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Evolutional dynamics of product innovation: the case of consumer electronics

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Abstract

This report addresses the question of how product innovation occurs. In other words, where does it originate and what induces it? The aim of the authors has been to expand upon and systematize the research presented in our previous study (Orihata, M., Watanabe, C., Technovation, in press) through the application of a new, evolutionary approach. We have chosen to focus on the consumer electronics industry, taking as our case studies three producers of revolutionary products such as Sony's video camera, Sharp's PDA (Personal Digital Assistance) and Toshiba's notebook personal computer. These examples have the virtue of encompassing both visual and text-based data transmission devices, as well as hand-script input and keyboard input methods.
The main point we shall consider here is the stage that takes place before product innovation occurs, the process that we have termed "institutional inducement", which forms part of the feedback loop between the market, or environment, and the producer. Because this process is "a flow of information and knowledge" we have structured it using a semiotic methodology, which has led us to conclude that product innovation is induced by the creation of new product concepts. In accordance with this, we propose that the evolutionary, dynamic pattern of product innovation is linked to the institutional trajectory.

Keywords: Radical/incremental product innovation; Evolutional dynamics of product innovation; Exploration/exploitation spin cycle; Institutional trajectory; Institutional inducement

1. Introduction

Based on actual case studies, this report discusses an evolutionary model for examining the origins and inducement of product innovation on the corporate level. The logic that this implies is that the evolutionary process of innovation consists of a synergy, or mutual interaction, between the product and the institutional system. Furthermore, we have understood the direction of product innovation brought about by this interaction to be dictated by the "spin cycle" and "institutional trajectory" between the product and the institutional system, and that innovation is the result of inducement through the spin cycle. In this context, "institution" specifically refers to the market and to technology that exists outside the corporation through spillover. This study is a continuation of our previous paper, entitled "The interaction between product concept and institutional inducement: a new driver of product innovation" (Orihata and Watanabe, in press), on which we have expanded and applied a more systematic analysis.

Answering the question of what drives product innovation — that is to say, probing the "origins of innovation" — is an extremely daunting and difficult task, but also one that has received much attention. This problem is referred to in economic terms as "induced innovation" and in management terms as "idea generation management." If we consider the work of Kuhn (1962) to fall into the category of innovation research, then we should also place the scientific–historical work of Hanson (1958), "new scientific discoveries", in this category.

Going as far back as Hicks (1932), economic research has tended to see innovation as induced. As typified by Rosenberg (1969), early inducement theory understood innovation to be induced by bottlenecks which occur in the numerous and closely linked systems of production. One innovation will give rise to a bottleneck which in turn will require other innovations in order to resolve

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the bottleneck (in other words, a change in technology at a certain stage of production increases output, so in order for overall output to increase productivity also must be increased at other stages). Furthermore, Rosenberg proposed the concept of a "technological imperative" as being what determines the course of technological progress, and he proposed that innovation arises at least in part from within the economic system. In other words, the target of innovation is the bottlenecks or weak spots in the chain of production.

According to Rosenberg's notion, the target of innovation is always shifting. Nelson and Winter (1982), however, proposed that innovation follows a straighter course along what they called "natural trajectories" and that engineers have a clear idea and awareness of the direction in which they are heading. According to this theory, natural trajectories are specific to a certain technology, but that when expanded to a larger framework one can refer to a "technological regime". An example of this would be innovations that aim to create economies of scale or to replace human labor with machines.

Abernathy and Utterback (1978) and Dosi (1982) have also proposed evolutionary models for innovation patterns. Abernathy and Utterback understood products and processes to be fluid during the initial state of innovation, but supposed that they gradually evolved into concrete and fixed states. In particular, once a dominant design has appeared, the diverse range of designs that existed in the early stages gradually converge into one basic design. Based on Kuhn's model, Dosi proposed a technological paradigm rather than a scientific paradigm. The basis for this paradigm is the "normal" problem-solving process which determines the technological trajectory.

From these various theories of what determines the direction of technological development gradually emerged the notion of "technology-push", whereby technology causes innovation. Schumpeter's work (1912), too, is basically founded upon such a supply-side view of innovation.

On the other hand, between the late 1960s and mid 1970s, a number of case studies—e.g. HINDSIGHT (Sherwin and Isenson, 1967), Queen's Award Study (Langrish et al., 1972), MIT Study (Utterback et al., 1973), Textile Machinery Study (Rothwell, 1976)—were conducted that importance of demand as a determining factor in innovation (Rothwell and Walsh, 1979; Coombs et al., 1987). Based upon later discoveries of the influence on innovation of demand-side factors, Rogers (1982) proposed that a process of re-invention is begun as innovations spread. He also states that until the mid 1970s it was not believed that re-invention occurred on the user side. Efforts such as this to revise technology-push innovation theories can be found as far back as Schmookler (1966). According to Rogers, it was Charters and Pellegrin (1974) who really stirred considerable interest in processes of re-invention through the market.

When these market-side influences on innovation were merged with the aforementioned technology trajectory theories, a new evolutionary perspective began to emerge. That is to say, innovation advances through a synergy between technology and the market, a notion for which Clark (1985) served as the model (hereafter referred to as the "C-Model"). Clark based his work on Abernathy and Utterback's model (which he termed the "A—U Model") in devising an evolutionary model that incorporated consumer demands and experiences based on using the product. Driving this evolution was the interaction between how consumers learn to use new products and how designs respond to the way in which consumers are observed to use the product. The C-Model proposed a process of evolution that carried the A—U Model three steps further. First, it made a distinction between technology innovation and product innovation. Second, taking into account market influences, it suggested that the interaction between technology and the market induces the product innovation process (in other words, it expanded upon the theory that "innovation induces innovation"). Third, it provided a newer, more refined analysis of the mechanisms that drive product innovation.

