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The integration of information and communication technologies (ICTs) with mechanical engineering products as an example of technology transfer and the business model

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A B S T R A C T

Using the technological prospects presented by cross-fertilization, this article explores the growing interdependence between several domains of product knowledge and how businesses seek to appropriate economic value from their technical potential. The research focuses on three multinational firms and how they have incorporated new information and communication technologies into their well-established mechanical engineering offerings. The examples demonstrate the need of modifying business models in tandem with implementing cross-fertilization of technologies for maximum economic benefit. While the input side of multi-technology products has received a lot of focus in the literature so far, the economic and commercial sides have been mostly overlooked. This research adds to the management canon by connecting input resources with market output in order to generate and appropriate value through technological exchange.

Keywords: Conceptualization of a Profitable Business Cross-fertilization The Value of Information and Communication Technologies and How to Get Your Hands on It

1. Introduction

Diversification has long been seen as a critical strategic component in the expansion of successful businesses1 (e.g. Ansoff, 1957; Penrose, 1959; Rumelt, 1974; Montgomery, 1994; Markides and Williamson, 1994). This viewpoint has mostly concerned itself with expanding into new output markets, such as additional product categories, new types of firms, and new countries or regions for sale of goods and services (internationalization). A fresh body of work on diversification (Kodama, 1986; Pavitt et al., 1989; Granstrand and Sjölander, 1990; Patel and Pavitt, 1994; Granstrand et al., 1997) emphasizes the relevance of input technology diversification for firm development. Significant progress has been achieved in this body of literature on technology diversification by demonstrating that big firms employ and acquire competences in a wide variety of technical fields. Opportunity to bring new technologies into goods via cross-fertilization of technologies and pressure to sustain a certain product line to keep its relevance are cited as primary motivators of technological diversification in the literature (Granstrand et al., 1997). Thus, the literature stresses the need of incorporating a wide variety of technologies into goods (Pavitt, 2001). Existing studies on technology diversification tend to emphasize the breadth of a company's technological competencies, which is often measured by the distribution of patents across technological classes (e.g. Pavitt et al., 1989; Granstrand et al., 1997; Patel and Pavitt, 1997; Gambardella and Torrisi, 1998; Garcia-Vega, 2006), while minimizing the connections between the integration of new technologies into products and the creation and appropriation of value.

Innovation in management is required to create and appropriate value from a diversified product technology base (technological cross-fertilization). Therefore, the creation of value for consumers and the appropriation of economic value by firms are important considerations from a management or firm viewpoint. Customer or user value is not always increased when two technologies are combined. Neither does a rise in value for end users automatically translate into a rise in value for the integrating company. Thus, it is evident that managing the creation and appropriation of value from expanding goods' underlying technology is a need. Some users may benefit from the cross-fertilization, but there may be management issues with realizing that benefit and also appropriating a portion of that benefit, which are likely to be strongly related to the activities in the business model being used. With the goal of expanding upon the present sparse empirical knowledge, this research zeroes in on these specific topics.

For the purpose of this article, we investigate how the combination of Information and

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Incorporating Information and Communication Technologies (ICTs) into a product's technological foundation might reveal previously unexplored niches in terms of the product's technical performance and usefulness. Products can now acquire, regulate, process, store, and share information in ways that were before impossible because to the fast and constant increase in the performance and affordability of ICTs. That is to say, relics of the mechanical arts and sciences has a growing potential for 'intelligent' development. We look at the ways in which companies strive to take economic benefit from this cross-fertilization of technologies. We analyze in detail the efforts of three MNCs (multinational, multiproduct, multitechnology firms) to include ICT components into their respective mechanical engineering products: (1) decanters for wastewater treatment facilities, (2) industrial compressors, and (3) ball bearing housings.

This paper will be organized as such. The first section provides context in the form of empirical data and theoretical frameworks. After this introduction, you'll read about the approaches used, and then you'll learn about three companies' efforts to broaden their product lines' appeal by incorporating previously unrelated technologies into their offerings. This research delves into their efforts to produce and appropriate monetary value for themselves from these endeavors. Conclusions and management ramifications are discussed.

2. Theoretical and empirical background

Companies and goods that use several technologies

Multiple technologies, components, and sub-systems are now integrated into a wide range of products across industries. The technology bases of major firms are often significantly larger than their product bases due to the trend toward multi-technology use in both goods and businesses (Patel and Pavitt, 1997). As the level of technical competition rises, businesses have forced to broaden their resource bases to continue offering a competitive selection of products. However, firms have been forced to specialize on fewer areas of production due to the challenges of maintaining the resources needed to serve a broad spectrum of fundamental production sectors. This was predicted by Penrose (1959), and subsequent research by Gambardella and Torrisi (1998) in the electronics sector and von Tunzelmann (1998) in the food business provided convincing evidence of the phenomenon.

A strong case can be made, and enough evidence supports the claim, that not even the

When developing multi-technology goods, vertically integrated companies require access to external resources in order to fully use their internal ones. When the production of technologies and components is centralized in specialized produc- ers, it is inefficient for firms to create everything required in the manufacturing and product design of multi-technological goods. They have little choice but to depend on third-party vendors for everything from raw materials to finished goods. This means that numerous businesses fit the description of "systems integrators" (Davies, 2003, 2004; Hobday et al., 2005). However, Granstrand et al. (1997) discovered that large firms increasingly develop technological competencies in a wide range of technological fields outside their "distinctive core," or the technologies that are dominant within the firm, and beyond the fields with which they are associated in terms of production activities. To rephrase, a company may need to cultivate certain in-house capabilities in a technology that isn't part of its primary field if it wants to coordinate its efforts effectively.

items that are already on the market to boost their efficiency and capabilities (Granstrand et al., 1997).

