Innovation of Complex Technologies: Five Cases, Five Cultures

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Abstract

This paper investigates the cultural impact on innovating complex technologies. Three innovation patterns (transformational, normal and transitional) are introduced. A conceptual framework of cultural impact on innovation is presented and elaborated using five cases of technologies from different nations. Policy implications are discussed.

Key Words

Innovation Patterns, Culture, Complex Technology

INTRODUCTION

The capacity of technological innovation is critical to the competitiveness of modern corporations and, thus, is of primary concern of business leaders around the world. However, there is a great variation in the degree of success different corporations have in innovating different technologies. Among the key determinants of this variation, culture has long been identified as an important one.

This paper investigates the role of organizational culture in innovating complex technologies. The authors postulate that differences in organizational culture at company level are heavily influenced by the variation of national cultures. Thus, rather than comparing organizational culture in various companies within a nation, five companies from five nations are used to elaborate the cultural impact on technological innovation.

The rest of the paper is organized as follows. Patterns of innovation of complex technologies are discussed. A conceptual framework of cultural explanation for the variation in innovative capacity in different firms is presented. The five cases of evolving technologies are then used to explain how national and organizational cultures influence technological development, decision-making, knowledge management, and evolution of organizational networks. Policy implications for strategic management in enterprises under different culture environments are discussed.

INNOVATION PATTERNS OF COMPLEX TECHNOLOGIES

This paper adopts the Rycroft-Kash framework[1] of innovation of complex technologies. Complex technologies are defined as those that cannot be adequately understood by an individual so that the technology can be communicated across time and distance for precise reproduction. In contrast, simple technologies can be so understood.

Complex technologies are the largest, and a growing, component of high value-added technologies traded in the world. Simple goods are mostly commodity products and the competitive advantage is usually associated with low labor costs. Alternatively, the source of competitive advantage for complex technologies comes from the capacity to use synthesis to carry out repeated innovations ahead of or in parallel with competitors[2,3]. Typical examples of complex manufactured products are aircrafts, autos, transistors, and telecommunication equipments. In contrast, shoes, clothing, and toys are of simple products. In 2001, among the top 30 most valuable manufactured traded globally, complex manufactured goods represented 86% [4].

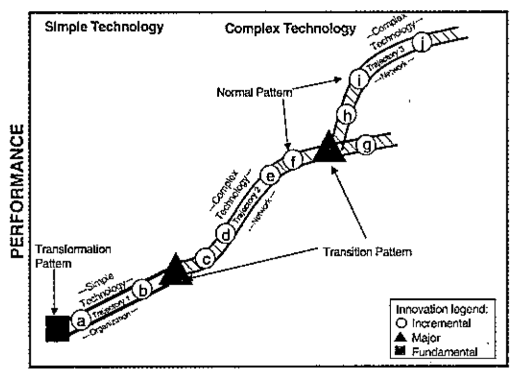

Figure 1 Generic Innovation Trajectories

Innovation of complex technologies happens with one of three patterns[1]: transformational, normal, and transitional (see Figure 1). The transformational pattern is distinguished by the innovation of first-of-a-kind technologies. When the first-of-a-kind technology is complex, a network of organizations that range from complementary asset suppliers to end-users must be formed in order to incorporate the diverse knowledge needed for the innovation. Thus, within the transformational innovation pattern both a new network and a new technology must be designed and built, in part, through a trial and error learning process.

The normal pattern is distinguished by innovations that deliver enhancements of established technology designs, for example, the ever more powerful microprocessors emerging from incremental innovations. Incremental innovations are predominately the product of cumulative learning within the network that was established to innovate the first-of-a-kind technology. During the normal pattern new innovator competitors can work within an established design (e.g., VHS design for VCR systems), and they can work in an environment where there is general agreement on what will be the next increment in performance[5].

The transitional pattern is distinguished by innovations that deliver major redesigns, for example, the synthesis of electronics and mechanics. Like the technologies, the networks that carry out transitional innovations must undergo major redesigns. The most distinctive characteristic of the network redesign is that new core capabilities must be integrated or merged to create a new network with the needed innovation capabilities. Thus the redesigned network must be able to access, create, and synthesize knowledge that did not previously exist in the network.