On the other hand, in the field of economic theory, technological innovation had always been treated as an exogenous factor (i.e., a factor externally provided). Emphasizing the interaction between technology, the economy and society, the new model identified technological innovation as an endogenous factor (i.e., a factor internally generated).

In addition to the two factors driving economic growth identified by Solow (1956) — labor and capital — a third factor, total factor productivity (TFP), was later added (Denison, 1962; Jorgenson and Griliches, 1967). However, according to these concepts, technological progress was exogenous. Furthermore, Arrow (1962) suggested that technological innovation was induced by basic research, but that basic research takes place in the public sphere and is translated into technological innovation through a process of "learning by doing". Rome (1986) further drew a line between the public and private aspects of technological innovation, advancing the notion of endogenous (i.e., internally generated) technology change. This signaled a break with the "R&D–technological innovation–industrial growth" linear model of innovation, instead emphasizing the feedback loop from the market, or environment, to R&D. The notion of a system linking technological innovation and the diffusion of that new technology began to emerge (e.g., Metcalfe, 1981; Watanabe and Clark, 1991; Watanabe and Honda, 1992; Watanabe, 1995; Watanabe and Wakabayashi, 1996; Grübler, 1998; Nooteboom, 1999). Baranson (1967) had already introduced the notion of external technology (referring to the economic environment, natural environment, social and cultural environment, as well as the system of government policy). Baranson's work suggests that the positive interaction and synergy between this external technology and internal technology, the process of R&D which produces technological innovation, induces vigorous R&D activities.

Among these analytical studies were several examples of empirical studies (e.g., Watanabe and Clark, 1991; Watanabe and Honda, 1992), but due to the fact that the systems that these targeted were macrosystems (governmental systems, for example) they did not shed any light on the mechanism of innovation on the corporate level nor on the formation of innovation strategies that are our objectives.

On the other hand, research that has pondered the origins of innovation on a more micro, or corporate, level has by and large focused on organizational, management processes. Such studies have tended to emphasize a cross-functional approach, in particular stressing the importance of the interaction between product developers and marketers (Clark and Fujimoto, 1990; Dougherty, 1992; Manz and Sims, 1995; Iansiti, 1995; Ottum and Moore, 1997).

It seems, however, that relatively little research exists directly addressing the question of how innovation occurs, and especially the process of developing entirely new (revolutionary) products (Veryzer, 1998). One of the main reasons for this, perhaps, is that the problem crosses over to the fields of psychology and cognitive science (Kuhn, 1962). What complicates the issue even further, moreover, is the trend in recent years for market needs to become submerged, or latent.

In short, these were the factors that motivated us to undertake a case study of product innovation on the corporate level using an evolutionary model.

This study is founded upon not only techno-economic macro systems research accumulated over more than 10 years, but also seven years of microeconomic research on the corporate level relating to product innovation by the authors. In the first stage of our research on product innovation, based on a study of literature on 46 companies, 13 companies with impressive track records in product innovation were chosen for an in-depth study. These included technology-based firms, material/industrial products producers, consumer products producers, and service companies. For the present study, three consumer electronics companies — Sony (video camera), Sharp (personal digital assistance) and Toshiba (notebook personal computer) — were chosen for an even greater in-depth study. We also examined makers of TV/VTRs, digital cameras, cellular phones, portable audio players, karaoke machines and home video games, but in the end only these three were selected based on the following criteria: (1) pioneering Japanese companies in product innovation, (2) makers of machines that handle text and imaging data (cf. voice transmission devices, such as the cellular phones, in which Japanese companies did not play a pioneering role) and (3) ease of gathering information for research purposes.

The body of the present work is comprised of four main sections. Section 2 presents an overview of the evolutional innovation system in order to provide a clear understanding our thesis and the terminology involved. Sections 3 and 4 analyze two "spin cycles" directly related to product innovation. In particular, Section 4 attempts to explain how innovation occurs and hence it constitutes the core of this study. In Section 5 we look at the innovation system being proposed here in the light of management strategy. Finally, the concluding section identifies some problems for further investigation.

2. Overall system for evolutional product innovation

In order to provide a clearer understanding of our study, we first give an overview of the Evolutional Product Innovation System (EPIS) and, at the same time, define the terminology which we shall be using.

To begin, the term "evolution" as applied here, of course comes from the field of biology. As Nelson and Winter (1982) — considered the first proponents of evolutionary economics — have argued, however, we intend the term here to have broader connotations than normally used, and therefore were make no strict distinction between evolution and revolution. When sudden changes occur these are absorbed and continuity is maintained. We also make no strict distinction between "blind" evolution and "deliberate" goal-seeking. In other words, evolution as it is used here has the meaning of both the process of long-term and progressive change as well as including dynamic processes.

As illustrated in Fig. 1 by the schematic of the Sharp case study, EPIS is composed of an evolutional "spin cycle" and "trajectory" as the basic evolutional structure.

"Spin cycle" refers to the spin cycle that exists between products and the "institution", a relationship of mutual interaction, or synergy. Our use of "institution" is based on the definition of North (1994): "The humanly devised constraints that structure human interaction. They are made up of formal constraints (e.g., rules, laws, constitutions), informal constraints (e.g., norms of behavior, conventions, self-imposed codes of conduct), and their enforcement characteristics. Together they define the incentive structure of societies and specifically economies". In particular, in the present study which focuses on consumers and technology, we shall refer to these separate institutions as the "socio-institution" and the "techno-institution". Therefore, one should think in terms of the spin cycle as consisting of both a socio-spin cycle and a techno-spin cycle.