The 2.2. Transfer of Technologies

New technologies are added to a product's technology base via a search process in which potential technologies are identified, evaluated, and ultimately incorporated into the technology base to improve technical performance along the product's current trajectory and/or provide new functions. Product-related technology diversification2 is another term for this process (Granstrand, 2001). In this case, the search for new technologies is limited by the need that they cross-fertilize inside the product, therefore creating new technical performance and functionality sub-spaces. As a subset of economies of scope, this one is distinct from resource sharing-related economies of scope in terms of both cost and (Granstrand, 1999).

Breakthroughs in science and technology pave the way for novel fusions of previously unrelated fields (Granstrand, 2001). In particular, so-called general purpose technologies (GPTs) (Torrisi and Granstrand, 2004) are used to facilitate cross-fertilization since they are ubiquitous, transcend most industry barriers, and are highly complimentary to other technologies. Instead of providing end-to-end product solutions, GPTs serve as enabling technologies by creating new avenues for innovation (Bresnahan & Trajtenberg, 1995). The flexibility and adaptability of these three ICTs makes them ideal candidates for integration with other tools. It has been shown that the information and communication technology (ICT) sector is where most companies that patent outside of their primary technical area are doing so. In fact, more patents are issued in this area than any other, causing it to spread out into related but distinct fields (Mendonc a, 2002). Constant technological development in this area has led to better price/performance ratios, the introduction of novel applications, and the monetization of increased speed, adaptability, network capacity, and data storage (Freeman, 1995). Freeman (1995, p. 55) argues that it is a fallacy to see the information and communications technology (ICT) sector as nothing more than a collection of emerging, high-growth businesses. Also, technology may be a powerful catalyst for change in more "traditional" sectors, such as mechanical engineering. Productivity increases, ICT use in manufacturing and product design, cross-border knowledge flows, information exchange, workforce adaptability, organizational practices, process improvements, and economic growth are just some of the topics that have been examined in the context of inter-industry spillovers (see e.g. Freeman, 1995; Helpman, 1998; Pavitt, 2001; Fabiani et al., 2005). Few studies have looked at the effect that ICTs, which are built on different engineering principles, have on already-existing goods, despite the fact that they enable and may be used to enhance them. It's puzzling that this is the case, given that ICTs may be used across a broad variety of product categories and sectors, providing both technical and business potential for companies.

management of industrial processes, inventory, and supply chains the technical window of opportunity is dwindling. When the product includes highly interdependent components or subsystems whose interaction can't be predicted or when there are uneven rates of change in components or sub-systems, Brusoni et al. (2001) argue that it is necessary for firms to develop technological competencies without associated production. This last point explains why it is essential for businesses to have expertise in emerging technologies over time (Pavitt, 2001). In order to keep up with the rapid advancements in science and technology, businesses of all sizes are increasingly diversifying their areas of expertise (Pavitt, *2001).*[2] The reverse of product related technology diversification is technology related product diversification, meaning that for a given technology

and not the existing products, is discussed by Kodama (1992), which states that thefusing of existing technologies (technology fusion) can create so-called “hybrid tech- nologies”, e.g. fusion of mechanical and electronics technologies, which produced the mechatronics revolution, and the fusion of optics and electronics which cre- ated optoelectronics (the first would be characterized as production fusion and the second as scientific fusion, Freeman, 1995). These technology fusions gave rise to new products that revolutionized markets. Kodama (1986) ascribed much of Japan’s success in the 1980s to its achievement in fusing science based and mechanical engineering technologies.

innovative items and the technologies upon which they are built.

This type of cross-fertilization of interdisciplinary bodies of knowledge seems offer extensive technological opportunities for mechanical engineering firms that adhere to Rumelt's so-called related-constrained diversification pattern, i.e. sticking to the original business area (Torrisi and Granstrand, 2004). There looks to be a wealth of opportunities in the ICT sector for enhancing mechanical engineering products with ICT features including sensors, communication capacity, and real-time information systems. As a result, the parameters of this "conventional" sector have shifted significantly, and companies now have more leeway in deciding how, if, and when to grasp chances.

Value generation and capture

The opportunity to generate value via the inclusion of new technologies in current goods is well recognized in the literature on technology diversification as a key motivator of technological innovation (Oskarsson, 1993; Granstrand et al., 1997; Torrisi and Granstrand, 2004). There is a widespread acknowledgement in this body of work of the importance of developing technologies to the value creation process. It does not, however, examine how the value that is produced for consumers as a result of the incorporation of new technology into goods is captured by the manufacturing firm. Expanding the scope beyond technologies as input resources to include economic output and the relationship between the two is essential for comprehending how businesses may generate value and profit from technological exchange.

There has been a suggested business strategy to investigate this complex interplay. Since the mid-1990s, this idea has been widely discussed (see e.g. Slywotzky, 1996; Slywotzky and Morrison, 1998; Amit and Zott, 2001; Chesbrough and Rosenbloom, 2002; Magretta, 2002; Markides and Charitou, 2004; Morris et al., 2005). Substantial amounts of this literature have zeroed in on various, often conflicting, facets of the company's operations (Morris et al., 2005). Even if the various conceptualizations do have a common denominator—to generate and capture value—the notion is clearly a little convoluted. In contrast to traditional strategy literature, which often focuses only on the appropriation of value, the business model literature has attempted to expand its focus to include the production of value for the user. Since the focus of Teece's (1986) framework on how to appropriate value from innovation is on protecting an innovation in order to appropriate economic value, rather than on value creation and value sharing (Moran and Ghoshal, 1999; Jacobides et al., 2006), the literature on business models goes beyond Teece's (1986) approach. Although value appropriation plays a larger part in conventional views of strategy, it is commonly agreed that one of the business model's primary functions is to generate profits for customers (see e.g. Chesbrough and Rosenbloom, 2002). 4 However, neither can be neglected since they are essential. Value must be generated before it can be appropriated, and managers of the firm must think forward to the ways in which that value may be appropriated while they create it.

