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Demand articulation in the open-innovation paradigm

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Abstract

Background: In the marketing literatures, "articulation of demand" is quoted as an important *competency* of market-driving firms. In this paper, therefore, I will demonstrate how the concept of "demand articulation" was effective in formulating corporate policies for technology and market development, and also in government policies for accelerating the commercialization process of emerging technologies.

Methods: In order to comprehend empirically what really means "demand articulation", i.e., how "market-driving" is different from "market-driven," we conducted a quantitative analysis of market growth paths in three different kinds of product categories.

Results: We came to the arguments of "business model" creation, which will bring the concept of "demand articulation" into a reality under an emerging business environment of open innovation.

Conclusions: In order for the concept of "open innovation" to be effective, the accumulation and advanced utilization of *big-data* is an absolute necessity. In other words, the combination of business model creation, accompanied by the accumulation of big data and its advanced utilization, can make the arguments of *market-driving* more plausible, and make the *accuracy* of demand articulation more enhanced. As far as business model itself is concerned, the *experimentation* and *simulation* of alternative business models becomes possible with the sheer existence of *big*-data. These are necessary conditions for IoT (Internet of Things) to be brought into a reality.

Background

A number of frameworks have been developed by scholars in recent years in order to improve analysis and understanding of systems of innovation, with implications for individual firms, industries and nations. One area of interest is the concept of *national systems of innovation* (Freeman 1987; Lundvall et al. 2014). Are systems of innovation sufficiently different from one country to another and internally coherent to justify the use of the term?

Another trend has been the increasing focus on the importance of *demand* aspect of R&D and technology in driving innovation forward. These efforts are aimed at understanding phenomena that are difficult to account for utilizing frameworks that emphasize the *supply* aspect of national R&D systems (National Research Council 1999). Indeed, in the era of "open innovation," the key issue of technology policy is not how to make possible unprecedented technological capabilities, but how to put technology to the best possible use (Chesbrough 2003). In the closed-innovation paradigm, technology policy has emphasized the supply side of development, but in the open-innovation paradigm, on the contrary, it must work on the demand side (Kodama 1992).

Sheth and Sisodia (1999), meanwhile, acknowledge that the *marketing discipline*, has generated an impressive body of knowledge over the past 75 years. This knowledge base has been founded on the widely accepted concepts and thousands of empirical studies. In the 1960s, as is well known, most markets were relatively *homogeneous*, based on a mass-production and mass-consumption society. The marketing discipline responded to this situation by developing and refining theories that centered on *customers* and *markets*. They labeled these theories as *market-centric* concepts (market segmentation, customer satisfaction), and a *market-driven* orientation. In recent years, a significant contribution to the marketing literature, however, has come from researchers studying the concept of *market orientation*. It is defined as "the organization-wide generation of market *intelligence*, *dissemination* of the intelligence across departments. They summarized that the market orientation literature's core message as "be close to your customers—listen to your customers." One of the *innovation* literature's core messages, however, is "being *too close* to the customer can *stifle* innovation." This dichotomy needs to be resolved by studying the applicability of the *market-driven* and *market-driving* mind-sets.

Many scientists, on the other hand, have recently become aware that scientific leadership does not necessarily translate into industrial or product leadership. Therefore, they begin to consider the connection between science and product (Gomory and Schmitt 1988). Usually, this connection is described as a type of *pipeline progression* in which a new technology emerges successively from basic research, applied research, exploratory development, engineering, and manufacturing (Alice et al. 1992). Gomory (1989) has called this progression the *ladder process*: the step-by-step reduction of new scientific knowledge into a radically new product. In the ladder process, a new technology dominates, and a product is created *around* it. The customers' needs are taken for granted.

Economists have also noted the intrinsic *dynamics* of technology development. Rosenberg (1976), for example, has concluded that *backward linkage* has been an enormously important *source* of technical change. He argues that the ordinary messages of the marketplace are not *specific* enough to indicate the *direction* in which technical change should be sought. Therefore, he concludes, there must be forces *outside* the marketplace that point in certain directions. Rosenberg suggests that *bottlenecks* in connected processes and obvious weak spots in products present clear targets for improvement. These become the *technological imperatives* that guide the evolution of certain technologies.

From the technologists' viewpoint, Kline and Rosenberg (1986) argues that innovation can be interpreted as a *search* and *selection* process among technical *options*. The sample population from which technical options can be drawn, however, varies over a wide spectrum of sources of innovation. In this *intricate* process, Nelson's "alternatives out there *waiting* to be found" is somewhat forced (Nelson and Winter, 1982). The most important element in technology development, therefore, is the process in which the need for a specific technology *emerges* and R&D effort is targeted toward developing and *perfecting* it.

According to Sheth and Sisodia (1999), *market-driving* firms seek to *uncover* the latent *undiscovered* needs of current and potential customers, while market-driven firms reinforce existing frameworks. Hamel and Prahalad (1991) have offered the related concept of "*leading* the customer." Indeed, it has been recently pointed out that the common view of the customer as offering marketers a *fixed* target is systematically *violated*. Rather, buyer perceptions, preferences, and decision making *evolve* over time, and competition is, in part, a battle over that evolution. Competitive advantage, therefore, results from the ability to *shape* buyer *perceptions*, preferences, and decision making.

This *market-driving* view, in addition, suggests an *iterative* process in which marketing strategy *shapes* as well as *responds* to buyer behavior. By doing so, the firm obtain a competitive advantage, which *in turn* shapes the *evolution* of the marketing strategy. Given this, we have to find a new and *accurate* way of describing the *dynamic* process of technology development. We have to give science policy administrators and research managers a *vocabulary* and a framework for talking *proactively* about the choices they must make in the high-tech environment. In this context, we have to conceptualize "a sophisticated translation skill that *converts* a vague set of *wants* into well-defined products." To do so, we will come to the concept of "demand articulation[1)]."

Now, we can define demand articulation as a dynamic *interaction* of technological activities that involves *integrating* potential demands into a product concept and *decomposing* this product concept into development agendas for its individual component technologies. Articulating demand, therefore, is a *two-step* process: market data must be *integrated* into a product concept, the concept must be *broken* into development projects. Potential demands are often derived from *virtual* markets. The fact that the technology is still considered *exotic* should not be a deterrent in setting development agendas. Sheth and Sisodia (1999) summarize that "demand articulation" is an important *competency* of market-driving firms. Most firms are more comfortable in a world of *pre-articulated* demand, wherein customers know exactly what they want, and the firm's challenge is to *unearth* that information. Firms that are able to sustain success over a long period of time, therefore, need to be market driven and market driving *simultaneously*; most corporate cultures, however, are attuned to one or the other orientations.