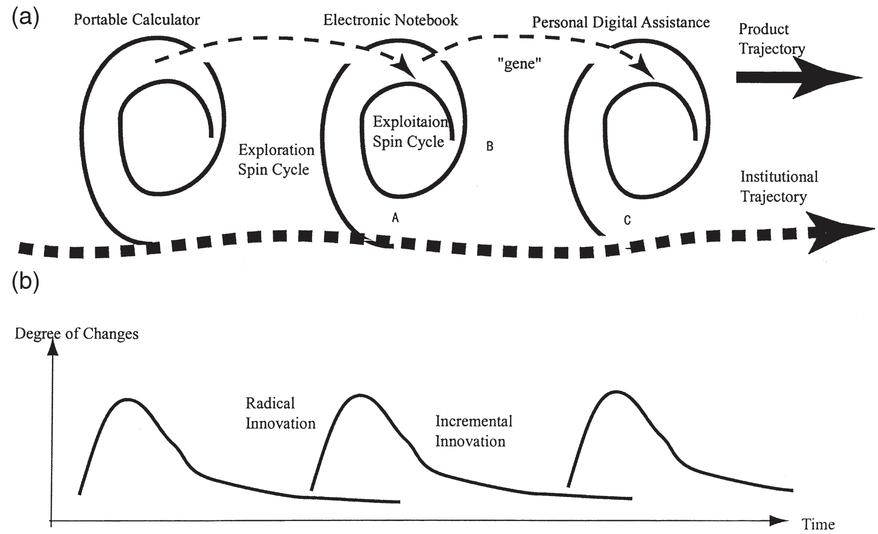

Fig. 1. (a) Schematic illustration of the overall evolutional system of product innovation (the case of Sharp Corporation). (b) The A–U Model corresponding to (a).

Moreover, as we will discuss in greater detail in Sections 3 and 4, we can also define the spin cycle in terms of an “exploration” spin cycle, which corresponds to radical innovation, and an “exploitation” spin cycle which corresponds to incremental innovation. In other words, the exploration spin cycle involves the search for entirely new products, while the exploitation spin cycle is the attempt to improve existing products in order to better respond to market needs.

“Trajectory” means both the direction, or course, of evolution as well as the distance, or size, of the innovation. One should think in terms of a “socio-institutional trajectory”, a “techno-institutional trajectory”, as well as a “product trajectory”.

“Product evolution” is the result of product innovation and includes both radical innovation and incremental innovation. Product innovation is induced by institutional evolution, to which it is linked via the spin cycle and is driven by the institutional trajectory, producing a product trajectory.

Furthermore, as product evolution advances, parts of the product concept and product technology are passed on, or inherited by other products. We have called these “genes”.

An understanding of this system relies on an awareness of the distinction between a product and its technology. In other words, a product is not only technologically substantial object.

The EPIS can be contrasted with the innovation pattern of the A–U Model. As shown in Fig. 1, a temporal change in EPIS begins with the exploration spin cycle at point A and moves in the direction of the arrow (radical innovation). Then at point B the exploitation spin cycle begins. The exploitation spin cycle goes through several times revolutions (incremental innovation). At the same lime, the institution shifts to the right, and so at point C a new exploration spin cycle beings (next radical innovation). Thus, using this schematic, we can describe the innovation pattern of the A–U Model.

3. Exploitation spin cycle and incremental innovation

Clark (1985) established the model in business administration studies for analyzing industry–market interaction in the innovation process on the micro level. Here, we have taken this C-Model one step further, using it as the basis for rethinking this interaction in terms of a spin cycle between the institution and the product.

As mentioned above, within the spin cycle we can think of there being both an “exploration cycle” in which entirely new products are created, and an “exploitation cycle” in which already existing products are further refined in order to fit the demands of the market. First, concerning the exploitation cycle, let us a take a look at how the product is delivered to the market, that is, to the institutional system. This “delivery process” encompasses production, sales and distribution. Though in the early stages the delivery process is not a highly standardized or automated process, as the spin cycle progresses, the process becomes increasing more standardized and automated (Abernathy and Utterback, 1978; Clark, 1985; Utterback, 1994).

The delivered product gradually permeates the institutional system. This is called the “diffusion process”. This diffusion process consists of several important elements that have an impact on product innovation. The first is a phenomenon called the experience-curve effect. The second is the spillover of the product concept and technology through production equipment manufacturers and parts manufacturers, which occurs as competitors start to copy the product technology. The third is the user's increased familiarity with how to use the product: in some cases this can even lead to "re-invention" of the product by the user (Rogers, 1982).

First, the experience-curve effect can be defined as the phenomenon whereby deflated unit costs and approximate price gradually decrease, or diminish, as accumulated experience and approximate accumulated production units increase (e.g. The Boston Consulting Group, 1972; Dutton and Thomas, 1984; Gulledge and Wormer, 1990). For example, Fig. 2 illustrates the experience-curve effect for the video camera. This effect further encourages diffusion of the product in the market. The curve can be expressed approximately by the formula:

$$\log(y)=6.19-0.298\log(x),\quad R^2=0.868.$$

Second, spillover can affect the product in question both positively and negatively. A classic example of how spillover can have a positive result is that competition encourages the experience-curve effect, the product achieves greater market penetration, and sales increase. In other words, spillover is a shared experience with one's competitors. On the other hand, there is the chance that competitors will reduce or even completely efface one's competitive advantage. For example, Sony invented the first 8 mm cassette video camera in 1980 (of which the TR55 model released in 1989 achieved wide commercial success) In 1992, however, Sharp came out with the "Viewcom", a revolutionary model that integrated Sharpe's special LCD (liquid crystal display) technology (the