Over the last three decades many industries have carried out transitions from simple to complex technologies. The most common example has involved the fusion of mechanical and electronic technologies into what the Japanese call "mechatronics" [6].

CULTURAL IMPACT ON TECHNOLOGICAL INNOVATION: A COMCEPTUAL FRAMEWORK

Technological innovation is a socio-technical process and is not free from impacts of the society. Culture—whether national or company—can facilitate or impede the ability of networks to synthesize and successfully carry out the innovation of complex technologies. Culture is defined as learned and shared values and attitudes and the way of thinking and acting in a society, an organization, or among a group of people.

Culture has many different dimensions and can be studied through the ways people use to solve problems. A five-dimension framework developed by Hofstede[7] provides one approach for understanding how value differences can influence human behavior. The five dimensions are power distance, uncertainty avoidance, individualism-collectivism, masculinity-femininity, and long term/short term orientation.

In the field of technological innovation, although the point that culture plays significant role in promoting or impeding innovations is widely accepted, detailed studies of how culture influences innovation processes are surprisingly rare. Kline[8,9] pioneered the study by comparing differences in innovation styles between Japan and the United States, but failed to develop a conceptual framework. The Hofstede framework aims at general human behavior and doest not work very well for the study of technological innovation. A revised framework is in need to accommodate issues specific to technological innovation. The framework used in this paper is based on Hofstede's work but with certain revision and expansion. It includes the following cultural characteristics: trust, comfort with tacit versus codified knowledge, equality versus inequality, individualism versus collectivism, and decision-making style[10].

Trust is a great contributor to efficiency as high trust means low transaction cost. A high trust system has great competitive advantage as knowledge is moved, created, and used rapidly. That is because those who give the knowledge are confident it will be used to their advantage or, at a minimum, not to their disadvantage. Further those who give knowledge assume that they will receive knowledge in return at some future time.

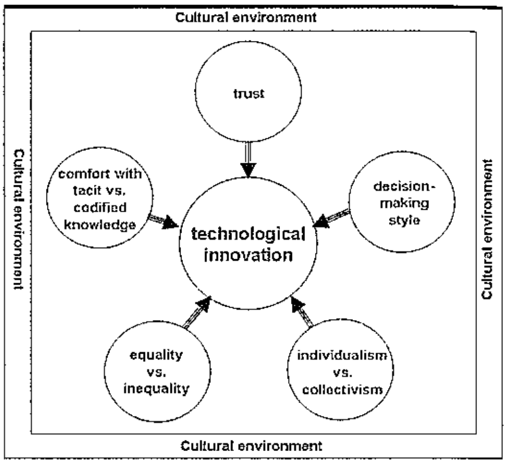

Figure 2 Cultural Impact on Innovation

Cultures vary in the degree to which they are comfortable with tacit knowledge. For example, the American culture is comfortable with codified knowledge but uneasy with both tacit and synthetic knowledge, the kind produced by systems integration. Both Japan and China appear to be more comfortable with tacit knowledge, certainly they are societies that find synthetic knowledge comfortable.

Inequality appears in many forms, i.e., family, organizational position, race or religion, age, education, experience and so on. A culture that emphasizes inequality among people is likely to be a barrier to rapid knowledge transfer and use. High speed of transfer occurs on the base of mutual respect.

A society that emphasizes individualism has barriers to giving knowledge away. In an individualistic society, being recognized as the creator or the source of valuable knowledge is how one gets recognition and status. At a minimum, individualistic societies slow down the movement of knowledge.

Decisions may be made by individual, vote, or consensus. Systems integration succeeds on the basis of a decision-making process that selects and tries solutions to problems that emerge from individual and group interactions. Detailed decisions by individuals in positions of organizational authority are often costly because individuals always have inadequate knowledge. Individual decision-making reduces the exchange of knowledge and information.