In this paper, I will demonstrate how the concept of demand articulation was effective in formulating corporate policies for technology and market development, government policies for accelerating the commercialization process of emerging technologies. And I will also describe a historical case in the area of the U.S. defense policy, how the shift in strategic stance had induced the emergence of the IC (Integrated Circuits) technologies.

Secondly, in order to comprehend empirically what really means "demand articulation," i.e., how "market-driving" is different from "market-driven," we will go to a quantitative analysis of market growth paths in three different kinds of product categories. Finally, we will go to the arguments of "business model" creation, which will bring an idea of "demand creation" into a reality even under an emerging business environment of open innovation.

Case studies on LCD in Japan and United States

The importance of *demand articulation* in technology and market development of commercial products is best *illuminated* by investigating a half-century long history of Liquid Cristal Display (LCD) technology and its market development both in Japan and United States.

Although Europeans discovered liquid crystals phenomenon more than a century ago, the basic idea of using them in display devices came about only when RCA (Radio Cooperation of America) invented the dynamic scattering mode (DSM) in 1967.

Thereafter, RCA demonstrated various prototype products.[2)] All the products, however, were *premature* given the then-available technologies, and RCA gave up on the commercialization efforts. At the time RCA was trying to commercialize liquid crystals, the standard for display technology was the *cathode-ray tube* (CRT). A flat panel display was nothing more than a *dream*, and other technological alternatives to liquid crystals existed, including electroluminescence and plasma display. Manufacturers agonized over which to use. Since RCA developed liquid crystal technology as a display method for *general* purposes, it chose to stick with CRT technology, as did most manufacturers of CRT screens.

On the other hand, Sharp followed a *demand approach* when it translated the customer's *desire* for a more powerful and sleek electronic *calculator* into a set of specific R&D projects for a thinner, lower powered, easy-to-read display. These R&D projects included research in LCDs and in low-powered complementary metal oxide semiconductors (CMOS). Sharp was quick to identify the liquid crystal display as a *promising* technology, and the fact that the technology was still considered *exotic* was not a deterrent. Instead, Sharp saw LCDs as a way to solve *specific* technical problems and change the rules of competition in the marketplace.

Generally speaking, demand articulation flourishes when an industry is very competitive and technically sophisticated. Brisk competition, almost to the point of excess, motivates companies to keep their attention on the customer. And the more technically competent the industry is as a whole, the higher the *absorption* rate of technologies from other industries. In the case of Sharp, indeed, the competition included the likes of Hewlett-Packard and Texas Instruments, both pioneers in electronics. Such a competitive environment spurred Sharp to *experiment* with alternatives that it probably would *not* have explored had the competition been less intense.

Ever since Sharp introduced an electronic calculator into market in 1964, the market for electronic calculators flourished and many companies entered in this growing market (Numagami 1999). Around 1971, however, when Texas Instruments started supplying the standard chips for calculators in open market, many small-sized manufactures that have assembling capacities only but have no design abilities, suddenly appeared in the Japanese market. This market entrance had reduced the market price of calculators suddenly and drastically. Existing larger manufacturers of calculators were involved into the price-cutting competition, and some of them had left the market. Sony and Uchida left in 1973, Bisicon and Sigma Electronics did in 1974, and so did Ricoh in 1975. Even the market share of Sharp decreased dramatically.

It was in this context that *LCD* was introduced into the electronic calculators for the first time, namely in circumstances of such a price-cutting competition. Responding to that situation, Sharp introduced the LCD-based calculators in 1973 in order to bring a *functional* differentiation, while other remaining competitors continued to introduce cheaper products. By making the product much thinner and reducing the cost by the mass production, Sharp succeeded in differentiating their products from those by small-sized manufactures. This change in Sharp's strategies can best demonstrated by the rapid decrease in thickness from 1973 to 1983, as shown in the Fig. 1. As shown in the figure, the thickness of 1976 Sharp product was more than 2 cm, four years later in 1979, however, it became less than 1.6 mm. As a new comer, Casio reduced the thickness of their product to

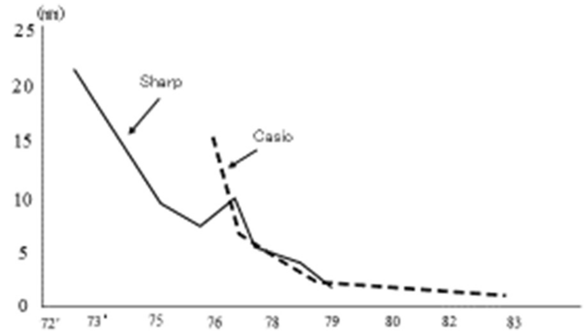

Fig. 1 Changes in thickness of calculators (1973–1983)

0.8 mm in 1983 from 1.5 cm in 1976. They named their products as "pocket calculator[3)]."

Under the severe cost-cutting competition, indeed, Sharp chose to adopt a radical innovation in spite of letting their products higher priced. By these decisions, Sharp could overcome the difficulties, and keep a stable market position. We can summarize that Sharp was successful in *articulating* the demand for the *pocket* calculators, by developing and bringing the LCD technology into market in a right timing. In adopting LCDs in its calculators, Sharp not only achieved effective demand articulation for the technology, but subsequently became the technology and market leader in LCDs. During the 1970s and 1980s, Sharp and other Japanese companies made a number of improvements in LCDs, and they are now a widely used high value added component of portable electronic products such as laptop computers.

When we entered into 2000s, however, the process of demand articulation is getting a little more *subtle*. For the Apple Co. and its founder, Steve Jobs, in particular, the *practice* of demand articulation was taken for granted (Cupertino Silicon Valley Press, 2011). However, it seems me that they went far beyond the demand articulation practice. Jobs is quoted to have thought: first was the *mouse*. The second was the click *wheel*. And now, we're going to bring *multi-touch* to the market in each of these revolutionary products (the Mac, the iPod and now the iPhone). I actually started on the tablet first. I had this idea of being able to get rid of the keyboard, type on a multi-touch glass display. This is in the early 2000s. In the moment of multi-touch technology, he is quoted as saying:

> So let's not use a stylus. We're going to use the best *pointing device* in the world. We're going to use our *fingers*. We're going to touch this with our fingers. And we have invented a new technology called *multi-touch*, which is phenomenal. It works like magic.