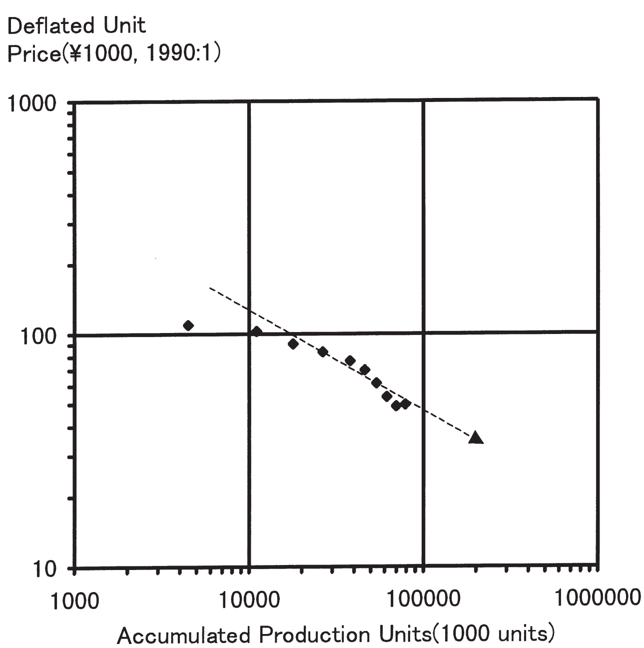

Fig. 2. Experience curve of video cameras produced in Japan (1987–1996).

rotatable display meant the user no longer had to peer into a view finder, could take pictures of himself or other people, and could view images instantaneously). Though Sharp's share of the video camera market had been just 1%, the Viewcom helped the company enlarge that to 26% in 1995, second only to Sony (40%) whose dominance became threatened. But Sharp, in order to secure their competitive advantage in LCDs (then the uncontested top maker with 30% market share), began selling their technology to other companies. Competitors began making similar video cameras to the Viewcom, and by 1997 Sharp's share of the video camera market had fallen to 18%.

Third, the diffusion of a product in the market leads to realization of its use value and in some cases even to the development of a use value other than the intended one, as consumers gradually become accustomed to using the product. The institution's ability to recognize and incorporate such re-invented values is a crucial part of product development. This is the next step after the diffusion process and is termed the "institutional inducement process" or simply the "inducement process". While up until this point we have been concerned with "the flow of materials", what we are concerned with in the inducement process is "the flow of information or knowledge".

What our case studies make clear is that leading-edge companies place great emphasis on the inducement process and have instituted a number of concrete methods for gathering feedback from the market.

For example, Sharp, in refining their first-of-its-kind PDA (Personal Digital Assistance), called "ZAURUS", analyzed the information on the consumer-response cards enclosed with the product when sold at retail (response ratio: 5–7%), conducted follow-up surveys on a random sampling of these responses, stationed developers in retail outlets to speak directly with users, and set up "consultation desks" in their marketing division to gather customer feedback.

What is of particular interest here is that Sharp and other companies have been making special efforts to gather implicit or "tacit" information as well as explicit information. In other words, they emphasize an "empathic" method. Tacit information is gathered through ordinary face-to-face conversation, meaning that these companies emphasize direct customer contact on the retail level.

In fact, this sort of user interaction has become a very popular activity, and most leading Japanese manufacturers employ it to some degree with their major products. The information they gather from users is utilized in refining their products to better fit user needs. Since most of this information is gathered by marketers, however, the nature of the system by which it is passed on to product developers has become a critical issue for these companies.

Another aspect of this feedback cycle, or inducement process, between producers and consumers, is the cooperation between the manufacturer and the retailer. Although a joint approach is being attempted in the convenience store industry with everyday products and food and beverages, we were unable to find any examples of such a trend in the consumer electronics industry.

The part of the inducement process in the exploitation spin cycle that deserves the most attention is the inducement of the institutional trajectory. As shown in Fig. 3, the example of Sharp's ZAURUS demonstrates that the evolution of data transmission is not just a simple matter of technological evolution, but it is also a reflection of socio- and techno-institutional trajectories.

As we have seen, the exploitation spin cycle is composed of four processes: product development, delivery, diffusion and inducement (feedback). Its main objective is the refinement, or incremental innovation, of existing products to make them more responsive to the institutional system of the market. Another important function is to maintain and extend a competitive advantage over one's rival products.

4. Exploration spin cycle and radical innovation

One of most intriguing aspects of product innovation is the question of how radical innovation occurs. Our concept of the exploration spin cycle is an attempt to explain the cause of radical product innovation.

The exploration spin cycle has three roles: first, perceiving latent needs using the emphatic method mentioned above; second, creating new product concepts; and third, producing a model prototype that makes latent market needs emerge.

4.1. Physical flow and knowledge flow in the spin cycle

We have already stated that the exploitation spin cycle consists of the four processes of product development, delivery, diffusion and inducement. Likewise, the exploration spin cycle contains the same four phases. Unlike the exploitation spin cycle, however, it does not form a closed circle. Moreover, the exploration spin cycle begins with the inducement process.

This inducement process is a flow of information that starts with the institutional trajectory and ends with a product concept. This flow could, for example, represent information about consumer needs emanating from the market. We can contrast this with the delivery process, which is a flow of materials that starts with the manufacture of a product and passes through sales and distribution systems until it arrives at the institutional system of the market. In between the inducement process and the delivery processes lie the product development process and the diffusion process, transitional phases separating the two kinds of flow. That is to say, in the product development process a product concept is transformed into a substantial object, while in the diffusion process the product is transformed by the user into a use value and into information about explicit needs (consumer dissatisfaction/complaints)

4.2. Institutional inducement process and product concept

Despite being the most important part of product innovation, the inducement process all but denies quantitative analysis or explanation. This is due to the fact that the process represents a flow of information, or "knowl-