Where national culture tendencies appear to facilitate innovation, companies can create and maintain cultures that are consistent with that of the national culture. Where national cultural tendencies impede innovation, companies can create and maintain cultures that compensate for the broader norms. Similarly, public policies can take advantage of cultural traits conducive to innovation and attempt to mitigate the effects of cultural traits that impede innovation. For example, Intel has created a company culture that has many of the characteristics of Japanese culture. Intel's company culture emphasizes the importance of giving information and knowledge away quickly, diffuse decision-making, and teamwork. In Japan, these kinds of explicit company rules are not required, as the traits of the national culture already support these organizational requirements.

FIVE CASES, FIVE CULTURES

The five case studies summarized in the following seek to trace the development of networks and their capabilities of synthesis, with the emphasis on cultural impacts, over the history of the five technologies produced by organizational systems centered in five different countries (see Figures 3 through Figure 7): the Bosch (Germany) diesel fuel injection technologies, the Sony (Japan) audio compact disc (CD), the Hewlett-Packard (HP) (United States) cardio-imaging technology, the TATA Consultancy Services (TCS) (India) software services and products, and the Haier (China) line of home appliances. A more detailed description of the five cases can be found in [11].

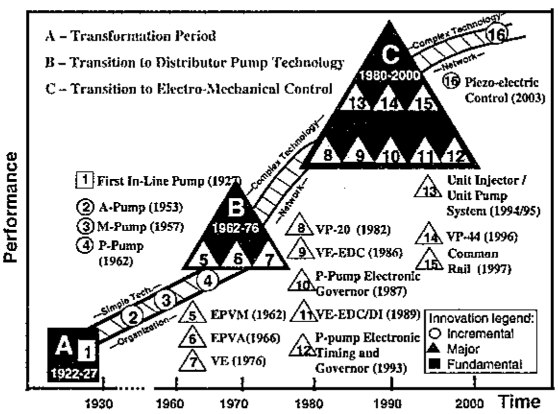

Figure 3 Bosch Innovation Trajectories

In the Bosch case the transformational innovation pattern encompassed the period in which a simple mechanical technology was produced. The initial design of a diesel fuel injection system is consistent with the hierarchical, codified culture of Germany at that time. The technology required craftsmen with narrow specialized technical expertise—both highly regarded in German culture. Once in the normal pattern of innovation, the dominant culture of the company and its organizational network is one of established routines and heuristics that have either engineered around or taken advantage of cultural traits. The normal pattern of innovation of diesel fuel injection systems appears to fit nicely with the German preference for ever greater depth of specialized technical knowledge—both tacit and codified.

The Bosch case was involved in two transitions: one from a mechanical in-line pump to a mechanical distributor pump and one from a mechanical injection system to an electro-mechanical system. Significant stress on the organizational system occurred at the second transition point, when the technology transitioned into an electro-mechanical system. It is at this point that Bosch implemented organizational changes in an effort to synthesize new knowledge and to overcome the hierarchy and highly specialized narrow focus of its personnel. During this period of transition, the company was no longer able to organize itself as a symphony orchestra [12]: assembling a number of highly specialized experts led by a "Master" designer. Rather, the transition required a merging and synthesis of expertise in which the interacting linkages and boundaries between disciplines were no longer clear. Thus, the company implemented a new organizational structure that established multidisciplinary teams.

The Sony innovation trajectory begins with what can be characterized as a self-organizing network: it has a style of operation that utilizes tacit knowledge to synthesize diverse types of knowledge. This is highly consistent with Japanese culture more generally.