The article defines a business model as the set of interrelated practices for creating and capturing economic value. Essentially, a business model is a description of the actions and decisions that lead to a company's success.

uses inputs of resources, often technological ones, and transforms them into economic outputs by way of consumers and markets, so linking resource potential with the actualization of economic value (Chesbrough and Rosenbloom, 2002). Business models describe how a company sells and distributes its product or service, as well as how it creates value for its customers and makes a profit. They also describe which customer segments are being served and what products or services are being offered to them (Slywotzky, 1996; Magretta, 2002).

Until a technology is commercialized, its potential worth remains untapped. Technology investments can only provide returns if the accompanying business strategy is tailored to the specifics of the relevant technical or market opportunity. An organization's existing business model may work well with certain technologies, but other times, it may be required for the organization to develop a whole new model. If the right economic model isn't found, the technology won't produce as much as it might, and the company could even back away from a promising line of research or the market entirely (Chesbrough and Rosenbloom, 2002).

Three business development initiatives, their commercialization processes, and their results within three separate mechanical engineering firms were researched to study the integration of ICT into existing goods and how it appears in the firm's efforts to appropri- ate economic value.

3. Methods

3.1. Methodological approach

Following Eisenhardt (1989) and Yin (1994), this paper adopts a multiple case study approach to analyze the specific pattern of inte- grating ICTs in established mechanical engineering products. The aim is to uncover how this technology cross-fertilization results in challenges to the firms' business models and to answer "how" ques- tions. In-depth case study research analysis is especially suited to these objectives, but does not accommodate "what" questions as its generalizability is limited. The paper does not intend to extrap- olate from the findings, but rather addresses the under-researched phenomenon of use and integration of ICTs in products, and how firms try to appropriate economic value from their technical poten- tial. The inherently limited generalizability of case studies is to some extent mitigated by the use of multiple cases that are not focused on a specific sector or technology, and which are linked to the established literature on multi-technology firms and business models.

In choosing the case studies for this study, I was particularly con-

cerned about their relevance to the subject of integration of ICTs in established mechanical engineering products. This required obser- vation of mechanical engineering products that were enhanced through increased performance or new functionalities through the integration of ICT components. Hence, the improvement in the established product should lie in the addition of new technologies and their complementarity with the existing technologies. There were two other reasons for the choice of case studies. First, they reflect substantial ICT investment in mechanical engineering prod- ucts for new and improved customer value. Second, the firms are all MNCs/MTCs/MPCs, which dominate their industries in terms of both technology and market share. These companies have grown with the constantly changing opportunities in technologies and markets and intend to maintain this growth through the creat-ing of more tailor-made solutions, which the integration of ICTsin products should facilitate.

3.2. Data collection and data analysis

The business development processes within the companies studied were followed for three years. For two of the companies the data collection process covered the period before and after var-ious product launches and changes in their business models, whichincreased the possibility to identify the business challenges faced by these companies.

Several data sources were used. The data are based on internal presentations, workshops and seminars for identify- ing viable business models from technology cross-fertilization. Archival analysis of business plans, annual reports, brochures, internal documentations and trade literature was also made. This was complemented with 13 in-depth semi-structured inter- views with managers at several hierarchical levels and functional positions, to get both retrospective and prospective views. The managers were asked to describe the firms' motives for integrating ICT and the perceived business opportunity and challenges from doing so, from a technical, strategic, commer- cial and organizational perspective. Interviews lasted 1.5–3 h and were recorded and subsequently transcribed. These inter- views were followed up with a number of supplementary telephone interviews and email exchanges, to clarify particular issues.

The data collection process was followed by case write-up and analysis. The different data sources were triangulated (Jick, 1979) during case write-up and analysis to increase the robustness of the results. Following Eisenhardt's (1989) recommendations for analyzing data, a within-case analysis was applied followedby cross-case analysis. In the within-case analysis, I examined how the companies created business models for their technology cross-fertilization. This process produced unique patterns for each case (Eisenhardt, 1989). Following the within-case analysis, I undertook cross-case analysis in which case pairs were compared for similarities and differences in the strategies for business model constructs. I looked for within-group similarities coupled with intergroup differences, based on dimensions suggested by the literature on business models. The idea behind this cross-case analysis was to go beyond initial impressions and enhance the probability of capturing novel findings from the data (Eisenhardt, 1989). Therefore, although my initial inquiry was based on existing theory, the ultimate focus was on the development of new insights through iterations of theory and data. In order to validate my analyses, the empirical parts of the paper were made available for comment by the interviewees.

4. Cases

Incorporating Information and Communication Technologies Into Decanters (4.1) Alfa Laval

In the first case study, we look at how Alfa Laval improved sludge dewatering operations at wastewater treatment facilities by incorporating ICTs into decanter centrifuges.

Effluent water is cleaned and disinfected in wastewater treatment facilities, then redirected to streams. Manufacturing decanter centrifuges to dewater the sludge by as much as possible is Alfa Laval's main business, which is connected to the last stage of wastewater treatment. The greatest money is spent on this step than any other in the wastewater treatment facility, which accounts for around 35% of all operating expenses.

