we started. ... Without that initial interest in the field that we knew very well, we wouldn't have bothered to put more money into developing the technology. We could have put more money into column improvements. ... So that's why we started out applying INERT in the chromatography field. ... We were so focused on chromatography, it's almost like we had blinders on. You know, like they put on a horse to keep it from becoming distracted. So as far as we were concerned, there wasn't a whole lot out there besides the chromatography world. That limited our perspective, I think. (Manufacturing Manager—T1)

The lack of second-order marketing competence limited the scope of the application of the technology:

The marketing side of CHEMAN is probably the weakest point of the company. In the past all of our products were marketed to the same group of customers. ... If you go after new types of customers and don't have a very strong marketing side to the company, you can flounder. I mean we've had INERT since I've been with the company. We've had that product for eight years. For the first seven of those years we didn't know what to do with it.

... Probably the biggest customers are not existing customers. And finding those is a lot more difficult. So there's a lot more prospecting work involved. So there's a lot more burden on marketing. ... We really developed INERT for the chromatography application of it. And then we realized that it has utility in many, many more areas. (Director of New Products—T1)

The lack of marketing competence is evidenced in various ways. First, managers struggled to assess the potential of alternative markets for INERT.

We didn't know where INERT would fit in. The easiest thing to say is that INERT is great and it will work for everything. But you've got to find out if it's going to apply to that market, where it applies, if something else already applies and you're competing against it. (INERT Business Development Manager—T1)

Consequently, they failed to make a strong case to justify the allocation of generic resources to be transformed into market-related resources.

It may be that someone thinks we should have hired a couple of chemists and just jumped in. And that someone, whoever it is, should have put together a plan that said if we do that, here's what we can expect. If this INERT group could demonstrate that they need more people to grow, we would support it. In the short term, ten years, I think chromatography is a very safe place for us to be. It's not going to go away. (Chief Financial Officer—T2)

I don't know that we are cash constrained to do more in INERT. I think we are knowledge constrained much more than we are cash constrained. Knowledge about where might this work. Where might you take INERT and be successful. (Chief Financial Officer—T2)

Documents repeatedly mention the lack of information about markets for INERT as a weakness, and emphasize the need for market studies. However, throughout the study period not one market study is reported. Even though they mention potential markets, such as anti-coking, anti-corrosion, and ultra-high vacuum, documents lack precise data on the size of these markets for INERT.

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. (Research Chemist—T1)

(INERT Business Development Manager—T2): In terms of studying the overall market, it's something we don't do a whole lot of. That's sort of the beauty of the process that we use. We didn't identify these market areas, they identified themselves to us. Call it dumb luck, but the companies have actually come to us, telling us what their needs are, what their market potential is. (INERT Senior Scientist—T2): Sometimes it's just a matter of us saying 'Oh maybe we should check that out.' (INERT Business Development Manager—T2): Yeah. Like we had this company come to us and say: 'We want to build a diesel engine and we need a coating that reduces coking.' It's like okay, you guys got a pretty big name so market study done, let's make it.

CHEMAN lacked the expertise to proactively investigate and assess potential markets, indicating a lack of second-order marketing competence. Instead, they engaged in retroactive sensemaking (Weick, 1995) of market opportunities, identifying potential customers after interacting with them (Danneels, 2003):

That's really how the business ran for many years before we focused our efforts on specific application areas. People sent us parts for coating and if it worked they sent us more parts. So now we are trying to play catch-up and see how we can make impact in the areas that have presented themselves to us over the years. (INERT Senior Scientist—T2)

Two prominent instances of retrospective sensemaking can be identified in the history of INERT. The first one occurred when CHEMAN started by putting the INERT-treated columns ('metal columns') in its catalogue, as an addition and alternative to its conventional components, targeting its current customers.

We felt that we could convince a broad base of customers to replace their old columns with the new metal ones. Some customers switched, but not as many as we expected. And when we looked at what customers were buying these columns, they really went into two classes: those who were using portable instrumentation and those who were using process-control instrumentation. So we realized that those were the two major market areas for this. And that's when we really started marketing heavily to those two market areas specifically with that product line. So we offered it to a broad base and then looked at who accepted it. And then once we found that out, we went after those markets. I don't think we set out saying that people in process

instrumentation or people in portable instrumentation need a rugged column to do their analysis. Maybe if we had studied it more we would have said, 'Well, what users really want a rugged product?' And we may have come up with the answer that it's really the portable and the process-control instrument people that want that. But it was more like we offered it as a general replacement to everyone and just a few people picked up on it. (Director of New Products—T1)

In other words, CHEMAN defined the target market for the INERT-treated columns retroactively, as opposed to analyzing and targeting the distinct needs of the portable and process-instrumentation market segments proactively.