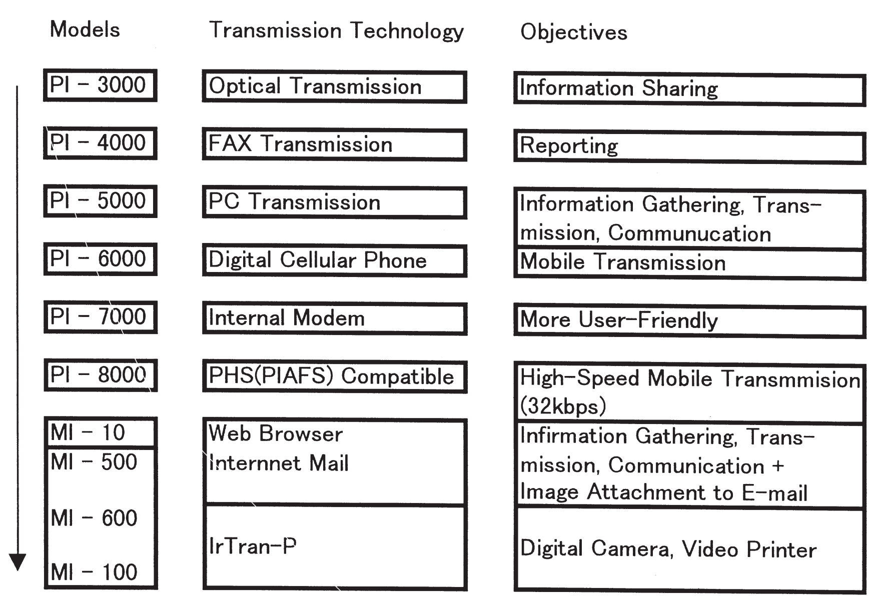

Fig. 3. Evolution of Sharp's ZAURUS in terms of transmission function. Source: Sharp Corporation.

edge". It registers a zero on a production volume chart and a logistic curve of diffusion, and even on an experience curve its effect is unnoticeable. There can be no doubt, however, that though the workings of the inducement process are not visible on any graph or chart, it is an important, hidden part of the whole process.

For this reason, we have chosen to analyze the inducement process using a "semiotic" methodology (Saussure, 1949; Eco, 1976). The systematic modern semiotics was initiated by Peirce (1929) and Saussure (1949) and its methodology has contributed greatly to the various cultural fields including architecture, linguistics, music and so forth. In this analysis, as shown in Fig. 4, the inducement process may be regarded as the semiotic process whereby the context of the institutional trajectory (the set of circumstances of the institution) is interpreted, and the contents "signified" by the product (the product is "signified", to borrow Saussure's terminology) are crystallized. Therefore, "product concept" refers to these contents. The expression of these contents (the "signifier" of the contents, again according to Saussure) is product development. Technology is a tool for expressing the contents (product concept).

We found in our case studies that it was typical for the companies concerned to identify a strategic direction prior to creating a product concept (contents). Of course, this strategic direction reflects the biases, point of view and desires of the corporation and its developers. Therefore, the product concept is a fusion between the subjectivity of the developers and the objectivity of the institutional trajectory.

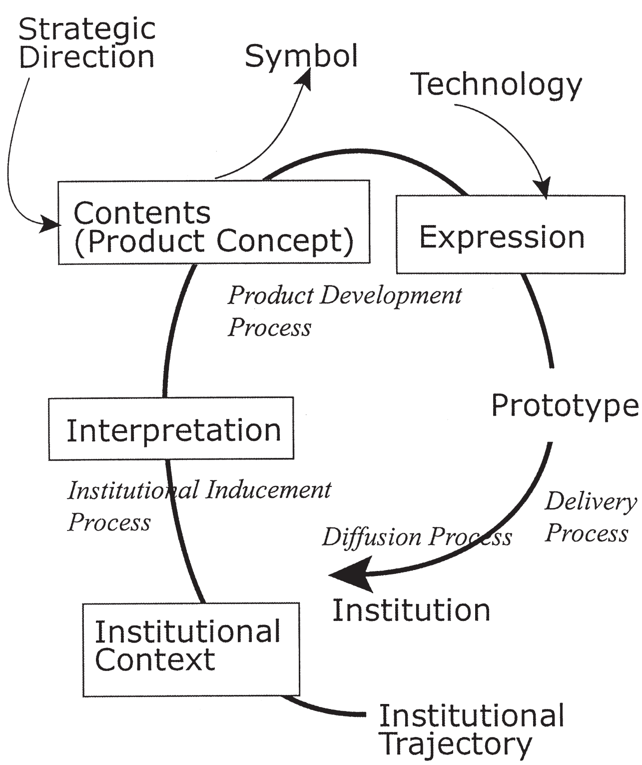

Fig. 4. Semiotic model of exploration spin cycle.

As pointed out by Deleuze and Guattari (1991), concept is nothing more than a linkage of linguistic elements. Hence, the product concept of a particular company is a collection of phrases. In this regard Sony is an exception because it expresses its product concepts diagrammatically using what it calls "Sony Designs". The traditional method of product design at Sony is to decide first on the size and shape of the product, only then filling this package with the relevant technology and making adjustments as necessary as one goes along.

4.3. Case examples of inducement and product development processes

4.3.1. Sony's video camera

The video camera was a natural evolution of Sony's VTR (video tape recorder). In accordance with the company's fundamental strategy of "changing people's lifestyles", in 1964 Sony released the world's first video recorder for home use, the CV-2000. This product offered consumers a revolutionary lifestyle change or, as Sony put it, "Freedom from the constraints of the television programming schedule and the ability for everyone to watch their favorite programs at their own convenience". The CV-2000 was gradually refined into the product known as the Betamax, though it was eventually to lose out to the VHS format video recorder as the industry standard. Despite this setback, in January 1980 Sony announced new plans to develop what it termed an "audio- and video-recording VTR camera". As early as July of that year, the first video camera, the "Camera Movie CX-I" was unveiled in New York and Tokyo.

Sony's video camera was not merely a commercial extension of the VTR into a product that allowed individual consumers to make their own personal videos. By launching the Video Movie CX-1 domestically and overseas, Sony was at the same time calling for the creation of an industry standard. The technology behind the product was charged coupled devices (CCDs), a new form of semiconductor imaging elements developed in the early 1970s. This, combined with the 8 mm width tape developed for the Betamax, enabled the birth of Sony's video cassette recorder.