Due to the ever-changing nature of the feed quality and feed density, sludge dewatering is a process fraught with considerable unpredictability. Due to the unpredictability of its input, the process needs close monitoring to ensure its smooth operation. To begin, polymers must be added to the sludge before it can be fed into the decanter. Fluctuating performance, excessive polymer consumption, reduced dewatered sludge in the cake, and dirtier centrate are all results of incorrectly adjusting the polymer dosing to the sludge in the decanter operation. The decanter operates at a pretty high performance, 70-80% of its capability, during "regular" working hours when an experienced operator is in control of the dewatering process, but this drops fairly substantially when no one is in charge of the process. To avoid any malfunctions or breakdowns outside of regular business hours, the process must be put into safe mode.

The process of automating decanter operations was first investigated by a lone Alfa Laval engineer in 1991. The project was abandoned because of difficulties in gauging sludge quality. As technology advanced, sludge measurement was implemented in 1999, breathing new life into the project. The Octopus self-optimizing system for sludge dewatering was pre-launched by Alfa Laval in 2002. This system would function at peak efficiency and optimize the dewatering process according to total costs, solids recovery, or cake dryness, all without regard to input conditions. Octopus is able to optimize the dewatering process without human intervention by continuously monitoring and analyzing the process parameters (torque and difference from decanter, polymer dosage, concentration and quality of sludge) (see Fig. 1). Octopus can reduce dewatering process running costs by as much as 20%, saving around 7% of the plant's overall operating expenses.

A computer, sensors with a control box, and cables link the sensors and the computer to the feed pump, polymer pump, and decanter, making up the new technologies included into the product. Real-time data collection and transmission from sensors throughout the dewatering process enables a feedback loop to maximize outputs by adjusting modifiable inputs (torque and differential from decanter, and polymer dosage). Octopus relies on custom software developed by Alfa Laval that analyzes decanter performance in dewatering applications and then recommends new control parameters. While Octopus's hardware came from outside sources, its software was built using algorithms derived from decanter process flow maps. Although outside software professionals did the actual coding, this invention was made by in-house process specialists at Alfa Laval.

Since Octopus eliminated the need for Alfa Laval to manufacture anything, the company has been able to focus on selling its expertise in process control and decanter design. In Octopus, Alfa Laval recognized a real chance to profit on its expertise and set itself apart from rivals. Alfa Laval struggled to understand how it might profit from the latent value in the technology without making significant modifications to its present business model, despite the new technology's potential to provide economic benefit for clients in the form of lower costs (see Table 1).

Alfa Laval had always sold its goods via capital sales (i.e. a one-time charge for the client), and it was unclear to them how they would be compensated for the customer value the new technology would provide. The market division in charge of selling decanters intended to offer Octopus with the decanters, since this was already a common practice in the industry.

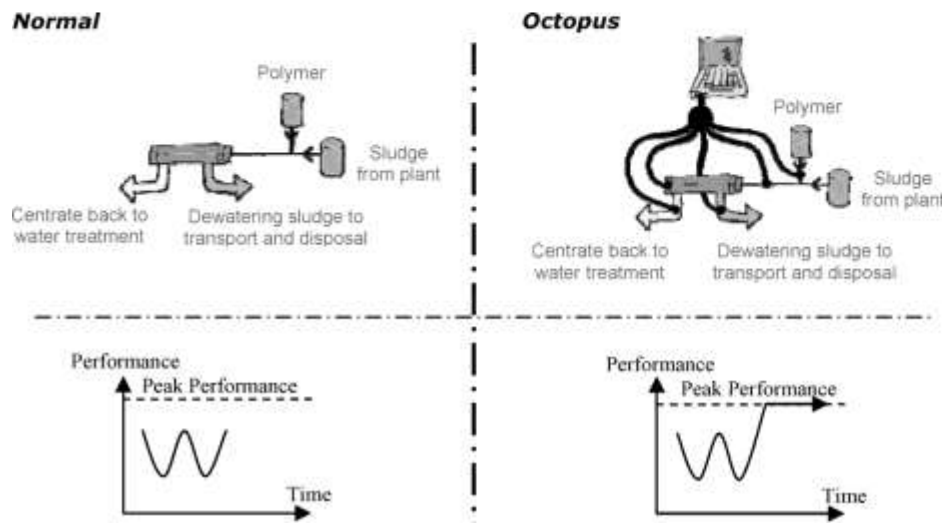

Fig. 1. Performances of dewatering processes.

company's history in this area. Selling decanters via public tender rather than directly to customers limited the company's ability to generate income through means other than capital sales. These public bids imposed particular requirements on Alfa Laval, and although Octopus offered many benefits, it was difficult to get clients to specify them without first educating them on the technology's benefits. Capital sales would have been required to sell Octopus with the decanters, and the firm would not have been compensated for the value it brings to customers thanks to the new technology.

The yearly savings in the customer's bottom line were worth much more than the decanter's initial outlay during its useful lifetime. Some clients might recoup the investment in the machinery in the first year alone. Even once Alfa Laval is no longer involved, the new technology will continue to provide cost benefits. If Alfa Laval had marketed Octopus using its capital sales approach, the price of its decanters would have had to climb significantly for the client to recoup part of the benefit of the decreased expenses. The management was worried that raising the cost of its decanters would lead to less sales of both the decanters and the new technology since there was already price pressure in the wastewater sector. Customers would have to put out a lot of money to buy decanters and the new technology. When consumers evaluated decanters using capital costs instead of overall life-cycle costs, Alfa Laval missed out on sales opportunities. Octopus was also deemed inappropriate for certain users due to the fact that the amount of money customers saved varied depending on the size of the plant. Consequentially, it was considered that a different approach was required to deploy the new technology; a trained sales staff was required to promote Octopus to Alfa Laval's installed base and highlight the substantial savings that the new technology would provide. Therefore, the management team at Alfa Laval concluded that the company's existing business strategy was insufficient to capitalize on the market potential presented by the new technology via commercialization.

