MUTUAL DEVELOPMENT OF TECHNOLOGIES AND THEIR GOVERNANCE: RELIANCE ON SYSTEMIC COINCIDENCE, NATURAL LUCK OR STRATEGIC PLANNING?

Annaleena Parhankangas[1]
Helsinki University of Technology, P.O.Box 9500, 02015 TKK, Finland
David L. Hawk
New Jersey Institute of Technology, University Heights, Newark, NJ 07102

ABSTRACT

We followed the development of three new-to-the world technologies as they emerged over several decades. In our analysis, we wanted to distance ourselves from the received diversification and governance theories, and observe how technologies evolve in a complex, paradoxical, systemic, even messy, real-life context. The results tend to refute the assumed rational nature of corporate management, diversification and development. More of the direction of successful technology-based diversification was found to be dependent on co-incidence and luck, rather than strategic (rational) intentions. Stated differently, the success in pursuing certain applications of a novel technology accrues more from being "in the right place at the right time" than in predicting the rightness of future places and times. Personal, informal contacts were seen to play a significant role in helping venture managers "get lucky" and connect into new constellations of resources, including first customers. The results suggest a necessity to find ways for a technology-based venture to break free from its old networks in order to improve the chances for success.

Keywords: Corporate Diversification, Novel Technologies, Governance, Luck

INTRODUCTION

Our interest is with the "triggers" to development of novel technologies in large corporate settings, and then, as a consequence of the pursuant technological change, our attention shifts to the corporation's prevailing form of governance. In particular, we are seeking to answer the following questions: how do managers choose amongst the array of possible technologies and then how do they select from amongst the numerous means to apply the technology? We believe that the system of governance often becomes strained or simply insufficient to the needs that arise as a consequence of the emergent technology.

[1] Corresponding author

We presume that our questions are best conceived within and answered via a systems perspective. Herein this means that decisions are presumed to take place within a rich and lively context, where the characteristics of that context inevitably influence the taking of a decision and outcome of the decision return to impact the context; i.e., the critical systems are best seen as open. From this systems perspective we go on to argue that part of context can best be described as governance. Our final concern is in deciding between the major modes of governance available to humans and identifying the form that is most appropriate to successful development, distribution and application of novel technology. Questions of possible and desirable forms of governance then emerge. Herein we take a somewhat unusual approach to the emerging concern over relations between technical development and social governance by focusing on the relationship between successful technology development and the role of strategy or luck in governing it. Strategy is herein presumed to be a highly rational, purposeful approach to objective achievement while luck is one part of a much larger and more inclusive domain of the non-rational, which includes chance and co-incidence.

The questions raised above are similar to those found in historic concerns with the "theory of the firm" studies, especially those that studied aspects of corporate diversification to deal with adaptation and change. A theory of the firm approach generally addresses, among other questions, what determines the scale and scope of a firm and why all transactions are not organized within a single firm (Holmstrom & Tirole, 1989; Foss, 1996). Some of the best-known theories, that attempt to explain motivations of corporate change via diversification, as well as its outcomes and governance, are those under the titles of: resource-based theory, transaction cost theory, agency theory, and the IO perspective.

Herein, we will argue that these contemporary theories of decision-making in the face of change seem wholly insufficient to explaining technology-based diversification changes that defy the limits of existing scientific and technological knowledge. We argue that managers are likely to abandon the lessons of the traditional diversification theories as they strive to deal with the world as it is being created (March, 1991 Weick, 1999). Under the conditions of rapid technological change, extreme ambiguity is an important part of a manager's operating realm along with very limited knowledge of the expected outcomes of their actions. The speed and direction of technology development appear to be closely embedded in the characteristics of the social and organizational contexts from which it emerges and on which it can have major impacts. Under conditions of these rich connections and high ambiguity an organization generally needs to break from its traditional view, concepts and operating principles. This agenda has become the renewed argument for using systems thinking and conceiving of networked connection as the vehicle of structure. This brings us rapidly and forcefully into the world of governance and involves changes in the roles and rules of governance of human entities.

We will examine and investigate this need for new forms and attitudes to governance via looking into evolutionary patterns of three technology-based ventures, initiated by large Finnish corporations. These point to some of the major milestones of technology development during the past thirty years. All the technologies studied in the work described herein were new and radical technologies. They were new to both the parent organizations and the world proving the context of the organizations. Common to most technologies developed during these three decades was the trait that they appeared as “solutions looking for problems.” This supply side approach seemed to be the impetus for their development where the specific triggers occurred by contemporary advancements in science and technology. During their life cycle, these technologies became embedded in various networks and ownership structures. As a side issue during the study evidence emerged that certain changes in the governance structure tended to help an organization avoid the tendency of being too closely tied to traditional attitudes and forms, some of which were seen to clearly impede the further development and application of a technology. Changes in governance created an environment that allowed for easier departures from preordained frames of reference. Moving from one set of connections to another was found to exert a major impact on improving the speed and the direction of technology development and adoption. The new connections were seen to come from happenstance, luck, chance associations and knowledge of others, thus we believe we can argue that co-incidence, luck and personal networks are better pathways to explaining the milestone events in technology development than are preordained strategy and reason. It seems clear that a systems perspective, that can accommodate relations as well as parts, is helpful to understanding and managing these phenomena.

TRADITIONAL APPROACHES TO TECHNOLOGICAL DIVERSIFICATION

The literature on corporate diversification is vast. It represents a variety of perspectives, disciplinary paradigms, and research questions. Herein, our interest is with questions related to choice of diversification mode and direction of diversification.

At the heart of diversification is a firm’s decision to enter new lines of business. According to prior diversification literature, the choice is dependent on attractiveness of a business opportunity linked to a firm’s capabilities to enter the area. A firm choosing to diversify can be presumed to be seeking ways to modify its business definition, so as to better satisfy some set of performance objectives (Ramanujam & Varadarajan, 1989). As summarized in Silverman & Castaldi (1992), diversification may be driven by (1) external conditions such as mature markets, product obsolescence, growth or profit opportunities, changing economic or socio-political environments; (2) internal aspects of the organization, such as excess resources; (3) management objectives, such as growth, earnings, or stability; (4) or combination of these factors (Ramanujam & Varadarajan, 1989; Ansoff, 1965) One shortcoming of this prior research, all done from an analytic perspective, is that it sought a critical variable, one that was most important, not how multiple variables interact and may provide a systemic platform whose understanding is critical to the future events that unfold in a diversification effort.