A good evidence for demand articulation can be summarized by the following quotation. Some people say, "Give the customers what they want." But that is not only my approach. Our job is to figure out what they're going to want before they do. I think Henry Ford once said, "If I'd asked customers what they wanted, they would have told me, "A faster horse!" People don't know what they want *until* you show it to them.

That's why I never rely on *market research*. Our task is to read things that are not *yet* on the page.

National demand articulation for VLSI in Japan and United States

The concept of demand articulation becomes even more powerful when a national technology policy is analyzed. The government-sponsored research consortia both in Japan and the United States, best illustrate demand articulation at the *national level.* This suggests that national policy can be discussed better using the concept of a "national system of demand articulation" rather than the oft-cited concept of a national system of innovation (Nelson 1993).

As a technology shifts from the defense sector to the civilian sector,[4)] particularly the development of manufacturing technology becomes more important because cost is a critical factor in the civilian sector. Furthermore, as the shift to civilian sector occurs, many companies in different industries become involved in bringing the new technology into the consumer-products market, while only a few selected, technological elite companies are involved in the defense sector. In other words, the policy agenda shifts to building a national manufacturing infrastructure. Many companies, in different industries, indeed, were involved in bringing the integrated circuit (IC) technology from the defense sector into consumer-products market. In Japan, the government played a significant role in this transition by organizing a research association for very large scale integration (VLSI) development. When first formed, the association included all of Japan's major IC chip manufacturers, who then *articulated* their demand for manufacturing equipment for chip-making. In this way, an internationally competitive infrastructure was established (Oshima and Kodama 1988).

In the case of IC technology, the Japanese government, particularly MITI played a significant role in the creation of this infrastructure. In 1976, MITI orchestrated the establishment of the ERA (Engineering Research Association) for VLSI development. The association existed from 1976 to 1979 and spent a total of 73.7 billion Japanese yen, of which 29.1 billion yen was paid by the government on a project funding basis. Members of the association were Fujitsu, Hitachi, Mitsubishi, NEC, and Toshiba. Although we originally developed the concept of demand articulation to analyze the development processes conducted by a single firm, the dynamic process of collective action by rival firms creates the functional equivalent of demand articulation in a single firm. We can call this *collective articulation of demand*.

The collective articulation of demand, therefore, should be viewed in and can be explained by the overall framework of industrial technological linkages. It can assist in creating a national technological infrastructure. Sometimes it results in establishing upstream technological linkages. Indeed, the association for VLSI development made possible *demand articulation* for manufacturing equipment for chip making. The five member companies established a joint research laboratory within the association. The laboratory had about 100 researchers who were drawn from the companies and from Electro-Technical Laboratory (ETL), one of Japan's national research institutes. Approximately 20 % of the research was carried out in this joint research laboratory; the remaining 80 % was done by the individual companies in their own laboratories with an association steering committee as a coordinating body.

A great deal of the research and development carried out in the joint laboratory, was also *subcontracted* to supplier companies that were not members of the association, e.g., camera manufacturers, silicon crystal suppliers, and printing companies. Although cooperative research sounds good in theory, it is often difficult in practice. In joint research by rival firms in the same industry, in particular, success hinges on ensuring that the research is *basic* and of *common* interest to all the participants. Therefore, rather than focusing on the method of producing chips, the association centered its research efforts around developing a *prototype* for IC manufacturing equipment and analyzing a process for the crystallization of silicon, a basic material in chip production[5)]. No manufacturers of production equipment or chip materials were among the participants. Figure 2 depicts the major actors involved in the Japanese development of VLSI and the technical linkages between them (Sigurdson 1986).

A pervasive *uncertainty* not only characterizes basic research, where it is generally acknowledged, but also the realm of government-sponsored development projects. Consequently, as Rosenberg (1994) asserted, the pervasiveness of uncertainty suggests that the government should ordinarily *resist* the temptation to play the role of *champion* of any one technological alternative. He argues, therefore, it would seem to make a great deal of sense to manage a *deliberately diversified* research portfolio, a portfolio that is likely to illuminate range of alternatives in the event of a reordering of social and economic priorities.

In this context, the power of demand articulation in research consortia had been manifested most vividly in *exploring* all the spectrum of possible equipment technologies.[6)] It used to be a mainstream method to let the mask of circuit-diagram contact directly the wafer and print on it. When the micro-manufacturing progressed further, a new idea emerged. The original circuit-diagram is projected through the *lens* on the wafer by reduction *ratios* of one-tenth or one-fifth. In actuality, the wafer moves *stepwise* in four directions, while the mask stays in a fixed position. This equipment has become called as “stepper.”

In the beginning of the ERA for VLSI development, the other two methods than the stepper, i.e., direct printing by electron beam, and X-ray lithography, had already been