We figured out that the process and the portable GCs were our targets after we had already been selling to them and said, 'Oh, look at the common things.' We knew the advantages of metal versus fused silica. It's more rugged, it's not going to break, it can stand higher temperatures. But we didn't necessarily target new markets, or we didn't target the portable and process people specifically. Now we know who they are and we've got most of them as customers, but it's almost after the fact. Who are your best customers, well the people who bought the stuff, so that's who we're going to market to. (VP of Sales and Marketing—T2)

As a second instance, retrospective sensemaking occurred as CHEMAN performed custom applications of INERT.

We had ten years of customers coming in requesting custom applications here and there. Just people saying, 'Well, does your coating do this?' And so you start making note of some of the more popular requests. And then that spurred investigation into whether there was market potential for more than just this one customer who asked us. (INERT Senior Scientist—T2)

Paradoxically, a marketing competence is needed for a technology-driven approach, whereas only a first-order customer competence is needed for a market-driven approach. As discussed above, re-linking a technological competence to new markets requires more than opportunity recognition. It requires the development of first-order customer competences which will allow the company to serve those new markets, and this, in turn, requires the presence of a second-order marketing competence. CHEMAN evidently struggled to build the resources needed to address

alternative markets, including gaining knowledge of needs of customers in these markets.

(Me): See here's the contrast I don't understand. There is the realization that there is huge potential and this was common among everybody that I interviewed back then. But then that contrasts with the fact that there weren't enough resources put behind it. That's the paradox that I don't really understand. (Product Line Manager—T2): I think it was just a lack of knowledge of what to do next. It's maybe due to a lack of knowledge of those markets, a lack of knowledge of how do we go out and investigate that.

The first segment of the last sentence of this quote refers to the lack of first-order customer competences to serve alternative markets. The second segment of the last sentence refers to the lack of knowledge on how to build knowledge, in other words, the lack of a second-order competence.

Therefore, it seems that since CHEMAN had a strong first-order customer competence it tended to allocate resources to current customers only. A strong second-order marketing competence would have provided the impetus to allocate resources to unserved markets. Due to a lack of second-order marketing competence, markets were not clearly identified, assessed, and prioritized, and therefore resource allocation lacked focus and resources were spread too thin.

We were just doing all sorts of different things and that's fine. But every idea has its time when it should mature. It's like we had a whole garden with all these seeds and there was no one watering and taking care of them and they were just coming up a little bit and dying. It takes a tremendous amount of follow-up when you're entering into a new market, a tremendous amount of energy. If you focus on a particular area, water and nurture a seed and it grows to fruition, then you can afford the resources to start watering and fertilizing another seed to get it to grow. But our priorities weren't clear. (Founder and CEO—T2)

CONCLUSION AND DISCUSSION

The classic work by Penrose (1959) emphasized that some productive services of resources may be unused. In particular, a technological competence may provide potential access to various unserved markets (Danneels, 2002; Prahalad and Hamel, 1990). The potential offered by leveraging often remains unrealized, as the research site

of the current study poignantly illustrates. This study has examined the process of technological competence leveraging to explain these foregone opportunities. Despite the recognition that firms need to leverage their resources to extract more value from them, the mechanisms by which this happens have not been examined. This study has contributed to our understanding of the process of leveraging technological competence across multiple markets, and why the potential value offered by leveraging may not be tapped. It has explicated the steps necessary to disembodiment (termed 'de-linking') technological competence from its current product application and to apply the competence to serve new markets (termed 're-linking'). It was found that the presence of a competence to serve current customers (a first-order customer competence) and the lack of a competence to gain access to new customers (a second-order marketing competence) both constrain technology leveraging, and that the processes of resource allocation and resource transformation are the operative mechanisms through which these competences exert their influence. Because of its 'customer competence trap' and its 'marketing competence gap,' CHEMAN failed to allocate sufficient generic resources to be transformed into specific resources needed to re-link INERT to new markets. CHEMAN used the INERT technology to further exploit its competence in serving analytical labs, forming a customer competence trap. Their lack of marketing competence prevented them from overcoming this trap. Marketing competence would have allowed the impetus for resource allocation and transformation to come from inside, rather than be entirely driven by current customers.