Seeing the potential and the disparities between the new technology and the old methods of conducting business, Alfa Laval adopted a new business model in 2002. Alfa Laval realized it could make more money by licensing the technology to consumers for an annual charge that was proportional to the amount of money customers saved by adopting the technique (about 35 percent). Both Alfa Laval and the wastewater treatment sector could not have been more up to date than with this revolutionary new model. As a means of overcoming the need for substantial investment from consumers, it was thought to reduce entry barriers by making it simpler for clients to understand the financial benefits of the solution. Users would be charged only for their guaranteed uptime, making the license fee model ideal for both ensuring software upgrades are always free and attracting new users (thus maintenance and support were included in the licence fee). Alfa Laval's bottom line would benefit from the money its clients saved, and those customers would be able to terminate their license agreements if they so choose. Customers were enticed by the offer since there was zero risk involved in doing business with Alfa Laval. Alfa Laval had to put in a lot of effort with clients at first, but the new setup was worth it.

Table 1
Business model changes.

	Business model I	Business model II	Cause of change
Customer value	Dewatering of sludge	Optimization of dewatering of sludge (cost savings); process surveillance and piece of mind	Integration of ICTs
Customer segment	Wastewater plants	Installed base of large customers that can save a substantial amount of money	Upgrade and an optimization for existing decanters
Offering	Product	Service contract and maintenance	Payment based on savings; free software upgrades
Revenue model	Capital sales	License	Contracyclical revenues
Sourcing	In-house development	Sourcing of ICT components and sub-systems, hiring of software programmers	No ICT competence; standard equipment
Distribution/selling	Through the line organization	Through an own venture	Protection from the line organization; need for dedicated sellers

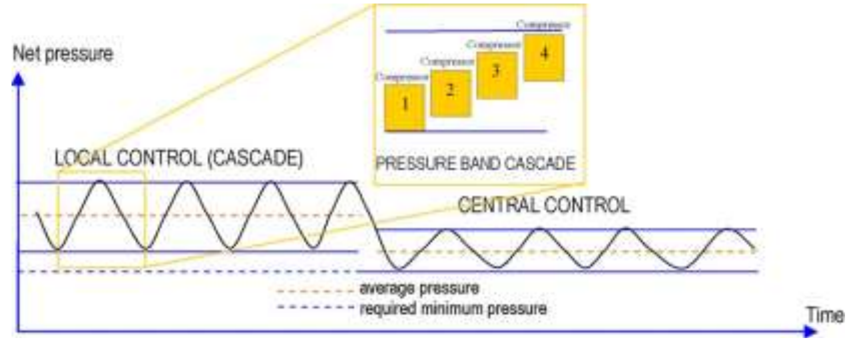

Fig. 2. Local control vs. centralized control.

lished business model proved very successful, and resulted in the company achieving a gross margin of over 80 per cent on the new technology.

Beta—ICT adoption in compressors

In this second case study, we look at how Beta6 enhanced the efficiency of their compressed air systems by using new technologies, hence cutting its energy expenditures. All sorts of businesses rely heavily on compressed air systems. 7 Compressors utilize a significant portion, up to 30 percent8 of all industrial energy (Source Newsletter, 2003). Compressed air serves as a power source or active air in many industrial processes, and compressors are utilized in a broad variety of these applications. Electricity usage has become a major concern in many sectors as a result of rising energy prices and regulatory pressure to reduce carbon dioxide emissions. Users of compressed air systems incur the biggest total cost of ownership during the compressor's energy consumption (Office of Industrial Technologies, 1998). Around 70% of the total life cycle cost of a compressed air system is attributable to energy consumption, whereas only 20% is attributable to capital expenditure and 10% to maintenance. Most compressors have their own control systems built right in (local compressor control). This regulation guarantees that the compressor provides a variable amount of air within a predetermined pressure range (Office of Industrial Technologies, 1998). The compressor loads when the pressure lowers to a certain level, and it unloads when the pressure reaches a certain level (and the pressure increases). The compressor's set-point, which specifies when the compressor should load and unload, is located between these two pressure levels. When there is just one compressor and consistent demand, local control is the best option for a business. Most businesses, however, include room for more than one compressor in their installations so that they can keep up with fluctuating demand. To avoid unexpected spikes in pressure and keep the network stable while many compressors are operating in parallel, it is necessary to balance the load/unload of pressure of individual compressors. Since of this, the pressure range may be greatly expanded because each compressor can be operated at its optimal setting. Cascading compressors is the conventional approach of meeting rising air demand, but it wastes a lot of power in the process.

Beta reasoned that it might save its customers a lot of money over the long run if it succeeded in reducing their energy bills.

lifespan of a compressor In 1999, Beta responded to this market opening by beginning work on a real-time, centralized control system. The goal was to maximize compressor utilization, allowing the end user to more closely synchronize their needs with the compressor's output. For this reason, it was crucial that the control system be able to determine which compressors needed to be operational, and then to maintain a constant low pressure (see Fig. 2).

Through a signal (pres- sure sensing) and control at one central location as opposed to at each individual compressor, the company in 2002 had achieved a centralized control system that allowed customers to automatically select the optimum mix of compressors, either by installed power or by technology, allowing a reduction in the necessary working pressure. The basic idea is that the control takes over for the local compressor controllers and uses a global setpoint instead of individual ones for each compressor. The control system decides in real time which combination of compressors and their respective operating points will be most efficient in terms of energy consumption. Beta sees this as a huge benefit to the client since it allows them to cut their energy bills by 10%.