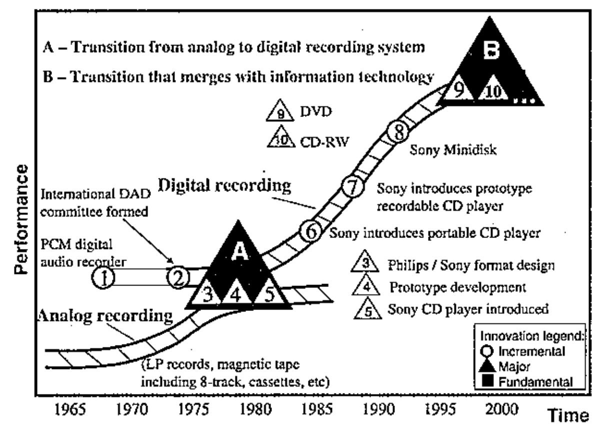

Figure 4 Sony CD Systems Innovation Trajectories

The Sony transition was from a complex electromechanical system to an even more complex electro-optical-mechanical system. When the transition point came, there was a need to link Philips for purposes of designing a CD system that integrates digital electronics and photonics. Philips had the leadership in optics and Sony in audio systems. The literature states that Japanese culture generally emphasizes the importance of relationships being mutually beneficial. This trait is obviously advantageous in the innovation of complex technologies, as an organization or network cannot operate in a tacit knowledge environment over a period of time without this attitude. Thus, this cultural characteristic is quite beneficial to the Sony-Philips partnership over the design phase.

Having a design in place, the Japanese focus was on getting the product to market quickly. Sony believed in its tacit knowledge and experience, so it approached future problems that would arise with incremental innovations as something to be dealt with later after the product was on the market. Philips, however, preferred codified knowledge and understanding in the scientific sense. The slowdown in reaction to the market put Philips in a disadvantageous position.

The HP cardio-imaging innovation resulted from a search for a new market for the company's medical electronics core capabilities. The company, in the early period, can be characterized as having a "not invented here" syndrome—a rejection of knowledge and expertise from outside organizations. The inability of the HP personnel to recognize the importance of tacit knowledge that was obtainable from other organizations reflected the traditional American cultural preferences for codified knowledge. However, HP did learn from this failure.

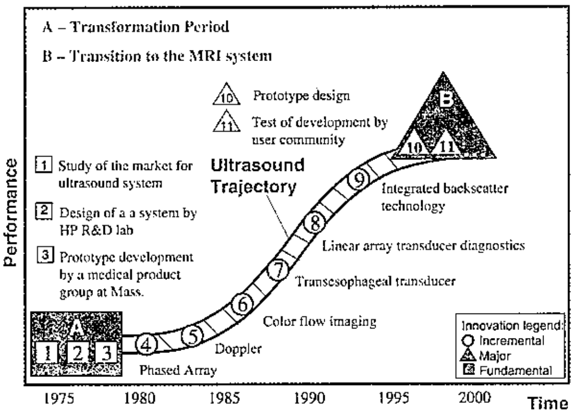

Figure 5 HP Cardio-Imaging Innovation Trajectories

The HP transition was from a complex ultrasound-based system to an even more complex magnetic resonance imaging (MRI)-based system. When the MRI transition point approached, HP decided to join forces with Philips in order to save time. This approach worked with the Philips' culture which was organized into distinct technology areas. Thus, the merging of the networks was easily facilitated. It is important to note that HP was a relative risk taker: it was willing to develop a technology that a consulting company said would sell but for which few cardiologists saw a need. One of the reasons for this risk-favorable organizational culture were the norms instilled by the founders, Hewlett and Packard, they emphasized the importance of developing state-of-the-art technology rather than pursuing short-term profits. By the time that the MRI transition took place, the company had learned the value of tacit knowledge.

The TCS case involved normal innovations and a transition from simple to complex technologies. In the TCS case, the transition has involved moving from a simple technology and single organization primarily concerned with applying software expertise to the problems of specific customers to the development of networks that exist for varying periods of time that merge substantive industry knowledge with information technology expertise in order to provide high level consulting services, as well as to design embedded software—software used on application specific integrated circuits (ASICs).