This study has addressed a gap in knowledge about the allocation and transformation of resources. Technology leveraging involves allocating fungible resources to be transformed into specific resources, in particular market-related resources. This case study examined the transformation of generic resources, such as time and money, into specific resources, such as sales and distribution channels and knowledge about customers. The findings support prior work on allocation of resources, by showing that the resources, both financial and human, need to be sufficient (in amount), dedicated (in allocation), and consistent (over time) in order for technology leveraging to occur. But beyond this accepted wisdom, the findings point to the importance of the

process subsequent to allocation: transformation. Resource transformation is the conversion of one type of resource into another. The allocation of slack generic resources is a necessary, but not sufficient condition for technological competence leveraging. In addition to merely being available, generic resources also need to be transformed into specific resources that are complementary to the technology and essential for its commercialization. This study has shown that this transformation of generic resources into specific market-related resources depends on the external impetus provided by customer competence or the internal impetus from marketing competence. Technological competence leveraging does not occur as an endogenous by-product of experience in serving current customers (Danneels, 2003); rather it requires the firm to deliberately devote resources to competence creation (i.e., exploration). In the firm studied here, this allocation of resources to build new competences was inhibited by the presence of a first-order customer competence (i.e., the competence to serve current customers) and the lack of a second-order marketing competence (i.e., marketing competence gap). The current customer competence had a strong impetus in the allocation and transformation of resources, driving CHEMAN to focus its application of INERT to its served market. As the technology was de-linked from CHEMAN's core market, it became detached from the external impetus from current customers, and CHEMAN lacked the second-order marketing competence necessary to generate internal impetus. The creation of new competence requires a deliberate managerial decision to divert resources away from the production of output to the production of competence (Dorroh, Gullledge, and Womer, 1994). Full exploitation of current resources requires delinking of those resources from the product in which they are embedded, a process that removes the impetus from current customers. This study has provided a contribution to the work in the resource-based theory tradition, which has heretofore assumed that the actions necessary to exploit resources are self-evident (Barney and Arikan, 2001; Sirmon, Hitt, and Ireland, 2007).

This study has also addressed a gap in knowledge about the generation of value from resources. Priem and Butler (2001b) noted that the extraction of value from resources is treated as if outside the purview of resource-based work, which has been mute on value creation. Barney (2001)

concurrent, and argued that resource-based theory needs to be augmented by theories of the entrepreneurial process to better understand value creation. The findings of the current study supplement the traditional focus on the cognitive process of entrepreneurial discovery with an appreciation of the role of resource-related processes, in particular allocating and transforming resources. Opportunities are 'problematic' (Shane, 2000) in that both their recognition and pursuit are a function of these processes. Opportunity recognition does not itself lead to the realization of those opportunities and creation of wealth. While the firm studied here recognized a plethora of market applications for its technology, it failed to manage these resource processes in order to pursue these opportunities.

Finally, this article sheds light on the intellectual property route to technology leveraging. Licensing the technology to another firm is an alternative way to commercialize technological innovation, and 'has become a well-established commercialization strategy which is used to fully exploit a company's technology assets' (Kollmer and Dowling, 2004: 1148). Licensing is a way to contractually combine resources across the boundaries of firms, where the licensor provides the technology and the licensee provides the complementary assets such as sales and distribution channels (Hill, 1992). Licensing has been referred to as 'a contractual technology transfer mechanism' (Kollmer and Dowling, 2004: 1141), but it involves much more than technology transfer. Regardless of the route to commercialization, via internal product development or intellectual property, firms need a second-order marketing competence. To address and serve new market applications firms use complementary market-related resources, and a second-order marketing competence is needed to build them. To extract value from licensing their technology to third parties, they need to understand customer needs to target applications, identify, assess, and select licensees, and negotiate licensing contracts. An important consideration is whether to license pre- or post-linking; i.e., whether to license before or after a technology becomes linked to specific market applications. To judge the commercial value of the technology, either the licensor or licensee need to link the licensed technology to one or several market applications. To the extent that the degree and types of technology-market linkages made by licensor and licensee differ, an information asymmetry may arise.

In sum, this article studied the process by which fungible technologies are leveraged beyond their initial application market to gain an understanding of why this source of value may be foregone. A longitudinal field study showed that the presence of a competence to serve current customers and a lack of a marketing competence to search for new ones inhibits the leveraging of technological competence, and that these competences exert their influence through the processes of resource allocation and transformation. Understanding the process by which firms may or may not extract the most value out of their resources and competences promises to be of great importance to both scholars and practitioners.