Because of the integration of ICT into the compressed air setup, centralized control is now possible. Hardware and software both contribute to the control system. There is a closed box containing an industrial computer, a monitor, and a controller area network that connects all of the local compressor controllers to the centrally located controller unit (the computer). The control system relies heavily on the computer's own software. Control logic for starting, stopping, unloading, and loading the compressors to maintain the user-defined pressure level, including decisions about which compressors should be run, is part of the software. The algorithms of the compressor's operation take into account reaction times, flow and energy characteristics, and more. These algorithms are unique to Beta and constitute its primary strengths. Although the algorithms were created in-house, the encoding and production of the hardware were outsourced.

In 2002, Beta introduced its centralized control system with nothing more than the hope that it would bring in more money for the company's compressor business by appealing to both existing and potential clients. Beta's early success in selling many of its systems was accompanied by the realization that the firm was not expanding its profits in response to the investment it had made; this was the case even though the target market was big and the new technology had an appealing value proposition. Managers admitted that the company did not keep a fair portion of the cost reductions passed on to consumers. According to management, Beta's predicament was that they had technology with high intrinsic value but lacked a viable business strategy for extracting monetary gain from it (see Table 2).

Table 2
Business model changes.

	Business model I	Business model II	Cause of change
Customer value	Compressed air	Optimization of compressed air (cost savings) and monitoring of installed compressors	Integration of ICTs
Customer segment	Manufacturing companies. New sales.	Manufacturing companies. New sales and for the installed base	Optimization for both existing and new compressor installations
Offering	Product	Product or as a service contract including maintenance	Charging based on savings; free software upgrades
Revenue model	Capital sales	Capital sales or as a license	Contracyclical revenues
Sourcing	In-house development	Sourcing of ICT components and sub-systems; hiring of software programmers	No ICT competence; standard equipment
Distribution/selling	Through the line organization	Through the line organization but with trained sellers	Need to articulate the value and calculate cost saving

that scaled with users' savings[9] and, over time, gave the business an increasing cut of customers' money. They turned the control system from a capital expense into an operating one by incorporating software updates and maintenance in the service contract. Along with the standard promotion of the control system came the inclusion of this service contract. There were already businesses selling sequencing-based control systems,[10] so Beta's management reasoned that it should keep peddling its own, more sophisticated control system via the same channel. Customers saw purchasing the equipment outright as more cost-effective than signing a contract, and there were few vendors capable of calculating and promoting the cost reductions associated with service agreements. Customers found it hard to envision how Beta's system would yield greater energy savings than other systems on the market, yet this was the single most important factor in deciding which systems to purchase. Beta's clientele proved the importance of providing evidence of these possible cost reductions.

Thus, the company still had trouble appropriating economic value even after it had changed its business strategy. A lot of money had already been invested in the new advancements by the time management understood that the company's present business strategy was inefficient at capturing economic value. Managers realized that in order to turn their new control system into a very profitable company, it would have to cease selling equipment and instead earn monthly revenues from customers depending on what they saved, in the form of a fixed charge or variable cost. Beta was having trouble setting itself apart from competing control systems on the market because of its inability to demonstrate the savings to customers. It was concluded that further improvements were needed to set its system apart from the ones supplied by rivals and to adapt its business strategy accordingly. With these, it might show the consumer how much money they could save. Further, the company recognized that it required a regionally based sales staff that was given specialized training. As a result, the corporation reasoned, it would be able to collect licensing fees from customers again, sharing in their cost savings, and eventually turning a profit.

In 2005, Beta started work on a next-generation control system that would allow it to shift its commercial focus. They created a locally-controlled, off-line simulation of the air network and simulated compressor operation at certain pressures. Through this, the simulation's cost reductions were compared to those of the real-world process and graphically shown.

Beta realized it required a new business strategy to fully capitalize on the rising demand for its product because of its previous failure to properly allocate economic value to the product.

ICTs are being included into SKF's ball bearing housings (Section 4.1.1).

In the third scenario, we look at SKF's efforts to monitor client application processes revolving around its process point (the bearing) in order to give users with additional value.

Housings for ball bearings are a crucial aspect of SKF's product line, since they prevent the bearings they house from malfunctioning. In other cases, a bearing housing is not even required, since the bearing may simply be allowed to run until it fails. However, in other cases, the application's success is crucial, and it's essential that operations run smoothly without any interruptions or pauses that might lead to expensive downtime.

In order to improve production reliability, safety, and application expertise, SKF measures a number of characteristics around the bearing to determine how a certain machine or the real process is operating. Since the mid-1980s, SKF has used decoupled sensors to take point readings of key parameters in massive manufacturing and processing facilities. It reasoned that by adding a sensor solution to its ball bearing housings, it might provide more value to its clients.

It all started in 1999, when a member of the Service Division and the SKF development team got together to make this thing. The original plan was to integrate speed and temperature sensors into all ball bearing housings with shaft diameters between 50 and 120 mm, of which around 500,000 are sold each year. SKF determined that included these sensors in the bearing housings' preparation wouldn't be too expensive and may eventually become the norm. However, a vibration sensor is more costly, therefore it was planned to give consumers the option of installing one if it was deemed that the device required to monitor vibration down the line. Users' interest was piqued by this method of pre-installing sensors since it would allow them to get insight on the performance of their apps. It was decided that the new technology's capacity to gauge temperature and speed would be used as a selling point in the hopes that more people would desire that feature. Additionally, it was thought that this would serve as a useful avenue for dissemination. Customers may pay for an additional box that plugs into the housing and displays monitoring data, or they could be charged according on how extensively they use the monitoring capabilities afforded by the new machine control system. This is how SKF would be compensated for the value it created with the new technology, which is why it was created in the first place.