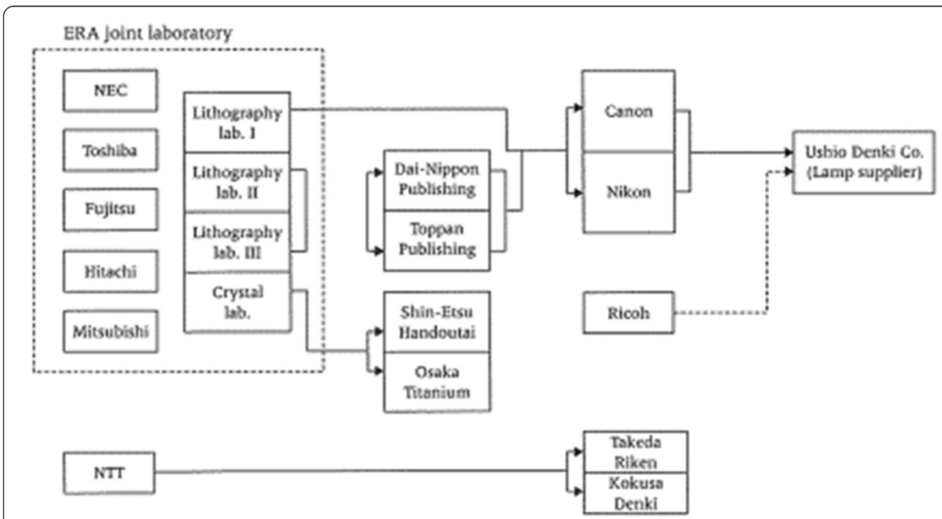

Fig. 2 Upstream Technical Linkages in Japanese VLSI Development

much advanced and their prototype had been existent. Therefore, the stepper was assumed as the *third* candidate for safety reasons after these two methods. None could deny this *priority*, because no one did expect the lens technology that print *40* lines on the *width* of a hair. What makes steppers into multi-million-dollar pieces of sensitive equipment is the need to maintain focus within a fraction of a micron and to control the wafer's position with similar accuracy. Therefore, steppers use the sophisticated optical feedback mechanisms and the stringent control to keep the conditions across the surface of the wafer as uniform as possible.

Meanwhile, Mr. S. Yoshida (2007), who later became the CEO of Nikon Co., had been confident on *three* kinds of critical technologies which made the "stepper" competitive: ultra-high resolution lens; the staging technologies moving the wafer; and, the censor of photo-electric tube. As to the high resolution lens, Nikon had developed a commercial hit product, which was about to be procured for lens of photo-mask manufacturing, specified both by domestic and overseas producers. As to the staging technology, Nikon had an experience to provide Tokyo University's astronomical observatory with the staging mechanism for precise positioning of the telescope.

Indeed, the specific activities of the association included the development of the lithography. One of the association's lithography laboratories contracted the research necessary for the development of the lithography to camera manufacturers that owned the lens technology. Thus, companies such as Nikon and Canon succeeded in the development. Before Nikon produced the first prototype of stepper, a U.S. precision machinery giant, GCA Corporation, had already succeeded in commercializing the stepper. Through the development process described above, the "stepper" has become a mainstream in the equipment for semiconductor manufacturing. After ten years of demand articulation efforts, which were initiated by the VLSI association, Japanese companies in the upstream sector of chip manufacturing are beginning to emerge as dominant players in world production. Because we have said that collective demand articulation can create a national engineering infrastructure, we need to consider *second-tier* suppliers (Kodama 1995). The suppliers of steppers, first-tier suppliers, were not the only beneficiaries of the joint effort. The real beneficiary was a second-tier supplier. Ushio Denki, the supplier of the lamp used for the optical stepper (see Fig. 2), ended up dominating the world market for lamps. In 1983, Ushio had a market share of 100 % for aligner lamps in Japan and 50 % for the global market.

We will demonstrate that the concept of demand articulation was evident and visible beyond the national border in organizing the research consortia, by investigating the brief history of SEMATECH (Semiconductor Manufacturing Technology) consortia which was established in 1987. During the early and mid-1980s, the U.S. semiconductor industry lost about half of its global market share—particularly in memory chips—to Japanese integrated-circuit producers. The decline in semiconductor manufacturing equipment by domestic makers was equally drastic. That was the background against which the principal American chip manufacturers organized the SEMATECH consortium to foster research and development on advanced semiconductor technology. SEMATECH is one of hundreds of consortia that have been ever organized since the 1984 passage of the National Cooperative Research Act, which gives companies engaged in cooperative research and development partial *exemption* from *antitrust* laws. Fearing that the integrity of the U.S. defense apparatus was threatened by a growing dependence on foreign semiconductors, the federal government agreed to contribute $100 million annually to SEMATECH's operations.

After struggling unsuccessfully for more than a year to organize a research program suitable to its diverse membership, the consortium decided that the best opportunity it had to aid the U.S. semiconductor industry was *not* to emphasize *direct* cooperation between its members but rather to concentrate on improving the *position* of the domestic companies that make semiconductor manufacturing *equipment*. The consortium focused in particular on *lithography* technology (Randazzese 1996). The U.S. share of the lithography market had slid from 71 % in 1983 to just 29 % by 1988. Most of the dramatic decline was accounted for by GCA Corporation. In the late 1970s GCA had invented the step-and-repeat (or stepper) technology that soon became the workhorse of the semiconductor manufacturing industry. A global downturn in the semiconductor manufacturing equipment industry and the rapid emergence of Japanese competition brought GCA to the brink of bankruptcy. In March 1988 GCA was bought by the General Signal conglomerate. Despite the highly visible failure of GCA[7)], the years since SEMATECH was founded have seen an improvement in the competitive position of the U.S. semiconductor industry. In 1993 American companies captured 43.4 % of the global semiconductor market, *surpassing* the Japanese share for the first time in eight years, and U.S. semiconductor manufacturing equipment companies once again held 50 % of the global market, compared with Japan's 42.9 %. Something of a consensus has emerged that SEMATECH deserves much of the credit for these gains, even though a number of other factors contributed to the recovery.[8)]

According to Randazzese (1996), SEMATECH's greatest accomplishment was probably not its technical achievements by themselves but rather its role in improving *relations* between chipmakers and their suppliers. Once almost *antagonistic*, these companies are now *cooperating* closely. Observers have universally considered these accomplishments, along with the consortium's ostensible contribution to the fortunes of the U.S. semiconductor industry, as the gauge to measure SEMATECH's success as a model for public policy[9)]. I would argue, the demand articulation had directly or indirectly made these changes possible in the relations between chipmakers and suppliers of the United States.

Demand articulation in the US defense sector

In the defense sector, the concept of demand articulation is effective for describing how product development challenges at the component and systems levels are addressed in the integrated manner. One important historical case is the impact that shifts in U.S. strategic defense policies had on technology development in the 1950s and 1960s. The shift from a strategic stance emphasizing "massive retaliation" in the Eisenhower Administration to the Kennedy Administration's goal of achieving capabilities for "flexible response" put a *premium* on precision *delivery* of nuclear weapons, and highly survivable systems, including missiles and command and control systems (National Research Council 1999).