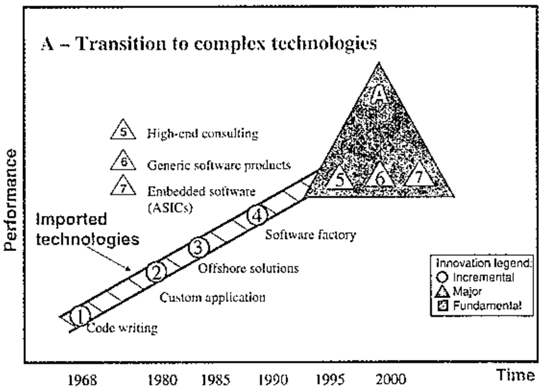

Figure 6 TCS Software Technology Trajectories

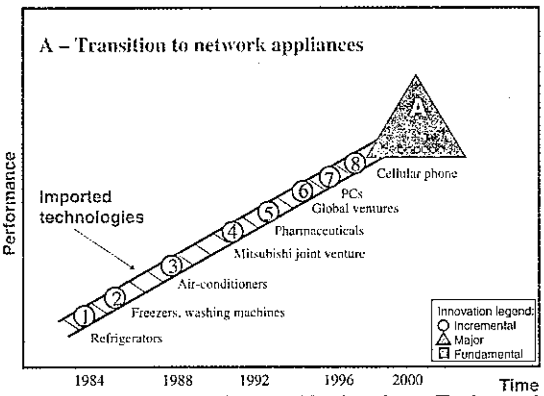

Figure 7 Haier Appliances Technology Trajectories

For TCS, the Indian cultural tradition that emphasizes mathematics, philosophy, and hierarchy works well when the software services and products involve a simple technology. However, as the company transitions to a complex technology and a complex organizational network, it will have to create a company culture that is different than traditional Indian culture. It will need a culture that allows people to act without centralized decision-making and rigid hierarchical organizational structures and one that promotes greater equality. Indian culture is advantageous in the innovation of complex technologies in the sense that it favors a synthesized view of knowledge rather than distinct specialization. TCS instilled a company culture that necessitates the codification of much tacit knowledge when it recognized the need for both tacit and codified knowledge in the innovation of complex technologies.

In the Haier case, the incremental innovations involved a simple technology, and the associated decision-making was centralized (restricted to company managers). The company has had to create a company culture not entirely consistent with Chinese culture. It has created a very rigid hierarchical management structure with rigid codified personnel and technical performance requirements that are strictly enforced. In order to quirements that are strictly enforced. In order to mitigate the characteristically Chinese culture of creating networks based on familial and friendship ties, Haier has substituted a hierarchical merit-based authoritarian system in order to ensure better efficiency. While it is still concerned with the innovation of simple technologies, Haier can continue to utilize codified knowledge and centralized decision-making. However, in order to transition to complex technology innovation, it will need to utilize consensus decision-making that can handle both codified and tacit knowledge. While Chinese culture is generally comfortable with tacit knowledge, Haier will need to institute strategies and actions that allow linkages with organizations that have the needed knowledge rather than with family or friendship ties.

CONCLUSIONS AND LESSONS

Public policies and organizational strategies designed to facilitate commercial technology innovation benefit from recognizing that very different organizational structures and processes are associated with the success of simple versus complex technologies. The capacity to carry out repeated innovations of complex technologies is a necessary condition, as complex technologies are the largest, and a growing, component of the high value-added technologies traded in the world.

Technologies and innovation processes are associated with one of three patterns: transformational, normal, and transitional. The three patterns are distinguished by different kinds of innovations and by the ways in which the networks access, create, and utilize knowledge and make decisions in carrying out the innovations.

Public policies and organizational strategies that facilitate the rapid development of trust among the participants in networks are particularly valuable during the transformational and transitional innovation patterns. These patterns represent time of change and uncertainty and require the active participation of company managers and public policy makers to guide and facilitate the innovations. For technologies that gain economic benefits from having a single universal design, public policies and organizational strategies that facilitate non-market choices of redesign appear to be beneficial.

Innovations of complex technologies are socio-technical processes. Both national and company cultures have significant impacts on the way in which people manage information and knowledge. Public policies and business strategies need to be designed to take advantage of cultural traits conducive to effective management of information and knowledge and to mitigate the effects of cultural traits that impede the exchange and use of tacit and codified knowledge. In general, a culture that emphasizes high level of trust, collectiveness, equality, consensus decision-making and that is comfort with both codified and tacit knowledge is highly desired for organizational learning.

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