Table 3
Business model changes.

	Business model I	Business model II	Cause of change
Customer value	Bearing protection	Bearing protection and measurement of temperature, vibration and speed.	Integration of ICTs
Customer segment	Users that need to protect bearings and that have critical applications. Mostly industrial applications.	Users that need to protect bearings and that have critical applications	No change
Offering	Product	Product	No change
Revenue model	Capital sales	Capital sales	No change
Sourcing	In-house development	Sourcing of ICT components and sub-systems	No ICT competence; standard equipment
Distribution/selling	Through the service division	Through the service division	No change

oped. Nonetheless, the Industrial Division, the product owner of the bearing housings, fought hard against these alterations to the preexisting economic model. As of 2001, the Industrial Division was in charge of the whole endeavor, and using SKF's tried-and-true business model, they created a company to exploit the new technology (see Table 3).

In 2003, SKF released a product it termed Smart Housing, which was essentially a bearing housing with built-in sensors and electronics for tracking how the product was being utilized in various client applications. Within the bearing housing, Smart Housing monitored axial and radial vibrations, temperature, and rotational speed to provide feedback on the customer's application. Smart Housing's sensors and electronics are housed in the bearing housing's lower cavi- ties. Two connections located on the front of the housing are used to transmit sensor signals. Dual axial and radial vibration are generated by the accelerometers housed in the sensor holder and linked together by a single connection. A printed circuit board safeguards and modifies the rotational speed and bearing seat temperature sent by the other connection. An integrated circuit sensor with a linear temperature response is used to detect temperature, while a Hall Effect sensor reading a magnet on the shaft provides a measure of speed.

Data collectors or analysis equipment receives the signals and processes them.

via the terminals for outputs. The user has the option of using a portable device for occasional checks or a local monitoring unit for round-the-clock surveillance. Both the connections and the sensors are industry standards that may be found in any third-party system or purchased directly from SKF. It is possible to use the signals in decision-making and process-control aids. These upgrades are not part of SKF's Smart Housing package, however.

SKF saw a commercial potential in embedding sensors and electronics into bearing housings so they could provide consumers with additional functionality and monetize those improvements. Despite SKF's confidence in the usefulness of the data that might be gleaned by monitoring applications and processes, the company ultimately failed to sell any Smart Housing. Managers said that this was the case since SKF's business strategy was identical to that of its classic bearing housings and other goods. Technology was prioritized above the company's bottom line.

The three most important points are as follows. Firstly, despite the fact that some customers had come up with their own ideas, SKF was the one that initiated the development rather than the customers. Even though SKF realized it could increase value by including sensors and electronics in its bearing housings, the company lacked insight into how consumers would react to this innovation. The new technology's benefits depended on the specifics of each bearing housing, so they couldn't be predicted in advance. As a result of this, SKF considered the product to be a general solution, one that would be useful for the vast majority of their clients. This complicated the process of defining SKF's value proposition and was compounded by the fact that

Although they were instrumental in its development, SKF was not responsible for the system's overall design. Despite the fact that a client has purchased Smart Housing, additional hardware was still needed to process and display the output signals in order to fully use the new features. More importantly, the user needed to know how to make sense of the data, because the nature of the most important details varied among applications.

Second, SKF's business model is predicated on the fact that the Indus- trial Division manufactures items and sells them to the Service Division. Since it manages the connection with the consumer, the Service Department is accountable for making a profit off of a product and selling it. When selling established, well-known brands, no dedicated sales team is generally necessary to drive product sales. In the instance of "Smart Housing," the Industrial Sector was tasked with supplying the Service Sector with cutting-edge technology. Smart Housing was simply categorized with the rest of SKF's offerings and given no special attention from the company's sales team. Customers weren't aware of this new product or its benefits because of this lack of publicity.

Third, in an effort to market the goods, the corporation attempted to appropriate economic value via the use of the business model it had already developed. SKF priced the Smart Housing ten times pricier than a standard bearing housing because the company wanted to be compensated for the value it brought for customers. There was an inherent risk in purchasing a product that allowed the client to use an instrument to pick up signals since the price was around 50 times that of the regular product. Smart Housing was a failure for SKF since the company couldn't come up with a workable business strategy for it.

5. Discussion and conclusion

This article analyzed how manufacturing firms appropriate economic value from their technological investments by incorporating ICTs into mechanical engineering products. Based on the examples provided, it is clear that businesses need to alter their business models in tandem with technological cross-fertilization in order to realize the benefits of this process. Despite widespread recognition of the need for product evolution in response to technological advances, researchers have paid comparatively little attention to the ways in which companies adapt their product's underlying business models.

Value creation and value appropriation are crucial to the business model, as many studies have shown (e.g. Amit and Zott, 2001; Chesbrough and Rosenbloom, 2002; Magretta, 2002; Markides and Charitou, 2004; Morris et al., 2005). However, these studies have been conducted at the firm level and have often focused on early stage technology and the business models of individual companies. Rather than examining the company as a whole or developing an entirely new product, the examples below examine how technology cross-fertilization might be used to diversify the technological base of existing products. The goal of this technological fusion is to generate new value for end users by releasing previously untapped pockets of technical performance and functionality space. To appropriate economic value, however, is a far cry from just creating value for customers. From the three case studies, we can draw conclusions about how pivotal it is to alter the business model in order to get monetary value from the investments in technology. It is challenging to both develop and appropriate economic value from the cross-fertilization, utilizing current business models, even if incorporating ICTs into established goods may give benefits. Based on their current business models, all three organizations had trouble appropriating economic value, and whether or not they were successful in doing so ultimately depended on whether or not they altered their strategies. Unlike SKF, which was unable to produce economic value, Alfa Laval and Beta were successful because they adapted their business strategies. It was shown, however, that focusing just on the satisfaction of consumers is not enough to guarantee a company's financial success.