According to a study carried out by the OECD (Organization for Economic Cooperation and Development), prior to the development of integrated circuits (IC), program sponsored by the US Department of Defense were driven by technology rather than by the *need* for a technology. In the case of the IC, however, the US Government *articulated* and *shaped* the problem which the innovative candidate technology was required to address. The resulting "articulated demand" for miniaturization and reliability in missile control systems went beyond what was possible using *vacuum tubes* or *transistors*, the available technologies at the time. Although they did not receive direct government funding for their work, Texas Instruments and Fairchild *responded* to this military demand in developing the first IC (OECD, 1977).

The dynamic and interactive relationship between defense strategic changes and technology developments have been studied by the author of this paper, by comparing the strategic changes around the concept of "containment" with the chronologies of IC related innovations. Gaddis (2005) summarizes his study of changes in "containment strategies," as follows: It would not be until the Kennedy administration that awareness would begin to develop of "the basic *unsoundness* of a defense posture based primarily on weapons *accidentally* destructive and *suicidal*[10)] in their implication." The chronological details of the relationships studied by the author follow.

- Immediately after the WW. II, *Truman's strategy* would have required *readiness* to fight everywhere, with old weapons and with new weapons.
- In 1951, the military services sponsored an effort to *improve vacuum tube* circuitry. The *reliability* argument was even more persuasive for *missiles.* The *first* major effort specifically in the *miniaturization* mode was "Project Tinkertoy," to miniaturize and *completely automate* the manufacture of selected electronic components.
- Texas Instruments (TI) initiated an *in-house* program to seek basic *new* directions. By mid-1953, the first IC, i.e., electronic components indivisibly *embodied within a semiconductor-material*, was demonstrated by TI.
- The Secretary of State in the Eisenhower Administration, John Foster Dulles, explained how *strategic initiative* could be combined with *budgetary restraint*. It could be done by relying on the deterrent of "massive *retaliatory power*." We would be willing and able to *respond vigorously* at *places* and with *means* of its own *choosing*.
- In 1958, the Air Force suggested a concept dubbed "molecular electronics." With much fanfare the Air Force awarded a contract to *Westinghouse.* The molecular electronics concept *per se* proved quite controversial and *did not achieve* its goals. However, it did *sensitize* the U. S. semiconductor components industry towards *new directions*.
- Kennedy, possessed of an economic rationale for disregarding costs, placed his emphasis on minimizing *risks* by giving the United States sufficient *flexibility to respond* without either escalation or humiliation*.* He declared, "we believe in maintaining effective *deterrent strength*, but we also believe in making it do *what we wish*, neither *more nor less*."
- Texas Instruments was awarded an Air Force contract. It built a *computer using* IC components. It offered *impressive advantages* and, served as a *showcase* vehicle to illustrate the IC's potential utility. TI's contract called for the construction of an *IC pilot line* of turning out *500* integrated circuits per day for ten days. It was a *reinforcement* of the IC *idea*, moving it one more step towards *reality.*

- The *Minuteman* contract to *utilize ICs* was announced, publicly stating that the advanced version of the ICBM (Inter-continental ballistic missile) would use these new components. Its orders were the largest IC *purchases*.
- NASA (National Aeronautics and Space Administration) announced that it intended to use *IC devices* for its *Apollo* mission. NASA would *test the IC components* to ensure the fulfillments within the very rigid constraints of the Apollo program.

The OECD study concludes: Although the two basic patents and key technological contributions that underlie IC technology in the United States were made by private companies *without* government support, these fundamental innovations were achieved because both companies sensed the needs of their various customers, present and hoped-for. These customers, however, were drawn mainly from the government via its military interests. Thus, although government influence helped create the landscape these companies viewed, it did not *dictate* the nature of the technological *route* to be taken. The need was *articulated*, the *means* to satisfy it was *not*. In short, breakthroughs were brought about by the in-house R&D efforts of those companies that responded to the *articulated* demand of the military (OECD, 1977).

Methods

Empirical evidences of market-driving growth path

In her book on the history of Internet, Abbate (1999) summarizes its history as follows: Computing technology underwent a dramatic transformation. The computer, originally conceived as an *isolated* calculating device, was *reborn* as a means of communication. When computers were scarce, expensive, and cumbersome, using a computer for communication was almost *unthinkable*.

Innovations that occurred in the PC, therefore, created new ways of using one after another. In other words, the PC (Personal Computer) technology created new *systems-of-use* (Christensen and Rosenbloom 1995). The drastic innovations that had occurred in *printer* technologies, meanwhile, seems to have produced the implications slightly different from the innovations occurred in PCs. The printer was used only as a machine for outputting character-based information on the paper during the 1960-1970s. It was also mainly used for business purposes. When *laser* and *inkjet* printers entered the market in the mid-1980s, the printer market expanded drastically as personal use began. There were two reasons for the expansion of the market for personal use. One was the ability to deal with high-resolution images and the other was the introduction of color printing.

In this context, we can interpret that new technologies related to the printer greatly widened the *scope of usage*. However, the commercialization of new technologies was conducted within an *existing* framework, i.e. printing on the paper. I would argue, therefore, that the printer did not necessarily create new system-of-use as had happened in PC case, although the nature of innovation in these products can be best described as “radical breakthrough,” in terms of a drastic widening scope of usage. It is now clear, however, that both printer and PC technologies did produce the “market-driving” pattern instead of that of “market-driven,” if we use the taxonomy proposed by Sheth and Sisodia (1999).

Now we will move to how different those two patterns of market-driving growth are empirically and quantitatively. Foster (1986) had once formulated the difficulty in managing technological discontinuities as the movements from one technology to another with *inherently* higher upper limits. When it comes to the market-driving growth of products, such as printers and PCs, therefore, it is reasonable to think that the product's potential market size could be increased by new value being added by technological innovation of the product during the period of diffusion. Now, we are interested in *visualizing* the differences in growth pattern between printers and PC technologies as well as the difference between market-driven and market-driving growths (Osaki et al. 2001); Kodama (2004)). Sharif and Ramanathan (1981) proposed a market-growth model in which the potential adopter (upper limit) increases over time in the following three different models:

Model A: Potential market size does not change (simple logistic model)
Model B: Potential market size increases stepwise (N-step logistic model)
Model C: Potential market size increases continuously (binomial logistic model)

The market growth data had been collected for Televisions (yearly production data: 1956–1980) as the example of the ordinary market-driven growth pattern (model A) for the reference case of our market growth study. As far as the case of market-driving growth (model B and C) is concerned, those market growth data were collected for Printers (monthly production data: 1983.01–1998.08) and PCs (monthly production data; 1987.01–2001.06). To identify the market growth patterns for these three product categories, we conducted the statistical fitting of these three kinds of growth models described above.[11)]

We confirmed that the growth trajectories of three different products followed the three different paths: Televisions identified best as following the simple logistic curve, where the upper limit does not change, as seen in Fig. 3. In retrospect, this result is a good quantitative evidence that the demand for televisions had been *pre-articulated* from the beginning and the essence of this demand did not change all through the time period studies.