The questions underlying corporate technological diversification are essentially the same as those addressed in the theory of the firm (see, for instance Coase, 1937; Williamson, 1975). The theory of the firm approach addresses, among other questions, what determines the scale and scope of a firm and why all transactions are not organized within a single firm (Holmström & Tirole, 1989; Foss, 1996). The theory of the firm has branched into several distinct sub-fields and diverging approaches (Conner, 1991). Of these perspectives, the transaction cost economics, agency theory, industrial economics perspective, and the resource-based perspective are most often applied to the diversification context.

a) Resource Based Approach: The resource-based literature approaches the direction of corporate diversification by highlighting the importance of inherited resources (Penrose, 1959; Cohen & Levinthal, 1990). The inherited resources affect the direction of diversification through two mechanisms. First, implementing radically new business ventures may be limited by shortage of labor or physical inputs, shortage of finance, and the lack of sufficient managerial capacity (Mahoney & Pandian, 1992) Besides the lack of physical and human resources, established routines (Nelson & Winter, 1982) existing dominant logics (Prahalad & Bettis, 1986), and structural inertia (Hannan & Freeman, 1989) may prevent the adoption of new perspectives, routines and new priorities required by a new business venture. As a result, opportunities for diversification can become firm-specific or locked-in to previous activities (Conner & Prahalad, 1996). Second, the firms tend to acquire a surplus of certain resources for various reasons. Penrose (1959) states that specialization typically leads to the surplus of certain types of resources. Surplus of resources may also arise due to asset indivisibilities and the increasing efficiency of human assets through continuous learning. Surplus of resources typically leads to the selection of strategies that help firms use better their excessive resources.

The resource-based literature predicts that firms will have a comparative disadvantage in carrying out ventures that do not fit their current resource base (see, for instance, Mahoney & Pandian, 1992; Bergh, 1995; Pennings et al., 1994; Grant, 1988). Looking at the situation from the opposite view, resource-based literature and some empirical studies suggest that comparative advantage accrues from synergy effects associated with grouping together similar or complementary activities. This approach seeks to take advantage of what is know as “synergy effects” which comes close to the subject matter of the general systems approach. This is where, as a consequence of relationships, there is an enhanced valuation of a combination of business units, which is said to exceed the sum of valuations for stand-alone units. This approach was widely used in the 1990s as a logic supporting a proposed mergers or acquisition. While the synergistic phenomenon is known to exist, it seldom appeared in most mergers and acquisitions of the 1990s era. Greater use of systems theoretical perspectives in this area could help address where synergies are, and are not present.

b) Industrial Organization Perspective: The industrial organization perspective generally comes from the Harvard tradition, and aims to address the question of how industry structure can determine the appropriate conduct of a firm, which can be clearly judged by its market performance (Tirole 1988; Rumelt et al., 1994; Caves, 1984). This famous structure-conduct-performance paradigm assumes that the strategic choice and structural adaptation are, to a large extent, exogenously induced. Consistent with this stream of literature, the purpose of diversification, technological or social, is to establish a profitable and defensible competitive position in an industry against present and future competitive forces.

c) Agency Theory: Agency theory suggests that the separation of ownership and control creates agency costs. The relationship between the owners and managers of a firm provide a good example of an agency relationship, susceptible to a conflict of interest between the agent and the principal. Agency theory is somewhat more cynical about the motivations of corporate diversification, viewing corporate diversification as a means of empire building of corporate managers at the expense of the shareholders (Jensen & Meckling, 1976; Baumol, 1967; Amihud & Lev, 1981). In a systems framework this would be consistent with seeking to gain control by increasing the complexity of the situation so it becomes less transparent with time, except to those who manage the diversification. Rappaport would argue that this process increases the complexity for those how manage it as well as those who are "strategically" managed.

The choice of a particular diversification mode may also rely on internal business development vis à vis acquisitions- or hybrid modes- as a means of entering new lines of activity (Ramanujam & Varadarajan, 1989). Transaction cost economics would be an instrumental means to address this question, where choice of an effective governance mode would cover the range from a pure market to a fully integrated firm where it can minimize the sum of transaction and production costs. Transaction costs associated with the outsourcing governance option, on the other hand, can include negotiating, monitoring and enforcement costs of exchange process via markets. Research of others points out that the main factors behind producing transaction difficulties are: their frequency, uncertainty and complexity, their small numbers, information impactedness, and asset specificity associated with the market transaction (Williamson, 1975; 1989; Jones & Hill, 1988).

The above listed theories of the firm are deficient on several grounds: they have not paid enough attention to the characteristics of technology, technology-based firms or their management (Granstrand, 1998), and they have not been able to accommodate or even recognize the role of the systemic theory in their analysis. In our view, the traditional literature on corporate diversification and the contemporary theories of the firm suffer from several serious limitations. These are most noticeable when introducing the issue technology-based diversification and the ambiguities involved therein. First, most studies provide a snapshot view of corporate diversification that is highly analytic and punctuated. This sets the stage for neglecting the fact that corporate diversification efforts, and especially those based on technological diversification, can often become a decades-long process. At a minimum it requires a longitudinal approach, yet there are very few studies that focus on how the governance of innovative activities evolves over time.

Second, previous literature seems to implicitly presume a high degree of focused rationality on the part of the corporate managers involved in determination of the direction and mode of a diversification move. By rationality, we refer to an assumption that diversification moves are: intentional, reflective of a strategic mission of the organization (or the individual manager), carried out through formal and careful planning. There is an apparent overemphasis on rationality and an avoidance of issues connected to luck, chance, serendipity interplay and factors of social ambiguity in technology development. And finally, the theories of the firm and corporate diversification listed above mostly ignore the systemic nature of technology development. Their authors thereby avoid Schumpeter's (1968) notion of innovations as new combinations of existing materials and forces. Following this stream of logic, Usher (1971: 50) and Kogut & Zander (1992) went on to call the process of invention a cumulative synthesis of many items, which were originally seen as independent. The implications of this logic are most absent from the diversification literature, analyzing the motivations and the consequences of diversification moves mostly from the perspective of a single firm, or in the best case, a dyad of firms.