Companies' searches for a sustainable business model varied greatly as they progressed through their growth, in part because each was aware of the challenges associated in appropriating economic value at a different point in time. When Alfa Laval realized it couldn't capture economic value using its current business model, the quest for a new model began far in advance of the product's commercial release. As a result, the means of distribution, the structure of sales and income generation, and the market segment being targeted all underwent revisions. As a result of senior management's foresight into potential challenges if the business continued to operate under the line organization, the company formed an independent venture orga- nization to provide flexibility in future business model modifications. When thinking on how to run its firm, Beta originally didn't examine any alternatives to the one it was using at the time, beta. After it became apparent that the company's present business model would only provide minimal profits while producing enormous economic value for its clients, the hunt for a new model became critical. The business strategy has to provide compelling benefits to the customer while generating sufficient income for the company. By reverting to an older business model, SKF was unable to achieve its goals of creating and capturing value. Furthermore, the corporation persisted in pursuing the outdated business model despite mounting evidence that it was failing to provide desirable financial results.

Two of the participating firms in the research missed the boat on the need of a business model shift from the outset. This demonstrates that businesses have difficulty adjusting their strategies. In this case, the corporations failed to connect the dots between the potential of the technology and economic production. of combining several technologies, it seems to be essential. However, the emphasis of SKF and Beta was on the technology's potential rather than its ability to build a profitable company, which appears to be at odds with the effective realization of economic value. Evidently, even if a technology has value for certain consumers, such value will stay dormant for the developing organization if it does not discover the appropriate economic model. If Alfa Laval and Beta hadn't changed how they did business, they wouldn't have been able to cash in on the benefits of their shared technological know-how. Importantly, the top brass at these companies agree with this assessment. The leadership of SKF thought that the firm might have improved its value proposition and return on investments by switching to a different business model. This lends credence to Chesbrough and Rosenbloom's (2002) claim that, as technology evolves, businesses need to be willing to test out new ways of doing business. Three of the firms in the survey all agreed that the toughest part wasn't figuring out how to make their service technically feasible, but rather developing a profitable business plan to capitalize on the synergies. This brings up the possibility that leadership has to pay more attention to the business model. These examples demonstrate that the value created by technological intermarriage is independent of the initial worth of the technologies involved. For this reason, I believe that a new technology's adoption rates and the value it may provide to the market are heavily reliant on the business model used to commercialize it. In reality, the instances demonstrate that broadening the goods' underlying technologies enhances their technical performance and functionality, which in turn enhances their usefulness and/or lowers their prices, hence providing more economic value for the consumers. However, adjustments in the business model are required alongside the growth of technology cross-fertilization in order to produce value and appropriate a share of the consumer value (see Table 4). Therefore, the relevance of the business model in producing and capturing value has been reaffirmed by this research.

Without a doubt, the amount to which various companies may alter their business models is constrained by the external environment. Based on the results of this research, it is clear that Alfa Laval and Beta were the pioneers in incorporating ICT components into decanters and compressors, allowing them to determine the most effective applications for these products. The firms' managements say that there are benefits to being an early adopter of the new business models. In reality, the lack of a competing alternative on the market is largely responsible for the current licensing structure.

Table 4
Summary of changes in activities.

Technology	Potential customer value	Business model change (value delivering)
Alfa Laval		
Sensors	Higher capacity utilization	Distribution channel
Software	Warning signals	Revenue model
Computer	Cost savings	Target segment
Signal sensing	Increased reliability	Free maintenance and upgrades
	No need of surveillance	Demonstration of customer savings
	Data storage	Sales channel
Beta		
Computer	Higher capacity utilization	Target segment
Software	Warning signals and automatically shutdowns	Revenue model
Control bus	Cost savings	Tangible savings
Signal sensing	Increased productivity	Free maintenance and upgrades
CAN network	Process surveillance (increased reliability)	
	Data storage	
SKF		
Sensors	Vibration: detect bearing failures, imbalance and misalignment	No changes
Electronics	Temperature: overheating and overload	
	Speed: Effective speed control	
	Less susceptibility to external abuse than decoupled sensors	

the market, without which the corporations' efforts to implement new value-capture strategies would have been greatly hampered. It may be challenging to adhere to the new business model and at the same time appropriate a higher value from the customer if other firms will provide similar offerings using the traditional business model adopted within their industries and perhaps even "give away" the increased value to the customer for free. It's also possible that rivals may follow Alfa Laval and Beta's lead and use a similar business model. Therefore, external variables, in particular competition, may limit the long-term viability of the new business models for the firms and the competitive advantages they deliver to Alfa Laval and Beta.

There is a high degree of danger in switching to a new business model without first testing it and gathering enough data on how consumers will respond. For their earlier products, the two firms that pioneered a new business model stuck with the tried-and-true method. Therefore, this form of technology cross-fertilization, in which companies add new technologies to their technological base to provide the consumer new and additional value, led to a diversification of business models (i.e. an extension of the different activities for creating, delivering and appropriating value). Therefore, both the technological and economic spheres became more complicated as a result of the cross-fertilization of technologies.

Due to the research method being focused on case studies, it is unclear how generalizable the results will be. More study is required to determine how often companies appropriate value while selling capital products that use ICTs using current business models. Furthermore, there are constraints on the extent to which one can generalize about the connection between product breakthroughs, new business models, and the confines of a given company. Therefore, further research is required to elucidate this issue, especially in regards to how shifts in the technological foundation of goods might result in downstream shifts into services, where the firms may take over client activities.

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