The growth pattern of market-driving products, as we can reasonably imagine, are found to follow the S-shaped curves where the upper limits also increase. The market growth for printers, turns out to be identified best as following the two-step logistic model (model B), as shown in Fig. 4. As seen in the figure, a *stepwise* expansion of the potential market size is estimated to have occurred in 1987. Indeed, laser and inkjet printers entered the market in the mid-1980s. Based on these facts, we can generalize that "breakthrough" innovations such as laser and inkjet printers, might be measured by a *stepwise increase* in potential market size.

Our findings concerning *printer* innovations described above, indeed, coincide with the following assertions by Anderson and Tushman (1991): the notion of a series of S-curves suggests, an industry evolves through a succession of *technology cycles*. Each cycle begins with a *technological discontinuity*. Discontinuities are based on new technologies whose technical *limits* are *inherently greater* than those of the *previous* dominant technology.

Apart from the results on printer innovation, the market growth path of PCs, we find, is identified best as following the *binomial* logistic model (model C), where the upper

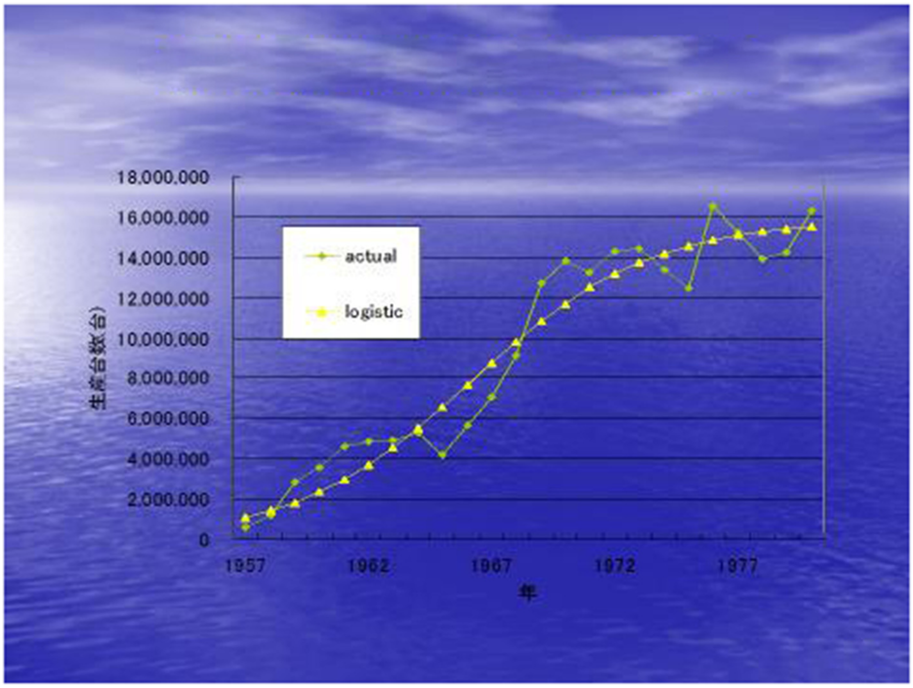

Fig. 3 Graphical representation of curve fitting (TV)

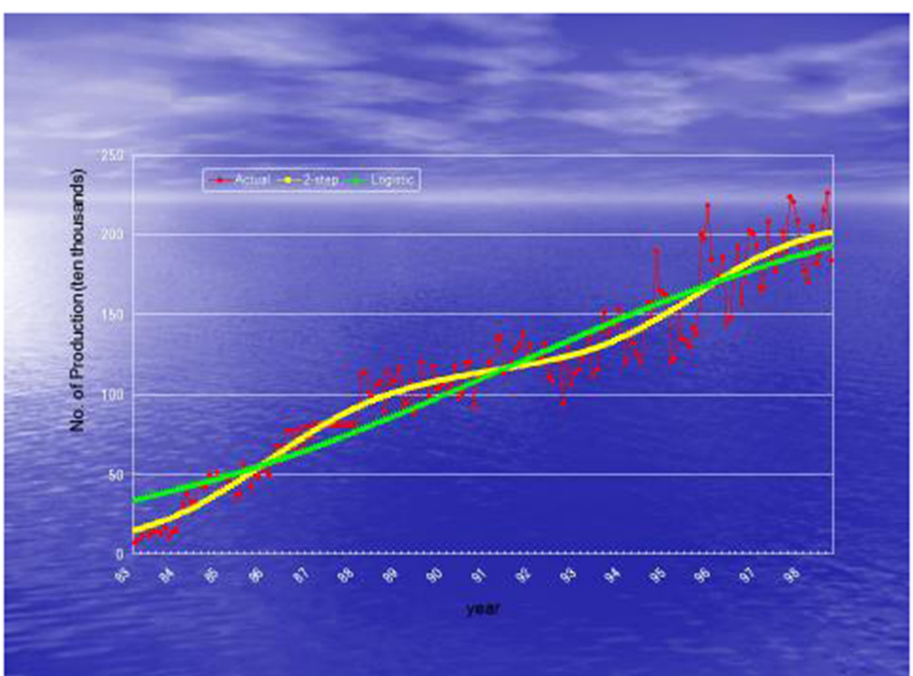

Fig. 4 Graphical representation of regression analysis for printers

limit of the potential adopters *continuously* increases, by following also a logistic curve (we might call it "*double*-logistic" curve), as seen in Fig. 5. This is very different from the patterns of discontinuous innovations. Indeed, a kind of consensus has recently arrived among several recent empirical studies on what is a real implication about the creation of "business model." (Ritala and Sainio 2014; Tongur and Engwall 2014; Mason and Leek 2008), They describe: dynamic business models represent *continuous* change and therefore make firms learn *constantly* new and better ways of doing things.