Sony decided to wait until 1985, however, for the true commercialization of its video camera. If a universal standard had existed, the company could have come out with a product immediately, but Sony held off because of the lesson they had learned from the Betamax. At the same time, 1982 saw the beginning of a series of informal talks on 8 mm video tape attended by 122 companies around the world, and in April 1984 it was chosen as the industry standard. Sony, seizing the opportunity, announced their new model video camera, the CCD-V8, in January 1985.

Other products were soon to follow. Although a number of important technical hurdles had been cleared (10 times the recording density of previously available products), however, the CCD-V8's price, weight and size prevented it from gaining wide acceptance with consumers. It was at this point that Sony realized it needed to think in terms of a product that expressed the "essence of Sony". It was not long afterwards that the company came out with the T55, a camera that was no larger than an ordinary passport (the Japanese passports in use then measured 9.7 cm×15.5 cm). Backed up by an extensive campaign of TV commercials featuring a popular actress mouthing the catch-phrase "passport-sized", the T55 was targeted at the increasing numbers of Japanese tourists heading overseas because of the strong Japanese yen resulting from the Plaza Agreement in 1985. As mentioned earlier, Sharp later followed suit with a revolutionary LCD-equipped model video camera that began to challenge Sony's dominance. As of 1997, however, Sony still enjoyed a secure position, holding a 45% share of the market: twice that of its closest rival.

The crux of our product innovation model lies in the spin cycles of the institutional inducement process and in the product development process. Respectively, these can be expressed as the following semiotic models: institutional context→contents (product concept) contents→expression (substantial object). When applied to the case of Sony's video camera, we get:

Inducement process:
- context — individual consumers are free to create and enjoy their own videos, especially useful for tourists going overseas;
- interpretation — combined camera and VTR;
- contents — passport-sized video camera.

Product development process:
- "squeezing" the necessary technology into a package designed to offer portability and ease-of-use;
- setting the product's price where it is affordable for the consumer;
- development of CCDs, the technological key to the camera's success.

The above is summarized in Table 1, columns 1 and 2, and compared with the other case examples.

4.3.2. *Sharp's personal digital assistance*

In 1993, Sharp released the first personal digital assistance (PDA), the ZAURUS PI-3000. Sales quickly surpassed their target of 20,000 units per month by as much as 50%. The development of the PI-3000 was driven by the following three factors: (1) the world needed a new way to transmit information; (2) since 1992, Sharp's strategical direction had been its PI^{2}T (Personal Information and Intelligent Tool) concept, that is, "a personal information tool that consists of a computer core dressed in the 'clothing' of user-friendly software"; and (3) Sharp was already producing an "electronic notepad", the forerunner of the PDA.

In accordance with (1) and (2), Sharp added a script-input function and transmission function (optical transmission) to its electronic notepad and released it as the Electronic Management Notepad PV-FI, but the product was not a commercial success. It did, however, play a crucial role in the development of the ZAURUS PI-3000. The failure of the PV-FI made it clear what market conditions needed to be met. Sharp put this information together and set a new target: to make a product that was half the size and price and had half the power consumption of the PV-FI while still delivering twice the functions, speed and operability. The product concept was "a device that revolutionizes the way people work and can be taken and used anywhere". In other words; the PV-FI served as a prototype for ZAURUS, constituting a transitional product between the electronic notepad and the PDA and helping translate latent needs into explicit needs.

In 1991 Sharp teamed up with Apple Computer. Together, in 1993, they created the PDA "Newton" which also proved a commercial failure. This has been blamed on the English script-input technology, although the developers on the ZAURUS side strong deny it. What is undeniable, however, is that there has been spillover of the PDA concept.

The evolution of PDA still continues, and Sharp remains the world leader in offering script-input PDAs.

A semiotic model in the same manner as Sony's video camera appears as follows:

Inducement process:
- context — the world is seeking a new means of communication;
- interpretation — a portable transmission device (tool) for individual use;
- contents — a device that can be used by anyone anywhere and changes the way people work.

Product development process:
- miniaturization of size and weight to pocket size;
- handwriting recognition/pen operation;
- enhanced transmission capabilities (optical transmission).

The above is summarized in Table 1, column 3.

4.3.3. *Toshiba's notebook personal computer*

The so-called notebook PC was originally developed by Toshiba. Even now the company boasts the largest share of the world notebook PC market.

In the 1970s Toshiba twice attempted to establish itself in the mainframe computer business, and both attempts ended in failure. Subsequently, the company had considerable success selling 32 bit minicomputers

Table 1
Semiotic structure of product innovation (examples)

Semiotic inducement and product development processes	Sony's video camera	Sharp's PDA	Toshiba's Notebook PC
Institutional trajectory		Individualism and networking	
Institutional context	Entertainment and new communication environment	New communication environment	
Interpretation	Combined camera/8mm video	"New mobile information tool"	Truly portable PC
Contents (product concepts)	Passport-size video camera	•Can be taken anywhere •Anyone can use it •Changes the way people work	Dynamic notebook
Expression (initial commercially successful models)	CCD-TR55	PI-3000	T-1100
Symbol	"Handy Com"	"ZAURUS"	"Dynabook"

and Japanese word processors. But in 1978 and 1981 they again met with failure, this time in trying to break into the personal computer business. It was not until 1984 that Toshiba finally made its big computer business breakthrough.

Toshiba's T-400, the company's first genuine ready-to-use general-purpose personal computer, was developed in 1978, about a year-and-a-half before NEC's PC-8001 became the first commercially successful PC in Japan. Toshiba's strategic direction in the computer business, however, was unclear at the time and the T-400 project had little support among the company's top executives. Just seven models were built for demonstration purposes. Meanwhile, NEC released the PC-8001 in 1979, and this was soon followed by the PC-8801 and PC-9801 in quick succession. NEC quickly captured the Japanese PC market.