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REFERENCES

- Barney JB. 2001. Is the resource-based 'view' a useful perspective for strategic management research? Yes. *Academy of Management Review* **26**(1): 41–56.
- Barney JB, Arian AM. 2001. The resource-based view: origins and implications. In *Handbook of Strategic Management*, Hitt MA, Freeman RE, Harrison JS (eds). Blackwell: Oxford, UK; 124–188.
- Berg BL. 1989. *Qualitative Research Methods for the Social Sciences*. Allyn & Bacon: Needham Heights, MA.
- Bourgeois LJ III. 1981. On the measurement of organizational slack. *Academy of Management Review* **6**(1): 29–39.
- Bower JL. 1970. *Managing the Resource Allocation Process*. Irwin: Homewood, IL.
- Burawoy M. 1991. *Ethnography Unbound*. University of California Press: Berkeley, CA.
- Burgelman RA. 1991. Intraorganizational ecology of strategy making and organizational adaptation: theory and field research. *Organization Science* **3**(2): 239–262.
- Burgelman RA. 1994. Fading memories: a process theory of strategic business exit in dynamic environments. *Administrative Science Quarterly* **39**(1): 24–56.
- Burgelman RA. 1996. A process model of strategic business exit: implications for an evolutionary perspective on strategy. *Strategic Management Journal*, Summer Special Issue **17**: 193–214.
- Christensen CM, Bower JL. 1996. Customer power, strategic investment, and the failure of leading firms. *Strategic Management Journal* **17**(3): 197–218.
- Collis DJ. 1994. Research note: how valuable are organizational capabilities? *Strategic Management Journal*, Winter Special Issue **15**: 143–152.
- Danneels E. 2002. The dynamics of product innovation and firm competences. *Strategic Management Journal* **23**(12): 1095–1121.
- Danneels E. 2003. Tight–loose coupling with customers: the enactment of customer orientation. *Strategic Management Journal* **24**(6): 559–576.
- Dorroh JR, Gilledge TR, Womer NK. 1994. Investment in knowledge: a generalization of learning by experience. *Management Science* **40**(8): 947–958.
- Dougherty D. 1992. A practice-centered model of organizational renewal through product innovation. *Strategic Management Journal*, Summer Special Issue **13**: 77–92.
- Eisenhardt KM. 1989. Building theories from case study research. *Academy of Management Review* **14**(4): 532–550.
- Ford D, Ryan C. 1981. Taking technology to market. *Harvard Business Review* **59**(2): 117–126.
- Gambardella A, Torrisi S. 1998. Does technological convergence imply convergence in markets? Evidence from the electronics industry. *Research Policy* **27**(5): 445–463.
- Hamel G, Prahalad CK. 1994. *Competing for the Future*. Harvard Business School Press: Boston, MA.
- Hargadon A, Sutton RI. 1997. Technology brokering and innovation in a product development firm. *Administrative Science Quarterly* **42**(4): 716–749.
- Hill CWL. 1992. Strategies for exploiting technological innovations: when and when not to license. *Organization Science* **3**(3): 428–441.
- Hirschman EC. 1986. Humanistic inquiry in marketing research: philosophy, method, and criteria. *Journal of Marketing Research* **23**(3): 237–249.
- Kollmer H, Dowling M. 2004. Licensing as a commercialization strategy for new technology-based firms. *Research Policy* **33**(8): 1141–1151.
- Lee TW. 1999. *Using Qualitative Methods in Organizational Research*. Sage: Thousand Oaks, CA.
- Levinthal DA, March JG. 1993. The myopia of learning. *Strategic Management Journal*, Winter Special Issue **14**: 95–112.
- Levitt B, March JG. 1988. Organizational learning. *Annual Review of Sociology* **14**: 319–340.
- Lincoln YS, Guba EG. 1985. *Naturalistic Inquiry*. Sage: Beverly Hills, CA.
- Lynskey MJ. 2005. Brewing up new technological capabilities: how corporate entrepreneurship enabled Japanese breweries to enter the biopharmaceutical industry. Working paper, University of Cambridge, UK.
- Mahoney JT, Pandian JR. 1992. The resource-based view within the conversation of strategic management. *Strategic Management Journal* **13**(5): 363–380.