In commercializing new technologies, moreover, Chesbrough and Rosenbloom (2001) argued that a new *business model* is required to commercialize a *disruptive* technology. They also argued that *new* technology creates only a little *disruption* if the business model of the related industry has not changed much. The printer technology is one such example that comes to mind immediately.

To summarize, we discovered the PC did continuously create new systems-of-use one after another. In other words, technical progresses in the PCs created new *business models* in terms of utilization of these innovations (Kodama 2004). This is equivalent to description by Abbate quoted in the first paragraph of this section: the computer, originally conceived as an isolated calculating device, was *reborn* as a means of communication.

Results and discussion

Innovation Spiral and Business Model

It is widely held that a "new economy" is emerging, one in which conventional wisdom about the innovation process becomes obsolete. Since "new economy" can be easily translated into "digital economy," we have to think about what is new about the "digital economy. In this context, the author of this paper was quoted by saying: In the analogue world, things cannot be easily combined. However, with digitalization, all sorts of combinations

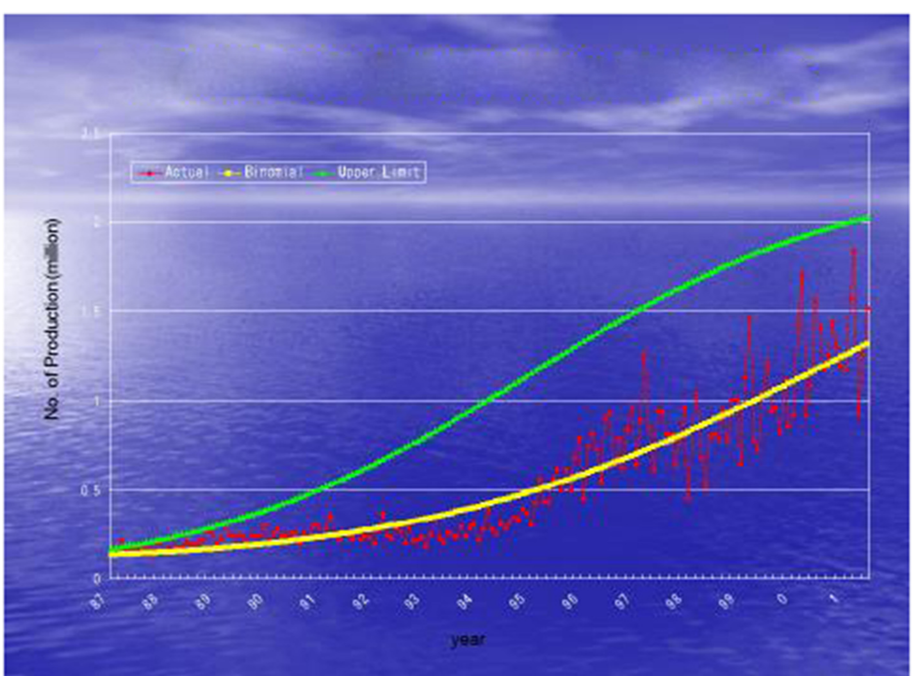

Fig. 5 Graphical representation of regression analysis for PCs

are possible and we can end up with something greater than the *sum* of the merger (Newsweek, 1999). In the age of digital economy, therefore, I would argue that the emergence of a new *business model* can be a source of discontinuity and disruption as well as that of technical breakthrough innovations (Kodama, 2000).

In inventing iPod, for example, Steve Jobs (Cupertino Silicon Valley Press, 2011) is quoted as saying: What's really interesting is if you look at the reason that the iPod exists and that Apple is in that marketplace, it's because these really great *Japanese consumer electronics companies* who kind of own the *portable music* market, invented it and owned it, couldn't do the appropriate *software*. In the revolution of portable music, therefore, I would argue, the Sony's *Walkman* was obviously a technical innovation derived by the notion of demand articulation. It was based on Sony's sophisticated translation skill to convert a vague sets of distant human wants into welldefined product concept, i.e., "portable music." And it is also based on Sony's product development skills to decompose the concept into a set of development projects. This decomposition was feasible by mobilizing all of the Sony's competencies: recording and delivery of music, owned by Sony Music Co.; and, the various audio technologies owned by Sony Corporation, like regenerating the recorded music by tapes or CDs, good earphone technologies, and etc. In any way, Sony completed the *first* cycle of portable music.

According to Anderson and Tushman (1991), an industry evolves through a succession of *technology cycles*. Each cycle begins with a discontinuity based on new technologies, along economically relevant dimensions of merit. In each case, a process with inherently higher limits redefined the state of the art, increasing machine capacity by an order of magnitude while lowering costs and improving quality. To sum up, each discontinuity *inaugurates* a new cycle. And the iPod innovation by the Apple inaugurated the *second* cycle of portable music. Steve Jobs is again quoted as saying: Our idea was to come up with a music *service* where you don't have to subscribe to it. You can just buy music at 99 cents a song, and you have great digital – you have great rights to use it. As is clear in this quotation, it is based on a breakthrough in *system-of use*, i.e., creation of new business model. This is easy to understand if we give some thoughts on what kind of core competencies are owned by Apple, compared with Sony, in terms of physical technologies related to the portable music. Therefore, we might generalize: while a breakthrough in technology starts the *first* cycle, a breakthrough in business model will inaugurate the *second* cycle.

We can further generalize this satement. Although the iPod example is characterized as B2C and IT innovation, however, we are now interested in a case characterized as B2B and IoT (Internet of Things). A Japanese construction machinery supplier, Komatsu Co. Ltd., turned out to be the first company which introduced disruptive technologies such as RFID (Radio Frequency Identification) and GPS (Global Positioning System) for development of building lots, and now is a market leader in construction businesses (Nikkei Business, 2007). In this system, RFID sensors are inserted inside their machines that are operating all over the world and all the data about their operating conditions are sent to Komatsu headquarters in Tokyo via *satellite* communication. The system Komatsu developed is called "KOMTRAX" system. They started its operation in 2001.

The development of KOMTRAX, however, was not as straightforward as we can imagine. In the mid-1990s, the country's investment in construction business fell down significantly. Facing this reduced investment, companies had to revise the ways in which machinery was procured. This meant a shift away from ownership to *leasing* and *rental* (21 % of machinery was either leased or rented by 1993, 30 % by 1997, and 40 % by 2006). In 1997, Mr. Masahiro Sakane (later became CEO of Komatsu Co. in 2001) was appointed as director of the business planning and administration office. At the time, this office was staffed by people dispatched from various divisions. At the end of 1997, the office had received a business plan of 10 pages long, from engineers dispatched from the development department. This plan was for a *business model* for remotely monitoring machinery, which was in effect the prototype of KOMTRAX system.