In 1981, Toshiba tried again, developing the Pasopia 7. NEC's PCs had already set a de facto industry standard, however, and the Pasopia 7's lack of compatibility was enough of a handicap that only 50,000 models were sold, another failure for Toshiba.

Toshiba decided to revise its fundamental PC development strategy starting from scratch. The company devised a six-point strategy which they termed a "Back to the Future Approach" that all but ignored existing desktop PC designs. In 1983, Toshiba sent a five-member team to the United States to speak with computer dealers and users in order to make a thorough study of what consumers were looking for in a PC. They concluded that there was significant latent market demand for a truly portable, IBM-compatible PC.

The Toshiba developers summed up their conclusions with the concept, "a product that integrates the main body, keyboard and display for real portability and ease-of-use by the customer". In 1985, the T-1100, the first laptop PC, was born, becoming a huge success in the US and European markets and somewhat less of a success in Japan. The main technological advancements realized by the T-1100 were a miniaturized (3.5 in.) disk drive, a specific liquid crystal display and a very-large-scale integrated (VLSI) circuit. Toshiba's design concept was subsequently copied by a number of rival manufacturers, making their laptop PC the dominant design.

Toshiba considered their laptop PC a milestone in the development of a truly portable PC. They had opened up an entirely new market, but competitors were quick to follow and cash in on their success. In response, Toshiba developed the Dynabook PC (Dynamic Notebook PC) J-3100SS in 1989, which proved this time to be a truly portable PC.

Dynabook was the name given to the product concept developed by Alan Kay which was essential to Toshiba's successful development of the notebook PC. Alan Kay was a former jazz musician turned computer engineer who worked during the late 1960s at Xerox's Palo Alto Research Institute (Shasha and Lazere, 1995). During that time he developed a definition of the ultimate PC, a personal intelligent tool for performing creative tasks. It should: (1) have the functional capabilities of a mainframe computer; (2) be easy enough for a child to operate; (3) be the size of a sketch book; (4) have multi-window capability; (5) have a flat display with touch panel; (6) have the ability to draw and exhibit graphics and figures freely; (7) have a resolution high enough to tolerate newspaper letters; and (8) have a sound mechanism with the quality of a high-fidelity system (Abetti, 1992). Toshiba's design team was inspired by this concept, eventually producing the Dynabook.

This example can be expressed as a semiotic model as follows:

Inducement process:
- context — a truly portable IBM compatible PC;
- interpretation — integration of the main body, keyboard and display for real portability and ease-of-use by the customer;
- contents — Alan Key's concept, the "Dynamic Notebook".

Product development process:

- a flat LCD display;
- a 3.5 in. floppy disk drive, in contrast to the standard 5.25 in. type;
- development of specific VLSI circuits.

The above is summarized in Table 1, column 4. Therefore Table 1 comparatively illustrates how the above case examples can be fit into the framework of the semiotic model.

5. Evolutional dynamics and product innovation strategy

From the above findings we can draw the following strategically conclusive perspectives.

Product evolution takes place through the mutual interaction between conceptual evolution and technological evolution. These two processes are determined by the following three factors: (1) the socio- and techno-institutional trajectories, (2) the exploration and exploitation spin cycles, and (3) “genes”.

The socio-institutional trajectory is composed of individualism and networking. This institutional trajectory materializes into a product after passing through a semiotic inducement and product development process (context–interpretation–contents–expression) within the spin cycle. The main strategical thrust is the interpretation of the institutional context which determines the success or failure of product development. Of the three companies — Sony, Sharp and Toshiba — in our case study, Sony in particular chose to focus on the individualism trajectory. We may conclude that this is the reason Sony’s products enjoy large popularity with younger consumers. The keyword in Sony’s development strategy is “entertainment”. Sony has become adept at reading popular trends (Fig. 5) and translating these into “products that, while one may be able to live with them, make life more fun”. This is the “Sony essence”, the image that the company strives to project in developing all its products. Networking is a context common to all three companies and as a techno-institutional trajectory it is a powerful driving force behind evolution, but it has little effect on strategic differentiation.

As we have seen, the spin cycle progress from exploration–exploitation–exploration– exploitation, etc. The inducement and product development processes that are part of the exploration spin cycle are an important focus of product innovation. And the speed at which a prototype can be produced is an important strategic variable in this process. Top managers in all three companies are continually pushing to decrease the amount of time spent creating a prototype; the sooner one is released, the sooner latent needs will become apparent. In other words, moving quickly from the exploration spin cycle to the exploitation spin cycle is one important strategy.

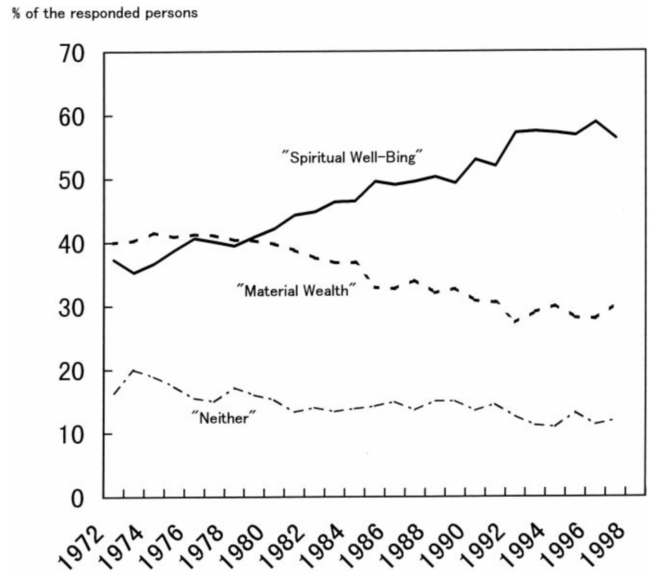

Fig. 5. Basic value system of Japanese consumers. Source: Public Relations Office, Prime Minister’s Office.