DEVELOPMENT OF NEW TECHNOLOGIES WITHIN ORGANIZATIONAL NETWORKS

The literature on inter-firm networks is extensive and has addressed some of the issues neglected in the traditional diversification theories of the firm. This stream of literature seems to acknowledge the significant role of personal, interpersonal and inter-organizational networks in technology development. These "soft" networks facilitate opportunity recognition, sharing of costs and risks, and the speed of response. They also signal the importance of technology development to the third parties, and spur innovativeness (see, for instance, Lee et al., 2001; Cohen & Levinthal, 1990; Hagedoorn, 1993; Teece, 1987; Goes & Park, 1997).

In a similar vein, the social embeddedness literature highlights how social structure assists economic performance and organization creation[2]. Prior research has demonstrated the concept's usefulness in illustrating how actors use network contacts to secure resources, and critical information, and to manage organizations (Granovetter, 1973; Uzzi, 1996; 1998), or recognize economic opportunities (Young, 2002; Jack & Anderson, 2002) However, it has been found that these positive effects rise up to a threshold, after which over-embeddedness may derail performance by making firms vulnerable to exogenous shocks or insulating them from information that exists beyond their networks (Uzzi, 1997). In other words, embeddedness may turn into a liability in case of an unforeseeable exit of a core network player, institutional forces rationalizing the markets, or social aspects of exchange superceding economic imperatives.

The literature on inter-firm networks points to some basic weaknesses for those wanting to better understand technology-based diversification. Even though there are some longitudinal studies on the evolution of alliances and networks (see, for instance, Ariño & de la Torre, 1998; Larsson et al., 1998; Kumar & Nti, 1998), the time span covered is too short to help one understand the context of important new-to-the world technologies. It has been argued elsewhere that new technology-based firms undergo several ownership changes and thereby become embedded in multiple networks during their lifetime

[2] Embeddedness may be defined as the nature, depth, and extent of an individual's ties into the environment (Jack & Anderson, 2002)

(Lindholm, 1994; Parhankangas, 1999). Most studies limit their analysis to the evolution of a single alliance or a network. It would be helpful to combine this insight with longitudinal studies of the evolution of change in governance forms, all viewed in parallel with the technological change process. From the short time span followed in previous studies, there is to date little known as to how companies deal with problems mentioned here.

METHOD

Others have called for the need of qualitative, longitudinal analysis of technology-diversification and inter-organizational relationships (Parkhe, 1993; Carrol & Ashford, 1995). Our study adopts this approach and follows a research design by Yin (1984). We chose to analyze three technology-based ventures from large Finnish corporations. These examples were selected based on two considerations: they represent new-to-the world technologies defying the frontiers of scientific knowledge, and they have been in operation for a sufficient period of time so that the inter-relations between technology development and governance structures could be expected to have surfaced.

We collected both interview and archival data. We interviewed the venture managers, corporate managers of the parent firm, and alliance partners to cover the entire lifetime of the technology-based venture from its inception to the time of the study. The interviews were conducted face-to-face privately and with various combinations of participants. The interviews were semi-structured and ranged from 45 to 180 minutes. The interviews were carried out between October 2001 and May 2002. All the interviews were taped and transcribed. The interviewees read and commented the interview transcriptions for accuracy. Archival data was employed to complement the interview data as a means to triangulate the validity of our findings (Eisenhardt, 1989). Archival data include minutes of the board meetings, organization charts, internal newsletters, as well as technical and market reports.

EXAMPLES: DEVELOPMENT OF NEW-TO THE-WORLD TECHNOLOGIES IN LARGE FINNISH CORPORATIONS

As you review these examples keep in mind the distinction between technology being developed for strategic reasons or momentary opportunities at the end of events. The first approach allows for discipline and predictability while the second allows for unplanned opportunities and developments to be realized. For more on this see the table at the end of the paper.

Conductive Polymers

In the early 1980's, a large Finnish chemical corporation (CHEMCO)[3] decided to diversify into the battery business, in an effort to pursue and enhance its international competitiveness. It was then believed that it would be technically possible to replace the heavy lead batteries with much lighter plastic batteries for use in for instance electric cars. In order to develop plastic batteries, an improved knowledge of conductive polymers was called for. Conductive polymers were discovered only a couple of years later by Alan Heeger, Alan MacDiarmid and Hideki Shirakawa of University of Pennsylvania. To access this new to the world knowledge, CHEMCO ended up recruiting a young Finnish PhD who had been working with Alan MacDiarmid in Philadelphia at the time of the discovery.

Applying the conductive polymer technology into plastic batteries proved to be a disappointment from the operational point of view. It seemed that plastic batteries could never replace the lead, nickel and cadmium batteries because of quality problems. This realization marked the end of the battery research at CHEMCO. However, the knowledge related to conductive polymers did not go wasted. At those days, the parent firm CHEMCO was a leading international plastic producer, and decided to explore the possibilities of blending conductive polymers with commercial mainstream plastics. It was believed that these polymer blends could be used in computers and emergency room equipment to protect this equipment from becoming electrically charged. The venture team started experimenting with various polymers and allied with several Nordic firms and research institutions. In mid-1980's, this phase was ended by another disappointment. It seemed that making a polymer chain conductive would also render it more rigid, and thus difficult to mold for various product applications. However, during this phase the venture team was able to build up production facilities, while all the competitors were still operating on the laboratory scale.

The venture team presented their results at a research conference in New Mexico. Based on the conference presentation, two leading scientists of University of California expressed their willingness to collaborate with the venture team. They had developed a dissolvable polyaniline derivate without sacrificing its conductive properties. CHEMCO, in its turn had the production facilities matching the needs of University of California. As a result, CHEMCO decided to establish a joint venture with these two American scientists dedicated to the development of conductive polymers, and their applications.

The subsequent years marked a very intensive period in the development of the technology, resulting in a pre-commercial product line of insolvable polyaniline and polymer-LEDs. The number of the people working for this project grew rapidly in the late 1980's. However, in the mid-1990's the strategic importance of the venture for the parent corporation decreased as CHEMCO decided to divest all its plastic-related businesses. In 1998, a spin-off company was formed to continue technology development

[3] For confidentiality reasons, we do not use the real names of the companies or persons in this report.

in Finland. Today, the spin-off company is active in selling and additives for basic polymers and developing applications related to anti-corrosive paints, and conductive surface applications.