- March JG. 1991. Exploration and exploitation in organizational learning. *Organization Science* **2**(1): 71–87.
- Maritan CA. 2001. Capital investment as investing in organizational capabilities: an empirically grounded process model. *Academy of Management Journal* **44**(3): 513–531.
- McCracken G. 1988. *The Long Interview*: Sage: Newbury Park, CA.
- Miles MB, Huberman AM. 1994. *Qualitative Data Analysis: An Expanded Sourcebook* (2nd edn). Sage: Beverly Hills, CA.
- Miller CC, Cardinal LB, Glick WH. 1997. Retrospective reports in organizational research: a reexamination of recent evidence. *Academy of Management Journal* **40**(1): 189–204.
- Miller D. 2003. An asymmetry-based view of advantage: towards an attainable sustainability. *Strategic Management Journal* **24**(10): 961–976.
- Mitchell W. 1992. Are more good things better, or will technical and market capabilities conflict when a firm expands? *Industrial and Corporate Change* **1**(2): 327–346.
- Nevens TM, Summe GL, Uttal B. 1990. Commercializing technology: what the best companies do. *Harvard Business Review* **68**(3): 154–163.
- Noda T, Bower JL. 1996. Strategy making as iterated processes of resource allocation. *Strategic Management Journal* **17**(7): 159–192.
- Noda T, Collis DJ. 2001. The evolution of intraindustry firm heterogeneity: insights from a process study. *Academy of Management Journal* **44**(4): 897–925.
- Nohria N, Gulati R. 1996. Is slack good or bad for innovation? *Academy of Management Journal* **39**(5): 1245–1264.
- O'Brien JP. 2003. The capital structure implications of pursuing a strategy of innovation. *Strategic Management Journal* **24**(5): 415–431.
- Orton JD. 1997. From inductive to iterative grounded theory: zipping the gap between process theory and process data. *Scandinavian Journal of Management* **13**(4): 419–438.
- Patel P, Pavitt K. 1997. The technological competencies of the world's largest firms: complex and path-dependent, but not much variety. *Research Policy* **26**(2): 141–156.
- Penrose ET. 1959. *The Theory of the Growth of the Firm*. Wiley: New York.
- Prahalad CK, Hamel G. 1990. The core competence of the corporation. *Harvard Business Review* **68**(3): 79–91.
- Priem RL, Butler JE. 2001a. Is the resource-based 'view' a useful perspective for strategic management research? *Academy of Management Review* **26**(1): 22–40.
- Priem RL, Butler JE. 2001b. Tautology in the resource-based view and the implications of externally determined resource value: further comments. *Academy of Management Review* **26**(1): 57–66.
- Rafaeli A, Sutton RI. 1991. Emotional contrast strategies as means of social influence: lessons from criminal interrogators and bill collectors. *Academy of Management Journal* **34**(4): 749–775.
- Shane S. 2000. Prior knowledge and the discovery of entrepreneurial opportunities. *Organization Science* **11**(4): 448–469.
- Sirmon DG, Hitt MA, Ireland RD. 2007. Managing firm resources in dynamic environments to create value: looking inside the black box. *Academy of Management Review* **32**(1): (forthcoming).
- Strauss AL. 1987. *Qualitative Analysis for Social Scientists*. Cambridge University Press: New York.
- Teece DJ. 1982. Towards an economic theory of the multiproduct firm. *Journal of Economic Behavior and Organization* **3**(1): 39–63.
- Teece DJ. 1986a. Profiting from technological innovation: implications for integration, collaboration, licensing and public policy. *Research Policy* **15**(6): 285–305.
- Teece DJ. 1986b. Firm boundaries, technological innovation, and strategic management. In *The Economics of Strategic Planning*, Thomas GL (ed). D.C. Heath: Lexington, MA; 187–199.
- Thomke S, Kuemmerle W. 2002. Asset accumulation, interdependence and technological change: evidence from pharmaceutical drug discovery. *Strategic Management Journal* **23**(7): 619–635.
- Tripsas M. 1997. Unraveling the process of creative destruction: complementary assets and incumbent survival in the typesetter industry. *Strategic Management Journal*, Summer Special Issue **18**: 119–142.
- Weick KE. 1995. *Sensemaking in Organizations*. Sage: Beverly Hills, CA.
- Wernerfelt B. 1984. A resource-based view of the firm. *Strategic Management Journal* **5**(2): 171–180.