There is no such thing as producing a revolutionary product on the first attempt. For example, before developing a new product that is likely to be successful, it is often useful to first put out a decoy product; even if it fails, that will draw latent needs out into the open. In other words, we observed that it was common among all three companies to release experimental products before jumping full-scale into the development of a radical product. Such test products help pave the way for other products that are assured of greater success. With Sony’s video camera, it was the Video Movie CX-1 and CCD-V8. With Sharp’s PDA, the PV-FI served this function. And with Toshiba’s laptop PC, it was the T-400 and Pasopia 7.

Passing on the “evolution gene” from earlier products to later ones is essential to ensuring successful product innovation. One example is Sharp’s ZAURUS which inherited the LCD and other technologies from the electronic notepad, which in turn had received them from the pocket calculator. Another example of a technological gene can be observed in the progression of Toshiba’s semiconductor technology from mainframe computer–laptop PC–notebook PC. Furthermore, genes are not limited to types of technology. The experience-curve effect is another source of economic genes. For Sharp, the fact that the company produces pocket calculators, electronic notepads and PDAs simultaneously, and that all three types of products employ LCD and other common materials and parts, reduces costs through shared experience (Fig. 6). Except for core technology and key components protected by patents, however, general-use components such as CCDs are shared among rival manufacturers. This spillover reduces the competitive advantage that can be enjoyed through the experience-curve effect.

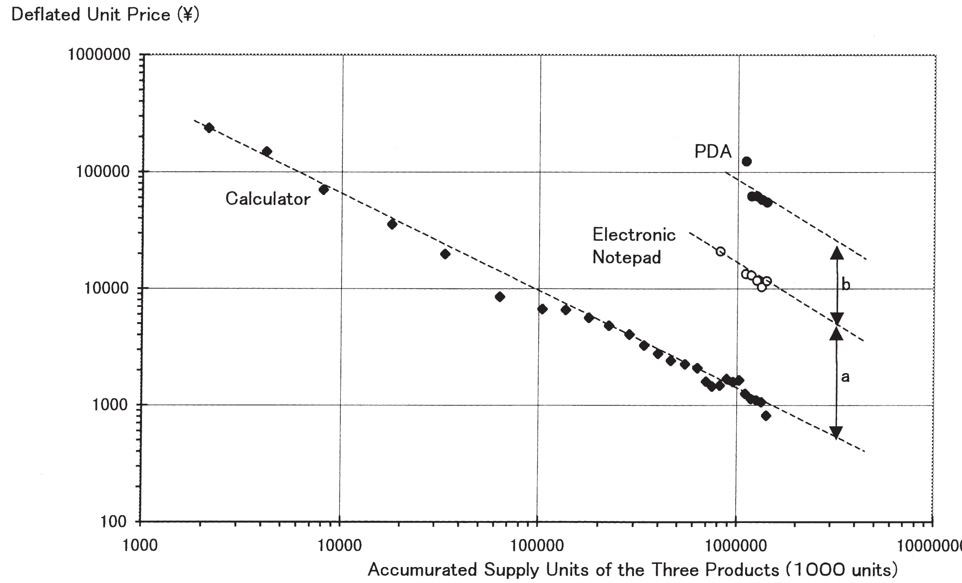

Fig. 6. Experience curves of pocket calculators, electronic notepads and PDAs in Japan (1970–1996). The distance *a* is shortened by experience shared between calculators and electronic notepads; i.e., electronic notepads are produced at a lower cost by shared experience with calculators. The same explanation can be applied to *b* and *a+b*.

As the example of Sharp's liquid crystal video camera display illustrates, a company's decision whether to keep its key components to itself or sell them on the outside is a critical decision. If they are kept within the company the experience-curve effect cannot be fully utilized and costs do not decrease significantly. But if they are sold outside costs may decrease but there is spillover. With a radical innovation, however, such a move is likely to create an entirely new market with great potential for growth.

6. Discussion

The ultimate goal of this study has been to investigate the question of how product innovation occurs on the corporate level. It is our conclusion that the key to solving this problem lies with the institutional inducement process, that is, the flow of knowledge from the institution. The foundation for this hypothesis has been both the 10 years of research into the institutional inducement process on the national level conducted by Chihiro Watanabe, one of the co-authors of this study, as well as the statements by subjects in our case studies to the effect that "the first step in understanding latent needs is perceiving the needs that lie just beyond the flow of consumer opinion". Moreover, once our conceptual framework had been formed, a similar assertion by Bill Gates (1999) and Jack Welch (Slater, 1999) came to our attention. It was Bill Gates who proposed the concept of a "consumer feedback loop" which allows producers to gage customer opinion on its products or services and then input those into the development process creating a continuous cycle.

The present topic, however, still calls for further study for the following reasons.

First, while the case studies presented here go beyond the level of simple statistical analysis, the sampling still represents just a few products in one part of the consumer electronics industry. It is necessary to broaden the focus to include other products, other companies, and other industries. A more global perspective is also called for.

Second, our characterization of the inducement process as a flow of knowledge rather than materials has made it difficult to construct a quantitative model, and so we have turned to the field of semiotics for a model. It might serve to attempt a more precise method of analysis, but we feel that this will prove difficult.

Third, in the present study we have avoided adopting an organization- or management-oriented approach, but such a perspective is perhaps essential to the goal of this research. From a management standpoint as well as an ontological standpoint (i.e., from the standpoint of how to induce innovation), such an approach becomes essential.

Fourth, a study derived from more academic interests is called for. In other words, given that the spin cycle generated by the institution inducement process of the feedback loop is an important concept both on the macro (national) and micro (corporate) levels, the interaction between the two levels, or as Koestler (1978) puts it — the dynamics of "stratified evolution", still needs to be explained and interpreted.

The authors of this study look forward to further progress in this area of research.

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