Immobolization Technology

In the late 1970's, a large Finnish corporation, FOODCO, was exploring new business areas to exploit recent developments in biotechnology. Their strategy was to move further into the biotech industry. At the same time, quite unexpectedly, FOODCO got an opportunity to acquire a manufacturing plant suitable for fermentation purposes. During those days FOODCO also entered into an alliance with a large US corporation, where FOODCO provided the production facilities and the partner technological competences related to the production of industrial enzymes. As a by-product of this alliance, FOODCO adopted many technologies from its partner, among them so called "immobilization technology", potentially applicable for enzyme immobilization, ion exchange, chromatography, and protein separation.

A project team was set up to explore potential product applications of the technology. By accident, the project manager found out about a parallel research project going on at the National Technical Research Center of Finland. The mission of this project was to apply immobilization technology in beer fermentation. FOODCO participated in this project, which resulted in an alliance between a large Finnish brewery and FOODCO. Besides beer fermentation, the venture team got gradually involved in the development of various other product applications, such as soft drinks, non-alcoholic beers, extremely pure lactic acid, just to mention a few. All these applications were developed in alliances with other firms or research institutes. Only the applications related to beer generated a continuous revenue stream. However, this revenue stream was not enough to pursue the development of other applications of immobilization technology. The fact that the project team was not able to come up with product applications for the core businesses of FOODCO made the technology less valuable in the eyes of the corporate management. Struggling with financial distress, the parent firm decided to sell the rights to the technology to an international engineering company in 1997.

Atomic Layer Epitaxy Technology

The foundation of the atomic layer technology was laid in the early 1970's, when Dr. Technology Champion [4] was developing sensors at the National Research Center of Finland (VTT). A friend recruited him to a large Finnish pharmaceutical company, PHARMCO, where he was expected to apply his knowledge to the manufacture of high quality flat panels for medical devices. The first prototype was launched in 1978, and the product was introduced to the market in the mid-1980's. However, technology development proved to be too time and resource consuming for PHARMCO. Thus, the corporate management decided to sell all the rights related to technology to ELETRCO, a large Finnish corporation specializing in the manufacture of consumer electronics.

[4] For confidentiality reasons, we do not use the real names of the companies or persons in this report

ELECTRO planned to apply the technology in the manufacture of TV displays. However, after only a couple of years ELECTRO decided to divest some of its business divisions, among them was also the business developing the ALE technology. As a result, this business unit became part of a US corporation.

In 1987, a large Finnish corporation, ENERCO, recruited Dr. Technology Champion and 20 of his co-workers to apply their technological knowledge in various emerging business areas of the corporation, such as manufacture of solar panels and catalysts. The project team received international acknowledgements for its scientific achievements. By the late 1990's, the venture team came up with a prototype for solar panels. However, commercial production of the solar panels did not prove to be a commercially feasible solution. ALE technology was also applied to the manufacture of catalysts. The most important applications of the technology is the ALE reactor developed for the manufacture of flat panels and thin layer membranes for the needs of the electronics industry. Except for catalysts, all the applications of the technology lay outside the core areas of ENERCO. That is why the corporate management ended up selling the business unit to a global semiconductor company in 1998.

Changes to Original Strategies and Goals of Technology Development

In the case of conductive polymers, the parent corporation had a clear mission for technology development activities, namely the development of a plastic battery. In those days, there was a strong belief that plastic batteries could compete against traditional ones in terms of quality. The decision to diversify into the plastic battery business seemed very rational given the state of knowledge at the time of the decision. However, years of development work proved this initial optimism to be wrong, where it seemed that the development team's efforts were defying laws of nature. As a result, the venture team decided to back off and apply their accumulated knowledge in closely related areas.

In the immoblization technology example, the parent firm was looking for new business areas utilizing biotechnology. In the beginning of this exploration, the parent corporation did not restrict its search to any specific applications. By chance, the parent corporation acquired a possession of fermentation plants. The possession of plants made it possible for the FOODCO to enter into an alliance with a corporation with complementary knowledge on enzyme manufacture. As a by-product of this alliance the parent firm was able to adopt the immobilization technology and started looking for commercial applications. It seems to us that this story demonstrates the serendipitous nature of technology development.

The development of the ALE technology was triggered by the parent firm's desire to explore new business areas with the help of new-to-the world technologies. However, the novel technology did not result in commercially viable products. As a result, the parent firm decided to divest the technology trough a sell-off arrangement. This started a chain of transactions where the technology was transferred from one organization to another resulting in numerous product applications during its decades-long history in various organizations.

In all three examples, the parent firms were searching for new business areas by exploiting new-to-the world technologies. In only one of our examples, the parent firm had an unambiguous goal for technology development. Ironically, this goal never realized. Instead, the technology development resulted in many other applications that were not known in the beginning of the project. In two other projects, the parent firm had only a vague idea of what it was after. The potential product applications were identified after a series of ownership changes. Many of them were nothing like the corporate management imagined in the beginning. In addition, many of these applications ended up being exploited by other firms than the parent corporation. Next, we set out to explore how this all happened.

Measuring Success: Working Forward via Ex Post Facto Markers

Developers of new technologies face many challenges along the way to successful commercialization of a product. First, developers often have a limited understanding on the technical aspects of their invention. Second, novel technologies generally offer a wide array of application directions, which developers may not initially be aware of. Third, formalizing agreements with a first customer and then scaling up production facilities to a commercially viable scale can prove to be a very significant challenge for the development team. Herein we examine these challenges via the history of the three technology-based ventures identified earlier as they progress towards the market place. Our particular interest is in finding the cluster of factors that seem to trigger the successful achievements in development of the technology. These involve factors for identifying, selecting from applications, and finding the first customers. These are summarized as major project milestones in Table 1.

Example One - Nine milestone events are identified for the conductive polymer technology[5], where the first involves launching a prototype for a plastic battery. Many organizations contributed to the technology development, including some leading American universities advanced the competencies of the venture, as did the National Research Institute of Finland (VTT) as well as a domestic manufacturer of lead batteries. The second breakthrough event was realization that conductive polymer chains might be rendered less rigid by polymerization. A third event was where the venture team was able, as a result of an unsuccessful experimentation with polytiofene derivates in collaboration with a large Nordic research consortium, to scale up their production facilities. A fourth event was a conference presentation at a conference in New Mexico which led to the establishment of a joint venture. This led to exploitation of the mutual technical expertise of the American partners and CHEMCO's production facilities. The result was the commercial production of conductive, insolvable polyaniline (resulting in milestone 4) and some sophisticated applications of the technology to other uses, such as polymer LEDs (which became milestone 5). After the divestment of the venture from CHEMCO, the spin-off firm started production and sales of additives (conductive

[5] By a milestone, we understand any major event bringing an application of a novel technology closer to the market.

polymers) to plastic combounders (giving milestone 6) and development of anticorrosive paints, conducting textiles, and other conductive surface applications in collaboration with a Finnish paint-maker, textile firm, paper manufacturer, respectively (milestones 7-9).

Example Two - The immobilization technology experienced seven major breakthroughs during its history. These milestone events involve the identification of new applications of the technology, such as fermentation of beers, soft drinks, non-alcoholic beers, manufacture of extremely pure lactic acids, fructose and glucose, just to mention a few. Some of these applications resulted in patents, or production lines generating a continuous revenue stream for the parent. The development of some of these applications is still on the hold or under way. Out of seven applications, only the development of two was triggered and conducted in-house. The idea for the development of rest came outside the parent firm. In a similar vein, further development of technology was pursued in collaboration with others.

Example Three - We identified five milestone events during the evolution of the ALE technology, including the identification and development of the medical device application, TV monitor application, catalyst application, solar panel application, and ALE reactor application. All these application are based on the key technological competencies of the venture manager. Over time, he moved from one organizational context to another applying his skills in different production applications relying on the complementary resources available in his location at that time.

What can we conclude from these storied examples? It seems to us that the informality, the more humanly ambiguous, teleological side, of inter-organizational linkages play a key role in the release and identification of opportunities related to technology development. Thus, the direction of technology development becomes extremely dependent on the ability of the venture manager to softly link to various inter-organizational networks providing complementary resources. It seemed that the joining into new inter-organizational relationships provided the venture teams with new product applications time after time. Somehow the softness of the informal allowed better access to the spontaneity and imagination of the systemic. The hardness of the formal, the rational, and the literal dampened or discouraged the seeing of the fragile connections found in the systemic. This finding seems important to the fashioning of new forms of governance of those how manage technology development.

Co-evolution of Technologies and Governance Forms

To better understand the link between technology development and governance structures, special attention was paid to aspects of the governance of novel technologies during their development.

While analyzing the evolution of the conductive polymer technology, it became obvious that there were four distinct partnership governance structures that came into use over time: 1) The first was an alliance between CHEMCO, National Research Center of

Finland, and a domestic lead battery manufacturer; 2) The second was a Nordic research consortium between CHEMCO, National Research Center of Finland, and Nordic universities and research institutions; 3) The third was a joint venture between CHEMCO and two scientists of University of California; 4) and the fourth was a spin-off firm from CHEMCO in alliance with a domestic paper producer, paint manufacturer and a textile manufacturer. All the organizational arrangements seemed dedicated to the development of one or two specific applications. It appeared that each relationship had a need to bring focus to the activities. A similar pattern was detected in the other two examples, as indicated in Table 1. In addition, it appeared that technologies become transferred from one organization to another because of an incapability of the original owner to further develop the technology. Finally, we noted that a rather generic technology can easily branch into several product applications, the development of which is managed by several individual firms or constellations of them, while a more specialized application of a technology ends up being managed in a more restrictive sense. The first requires a more systemic approach while the second can use it but is not significantly helped by it. This difference sets the tone for designing governance structures for technology development.

We saw where some changes in governance structure helped avoid the problems of an organization being so tightly organized and structured to make it incapable of encouraging and nurturing the development of novel technology. Established organizations were seen to seek solutions near the neighborhood of their existing solutions while relying on past historical experience for a guiding rationale (see, for instance, Ahuja & Lampert, 2001). They are therefore unlikely to recognize radically new innovations. Besides deficiencies in opportunity recognition, parent firms may lack resources required for the development of novel technologies. For instance, it would not have been possible for FOODCO to pursue beverage-related applications without allying with leading domestic and international breweries. In a similar vein, establishing a spin-off firm may serve as a means of separating a technology-based venture from a parent corporation not interested or capable of its further development. In each instance the organizations would have been well severed to open up their systems of thought and look to the environment for differences that could be brought into their frameworks. Instead, they tended to focus more intently on the core competencies and historical record.

Changes in governance structures can help deal with this shortcoming. Some structures are more open to building new relations to change and a changing environment. One aspect of this was seen in how a structure could facilitate a shift from developing a product via a tight scientific network to more inclusive commercial one. This was seen to provide a great boost to a technology-based venture successfully approaching a market. The clearest manifestation of this emerged from an interview with the technology director at CHEMCO where he stated that his personal contacts were too technical in nature to facilitate the commercialization of the conductive polymer technology. In a similar vein, the CEO of the spin-off company saw it necessary to break free from the old networks of CHEMCO in order to take a new product application to the market. It was noteworthy that as a venture moved closer to the market, there was a tendency to encounter and adopt to more hierarchical forms of governance. This was generally found to be counter productive, except that it did allow the development to better relate to the other organizations involved in the commercialization.

In all our examples, major technological breakthroughs were achieved in close collaboration with other organizations, with relatively little concern for the allocation of ownership rights. Later, as opportunities for commercial exploitation of the technology emerged, the organizations then tended to rush to secure their access to continuous revenue streams through hierarchical control, which brought a much more rigid governance system into operation. This tended to dampen the important role of spontaneity, co-incidence and randomness in development.

Role of Co-incidence, Luck and Chance Events

Our discussions with venture managers increasingly led us to believe that co-incidence, luck and chance events (non-planned activities) actually played a very major role in shaping the development paths of these novel technologies. First, perhaps due to market and technology uncertainties, managers found the role of formal planning of less relative importance during the process. In the words of the technology manager at FOODCO:

> *"Many of these things just happened. It seems to me that there was no systematic management of technology in this organization, at least you couldn't see it at the lower levels".*

This applies to the identification of new applications for the technology in particular:

> *"In search of potential applications for this technology, we engaged in a thorough and systematic analysis of existing literature and existing customer base. However, all the applications that actually worked and were implemented were found by chance. Companies often aim at modeling processes and using well-structured management methods. However, our experience shows that intuition can often lead to exactly the same results."*

This intuition was mainly based on the venture team's networks of contacts, relying on the personal history or chance events. For instance, the CEO of a spin-off firm from CHEMCO states that the identification of a market opportunity in the paper industry was purely due to this previous employment at a leading Finnish paper manufacturer. This is in line with prior network literature stating that the identification of collaboration partners relies heavily on individuals' existing business and personal contacts (Gulati, 1995; Wong & Ellis, 2002; Mitsuhashi, 2002).

In some instances, the impetus for technology development stemmed from being simply being in the right place at the right time. In the words of a venture manager at FOODCO:

> *"By chance, I heard about a research project going on at the National Research Center of Finland pursuing similar interests"*

In a similar vein, participation in a research conference led to an establishment of joint venture focusing on certain applications of conductive polymers:

> *"Our conference presentation in New Mexico caught the interest of two leading US scientists. Quite unexpectedly, they wanted to collaborate with us."*

Also, unpredictable and somewhat random changes in corporate strategy added uncertainty in the development of novel technologies. Unexpected changes in corporate strategy were seen to open up new applications for the technology, as was witnessed with the development of conductive polymers. Alternatively, sudden changes in corporate strategy were seen to lead to a tightening of philosophy and later closing of some important windows of opportunities, as we perceived with the ALE technology and conductive polymers. This may act as an impetus for changes in governance structures through sell-offs or spin-offs. Our conclusion from this was that strategic processes were never seen to operate in a rationally constructive manner, and could become destructive it taken too literally. [6]

Outcome of Technology Development

The outcomes of these three technology development projects are summarized in the last row of Table 1. It is striking that besides the revenues resulting from divestments, the parent firms appeared to benefit very little from decades of intensive investment in the development of the novel technologies. CHEMCO retained no rights related to the conductive polymer technology. FOODCO decided to keep those applications of immobilization technology in-house that had links to its core businesses, yet, eventually, the development activities were put on the shelf to wait for the better times. ENERCO divested most of the applications of ALE technology, although it did retain its catalyst applications.

Does this mean that these three projects failed in the strategic sense? None of them fulfilled the corporate mission, supported its strategic formulation nor created any new major business areas for the parent. Nevertheless, all become an important basis for creation of numerous product applications and new firms. Paradoxically, it seemed, in all instances, that corporations other than the parent were best able to unleash the potential of these technologies.

---

[6] We are fully aware that the more recent approaches to corporate strategy have broken free from the strict rationalism of the early planning school as put forward by Ansoff. However, even the more incremental or evolutionary schools of strategy tend to treat behavior of managers as attempts to adapt to the environment or learn from it. We argue that these perspectives, too, tend to ignore the non-rational nature of behavior and the concept of co-incidence and luck.

DISCUSSION AND CONCLUSIONS

Herein, we followed the development of three new-to-the world technologies as they emerged over several decades. In our analysis, we wanted to distance ourselves from the received diversification and governance theories, and observe how technologies evolve in a complex, paradoxical, systemic, even messy, real-life context. The results tend to refute the assumed rational nature of corporate management, diversification and development. More of the direction of successful technology-based diversification was found to be dependent on co-incidence and luck, rather than strategic (rational) intentions. Stated differently, the success in pursuing certain applications of a novel technology accrues more from being "in the right place at the right time" then in predicting the rightness of future places and times. Personal, informal contacts were seen to play a significant role in helping venture managers "get lucky" and connect into new constellations of resources, including first customers. The results suggest a necessity to find ways for a technology-based venture to break free from its old networks in order to improve the chances for success. New networks were seen to be critical to successful introduction of new applications of a technology, or in getting closer to a successful commercial exploitation of a technology.

Finally, evidence from the examples suggests that the very organization initiating the technology development is rarely able to exploit new-to-the world technologies within its boundaries. This points to a major organizational governance issue, where there is just now limited knowledge of what structures and procedures are best for which situations. We suspect that the degree to which the parent firm will able to cash on its investments in novel technologies is heavily dependent on its ability to form network relationships and to conduct technology-based transactions (licensing, sell-offs, spin-offs) within these networks. This points to shifting from command and control forms of governance into softer, more negotiable approaches. These findings may be summarized in the form of following propositions:

Proposition 1: When developing new-to-the world technologies, changes in governance structures are directly associated with success in introduction of new applications of a technology, and shifting governance towards softer structures with time seems advantageous.

Proposition 2: As technology development approaches the stage where the commercial exploitation of a technology becomes possible, there is a shift from non-formal, "open" networks towards more hierarchical modes of governance, but this may not be in the interest of full development of the innovation that began in a very open manner.

Proposition 3: With novel technologies, changes in governance structures can trigger and are triggered by forces of: co-incidence, luck and opportunities stemming more from personal networks than from introduction via deliberate corporate strategy and related rationalizations.

Proposition 4: With new to the world technologies, the parent firm's benefits accruing from technology development are more likely to materialize in the form of revenues from technology-based transactions that take place outside the firm, than from internal strategic benefits of building a new business area.

These findings are consistent with what would be expected from a more organic perspective of organizations and how they are governed. They all point to the need to find or invent ways to be more open, transparent, flexible and experimental in what an organization is and does relative to the environments it operates within.

REFERENCES

Ackoff, R. (1991). *The Best of Russell Ackoff.*, John Wiley, New York.

Ahuja, G., and Lampert, C. M. (2001). "Entrepreneurship in the Large Corporation: A longitudinal study of how established firms create breakthrough inventions," *Strategic Management Journal,* 22: 521-543.

Amihud, Y., and Lev, B. (1981). "Risk reduction as a managerial motive for conglomerate mergers," *Bell Journal of Economics,* 12: 605-617.

Ansoff, I. (1965). *Corporate Strategy*, MacGraw-Hill, New York.

Ariño, A., and de la Torre, J. (1998). "Learning from failure: Towards an Evolutionary Model of Collaborative Ventures", *Organization Science,* 9(3): 306-325.

Barney, J. (1991). "Firm Resources and Sustained Competitive Advantage," *Journal of Management*, 17: 99 - 120.

Baumol, W.J. (1969). *Business Behavior, Value and Growth*. Harcourt, Brace & World, New York.

Bergh, D. (1995). "Size and relatedness of units sold: An agency theory and resource-based perspective," *Strategic Management Journal*, 16: 221-239.

Caves, R. (1984). "Industrial Organization, Corporate Strategy and Structure," In *Competitive Strategic Management, (R. Lamb, ed.),* Prentice Hall , Inc, New Jersey. Pages 134-170.

Coase, R. (1937). "The Nature of the Firm." *Economica*, 4: 386-405.

Cohen, M., and Levinthal, D. (1990). "Absorptive capacity: a perspective on learning and innovation," *Administrative Science Quarterly*, 35: 128-152.

Conner, K., and Prahalad, C. (1996). "A resource-based theory of the firm," *Organization Science*, 7(5): 477-501.

Conner, K. (1991). "A Historical Comparison of Resource-Based Theory and Five Schools of Thought Within Industrial Organization Economics: Do We Have a New Theory of the Firm?," *Journal of Management*, 17(1.): 121-154.

Eisenhardt, K. M. (1989). "Building theories from case study research," *Academy of Management Review*, 14: 532-550.

Foss, N. (1996). "Knowledge-Based Approaches to the Theory of the Firm: Some Critical Comments," *Organization Science*, 7(5): 470-476.

Goes, J.B., and Park, S.H. (1997). "Interorganizational links and innovation: The case of hospital services," *Academy of Management Journal,* 40(3): 673-696.

Granovetter, M, (1973). "The strength of weak ties," *American Journal of Sociology*, 78: 1360-1380.

Granstrand, O. (1998). "Towards a theory of the technology-based firm," *Research Policy,* 27: 465-489.

Grant, R. (1988). "On "dominant logic", relatedness and the link between diversity and performance," *Strategic Management Journal*, 9: 639-642.

Gulati, R. (1995). "Social Structure and Alliance Formation Patterns: A Longitudinal Analysis," *Administrative Science Quarterly*, 40: 619-652.

Hagedoorn, J. (1993). "Understanding the rationale of strategic technology partnering: interorganizational modes of cooperation and sectoral difference," *Strategic Management Journal* 14(5): 371-385.

Holmstrom, B., and Tirole, J. (1989). "The theory of the firm," in *Handbook of Industrial Organization*, 1, (R. Schmalensee, and Willig, R., eds.): 61-133.

Jack, S.L., and Anderson, A.R. (2002). "The effects of embeddedness on the entrepreneurial process," *Journal of Business Venturing,* 17: 467-487.

Jensen, M., and Meckling, W. (1976). "Theory of the Firm: Managerial Behavior, Agency Costs and Ownership Structure," *Journal of Financial Economics,* 3: 305-360.

Jones, G., and Hill, C. (1988). "Transaction cost analysis of strategy-structure choice," *Strategic Management Journal,* 9: 159-172.

Kogut, B., and Zander, U. (1992). "Knowledge of the firm, combinative capabilities, and the replication of technology," *Organization Science,* 3(3): 383-397.

Kumar, R., and Nti, K.O. (1998). "Differential learning and interaction in alliance dynamics: A process and outcome discrepancy model," *Organization Science,* 9(3): 356-367.

Larsson, R., Bengtsson, L., Henriksson, K., and Sparks, J. (1998). "The interorganizational learning dilemma: Collective knowledge development in strategic alliances," *Organization Science,* 9(3): 285-305.

Lee, C., Lee, K., and Pennings, J. M. (2001). "Internal Capabilities, external networks, and performance: A study of technology-based ventures," *Strategic Management Journal,* 22: 615-640.

Mahoney, J., and Pandian, J. (1992). "The resource-based view within the conversation of strategic management," *Strategic Management Journal*, 13(5): 363-380.

McEvily, B., and Zaheer, A. (1999). "Bridging ties: A source firm heterogeneity in competitive capabilities," *Strategic Management Journal,* 20: 1133-1156.

Mitsuhashi, H. (2002). "Uncertainty in selecting alliance partners: the three reduction mechanisms and alliance formation process," *The International Journal of Organizational Analysis,* 10(2): 109-133.

Nelson, R., and Winter, S. (1982). *An Evolutionary Theory of Economic Change*., The Belknap Press of Harvard University Press, Cambridge, Massachussetts.

Parkhe, A. (1993). ""Messy" research, methodological predispositions and theory development in international joint ventures," *Academy of Management Review,* 18: 227-268.

Pennings, J., Barkema, H., and Douma, S. (1994). "Organizational learning and diversification," *Academy of Management Journal*, 37(3): 608-640.

Penrose, E. (1959). *The Theory of the Growth of the Firm*., Wiley, New York, NY.

Podolny, J., and Stuart, T. (1995). "A role based ecology of technological change," *American Journal of Sociology*, 100: 1224-1260.

Prahalad, C., and Bettis, R. (1986). "The Dominant Logic: A New Linkage Between Diversity and Performance," *Strategic Management Journal*, 7: 485 – 501.

Ramanujam, V., and Varadarajan, P. (1989). "Research on corporate diversification: A synthesis," *Strategic Management Journal*, 10: 523-551.

Rosenkopf, L., and Nerkar, A. (2001). "Beyond local search: Boundary Spanning, Exploration, and Impact in the Optical Disk Industry," *Strategic Management Journal,* 22: 287-306.

Ruef, M. (2002). "Strong ties, weak ties and islands: structural and cultural predictors of organizational innovation," *Industrial and Corporate Change,* 11(3): 427-449.

Rumelt, R. (1994). "Foreword," in *Competence-Based Competition*, (G. Hamel, and Heene, A., eds.), John Wiley & Sons Ltd, England: xv-xix.

Schumpeter, J. (1968). *The theory of economic development*, Harvard University Press Cambridge, MA (first published in 1911).

Smith, K.G., Carrol, S.J., and Ashford, S.J. (1995). "Intra- and inter-organizational cooperation: Toward a research agenda," *Academy of Management Journal,* 19(1): 7-23.

Teece, D. (1987). "Profiting from technological innovation: implications for integration, collaborating, licensing, and public policy," in *Competitive Challenge*, (D. Teece, ed.), Harper Collins: New York: 185-219.

Tirole, J. (1988). *The Theory of Industrial Organization*. The MIT Press, Cambridge, Massachusetts, London, England: 15.

User, A. (1971). "Technological Change and Capital Formation," in *Economics of Technological Change*, (N. Rosenberg, ed.), Penguin, Harmondsworth.

Uzzi, B. (1996). "The sources and consequences of embeddedness for the economic performance of organizations," *American Sociological Review*, 61: 674-698.

Uzzi, B. (1997). "Social Structure and Competition in Interfirm networks: The Paradox of Embeddedness," *Administrative Science Quarterly,* 42: 35-67.

Williamson, O. (1975). *Markets and hierarchies: Analysis and antitrust implications: A study in theconomics of internal organization*, The Free Press, London.

Williamson, O. (1989). "Transaction cost economics", in *Handbook of Industrial Organization*, 1, (R. Schmalensee, & Willig, R.,eds.), Elsevier Science Publishers, North-Holland: 136-182.

Wong, P. L-K., and Ellis, P. (2002). "Social Ties and Partner Identification in Sino-Hong Kong International Joint Ventures," *Journal of International Business Studies,* 33(2): 267-289.

Yin, R.K. (1984). *Case Study Research: Design and methods*. Sage, Newbury Park, California.

Young, N. (2002). "Social embeddedness and entrepreneurial opportunity: The case of African Americans," Working Paper, University of St. Thomas, Graduate School of Business.

	Conductive Polymer Technology(1982-2002)	**Immobilization Technology** (1980-2002)	**Atomic Layer Epitaxy Technology**(1980-2002)
Original Goal	A plastic battery for electric car	To explore recent developments in biotech	Medical device monitors
Role of co-incidence, luck and non-planned (chance) events	"Our conference presentation in New Mexico caught the interest of two leading US scientists. Quite unexpectedly, they suggested collaboration to us." "The decision to terminate the plastic battery research project co-incided with a change in corporate strategy. The new interest of CHEMCO lied in applications where conductive polymers were blended with main stream plastics" "The severe economic recession of the early 1990's made it necessary for CHEMCO to divest its plastic-related businesses, thus leaving a venture without home in the restructured parent corporation" "The application for the paper industry occurred to me just because of my prior job in that industry"	"Quite unexpectedly, we got an opportunity to acquire production facilities in Southern Finland. It was suitable for fermentation purposes and that is how it all began". "As a by-product of our alliance with this US corporation, we learned the immobilization technology" "Quite by chance, I heard about a research project going on at the National Research Center of Finland pursuing similar interests" "In the search of potential applications for the technology, we engaged in a thorough and systematic search of existing literature. However, all the applications that actually worked and were implemented were found by chance. Many times companies aim at modeling processes and using well-structured management methods. However, our experience shows that often intuition can lead to exactly the same results" " Many of these things just happened. It seemed to me that there was no systematic management of technology in this organization, at least you couldn't see it at the lower levels"	"Our conference presentation led to 4000 product inquiries. We should have saved that presentation to a moment when our product was ready" "Quite unexpectedly, ELECTRO decided to divest its consumer electronic divisions. As a result, our project was terminated"
Milestones in technology development	1) Plastic Battery → dead end 2) Experimentation with polytiofene derivates 3) Scaling up the production facilities 4) Conductive polyaniline→ a commercial product 5) Polymer LEDs→ a commercial product 6) Additives → a commercial product 7) Anticorrosive paints→ under development 8) Conductive textiles→ under development 9) Conductive surface application→ under development	1) Beer fermentation-→ a new product line at BREWERY 2) Fermentation of soft drinks→ patents 3) Fermentation of non-alcoholic beers→ new production lines at NON-ALCOHOLIC BREWERY-→ design and sales bioreactors to other breweries 4) Control of the PH level of beer → patent, in use at NON-ALCOHOLIC BREWERY 5) Production of extremely pure lactic acid→ development delayed at FOODCO 6) Manufacture of food ingredients→ development delayed at FOODCO 7) Manufacture of ciders and long drinks→ under development under a global research consortium	1) Medical device application-→ discontinued 2) TV monitor application-→ alive and well 3) Catalyst application→ under development at the parent 4) Solar panel application-→ alive and well with the new parent 5) ALE reactor application→ alive and well with the new parent
Governance Structures & Technologies Developed Within Them	1) Alliance between CHEMCO, National Research Center of Finland, and Lead Battery Manufacturer-> Development of Plastic Battery 2) A Nordic Research Consortium→ experimentation with polytiofene derivates & scaling up the production 3) A joint venture between CHEMCO and University of California)→ Conductive polymers and Polymer LEDs 4) Spin-off firm from CHEMCO in alliance with the paper manufacturer, textile company and paint producer→ additives, anticorrosive paints, conductive textiles, conductive surface applications	1) Joint venture between FOODCO and a US corporation-→ basics of immobilization technology 2) A project under R&D center-→experimentation with polytiofenes 3) RIFB consortium-→ beer fermentation 4) Alliances with BREWERY, SOFTDRINK, and NON-ALCOHOLIC BREWERY-→ fermentation of beers and soft drinks, 5) A business unit under ENGINEERING COMPANY-→ design of fermentation systems 6) Global research consortium→ fermentation of ciders and soft drinks	1) R&D lab of PHARMCO→ a flat panel display for medical devices 2) A business unit under ELECTRCO→ TV monitor applications 3) A subsidiary of a US corporation→ a world leader in TV-monitor related technologies 4) A subsidiary of ENERCO→ catalyst, ALE reactor, and solar panel applications 5) A subsidiary of a global semiconductor firm→ ALE Reactor & solar panel applications
Outcome	1) A spin-off company selling conductive polymers 2) High tech applications acquired by a global chemical corporation	1) Beer fermentation applications sold to a ENGINEERING COMPANY 2) The rights to other applications are retained by the parent	1) Most promising applications sold to a global semiconductor corporation 2) Catalyst applications retained by the parent

Table 1. Comparison of the technology-based ventures