Having spent a long time in the service department, Mr. Sakane had a deep appreciation of the *intricacies* of managing construction machinery maintenance, and hence understood well the value and potential of the KOMTRAX system (Nihon Keizai Newspaper, 2014/11/24), and thus this idea proceeded into the development stage. In this regard, the KOMTRAX development was initiated as a kind of local project using the funds provided by the business planning and administration office. The company completed 5 prototypes by 1998, and asked Mr. Chikashi Shike of the "Big Rental" (a rental company at Koriyama in Fukushima prefecture), which had only started up in 1997, to test the 5 prototypes. At that time, Mr. Shike had been also thinking about a brand-new rental business model that entailed using IT for centralized management to raise the utilization rates of rental construction machinery, and because this remote construction machinery monitoring system fit well with his idea, Shike agreed to take on the prototypes for testing. Being engaged in a rental business, Mr. Shike had no difficulties in understanding the *inherent* value of KOMTRAX system[12)].

At the end of 1998, it was suggested at Komatsu that *fifty* pieces of equipment should be subsequently tested. However at a development meeting, supervising executives took a negative view regarding continued testing. At that meeting, meanwhile, Mr. Shike was asked for his opinions about the commercial advantages of developing the remote monitoring system. Shike explained that the system was a piece of remote communications infrastructure, and thus it is not appropriate timing to discuss in details what sorts of businesses would be enabled by it.[13)] Unfortunately though, it was decided that the remote monitoring system development should be cancelled. The Komatsu development team had not been able to *draw* a picture of a business model using KOMTRAX, because they did not have an understanding of its *inherent* value.

Nevertheless soon after that Mr. Shike, who had understood the value of KOMTRAX, wrote an order for 1,000 units and paid Komatsu 150 million Japanese yen (JPY) – an order made despite of Big Rental's having only 500 pieces of rental construction machinery at the time. In those days, KOMTRAX units were externally attached and cost 150, 000 JPY per unit. Thus, such a large order made KOMTRAX a viable business, and so development was continued within Komatsu. In the beginning of 2000, the Big Rental grew rapidly and within 3 years became the *top* rental company in Fukushima prefecture. Shike quickly *refitted* all the Big Rental's construction machinery with KOMTRAX units as soon as the units arrived from Komatsu. The product originally consisted of a communications terminal and modem, GPS and a simple CPU etc.

The capabilities and advantages of KOMTRAX in remote management of machinery and in work on construction sites, became widely known gradually. Komatsu Co., meanwhile, filed the *business model patent* for rental businesses so that that ways KOMTRAX could be used in a rental business. At that time, KOMTRAX was known as a business model for rental businesses, and was only available as a user option. In June 2001, Mr. Sakane has become the CEO of Komatsu company. He had aggressively pursued the possibility of utilizing KOMTRAX, not only as a tool for customer service, but also as a tool for *visualizing* the corporate management (Sakane 2006).

By establishing the KOMTRAX system, Komatsu headquarters has obtained and access to all the data about operation conditions of all the Komatsu machines installed all over the world. In fact, these collected data are effectively utilized for discussion on *demand forecasting* being conducted at the headquarters. Based on this demand estimate, headquarters formulates production *schedules* and equipment *investment plans* at each factory. In 2004, for example, the Chinese economy was in *downturn*, due to the financial policies then implemented by the government. The collected data by KOMTRAX system showed clearly that the operating ratios of their machines were abnormally low in China. Komatsu halted production three months before the demand reduction was officially announced by a Chinese government agency. This gave Komatsu an enormous advantage.[14)]

A cyclical process of research, development, production, and distribution is called an *innovation cycle* (National Research Council 1983). Now, we have learned that the *second* cycle of innovation related to B2B and to IoT, is triggered by the new *business model* creation rather than by technological discontinuity. On the basis of this experiences both in B2C (iPod innovation) and B2B (KOMTRAX invention), I would suggest that the innovation cycle in the open innovation paradigm, becomes a *spiral innovation model* with three-dimensional cycles[15)]. Our review of the history of the second *spiral* of B2C and B2B case studies, I would argue, revealed that the trigger at each stage came from different fields of knowledge areas. Furthermore, each time a change in sources of innovation occurred, dramatic upgrading in the inherent value (higher upper limit) of innovation was accomplished.

In a spiral model of innovation, therefore, “demand articulation” is effective in starting the *first* spiral. When it comes to the *second* spiral, meanwhile, this wording had better be replaced by a term which is more *proactive* than the demand articulation by itself (Kodama 2000). Having described so far new phenomenon and new research findings, I would suggest that “articulation of demand” should be replaced by “creation of a new business model,” in the second innovation spiral, i.e., in particular, in the process of “open innovation.”

Conclusions

Chesbrough (2003) once concluded that technology by itself has no single objective value. The economic value of a technology remains *latent* until it is commercialized in some way. The value of an idea or a technology depends on its *business model*. There is no inherent value in a technology *per se*. The value is determined instead by the *business model* used to bring it to market. An inferior technology with a better business model will often defeat a better technology commercialized through an inferior business model.

Is this statement valid without any reservation? Let us review again what had happened to emergence of KOMTRAX system, from different standpoint than the simple creation of a business model. In the case of the Komtrax system in construction industry, the introduction of ICTs (Information and Communication Technologies) provides the machinery suppliers with drastic widening in the range of service activities and also enhances service quality. When it comes to innovation in corporate decision-making, a quantum leap in business activities was attained by utilization of *big-data* provided by the Komtrax system. This had not been originally intended nor planned since it is obvious that the Komtrax system was developed mainly for the improvement of after-sales activities by construction machinery providers as well as a rental company of this machinery. This prototypical case of the enhanced use of big-data available through the one-line and world-wide aggregation of operation data of their machinery being used, however, might trigger improvements in the quality of corporate decision-making countrywide. Indeed, the potential demand for this type of utilization of big operation data of construction machinery does exist in any company in any industrial sector.

In order for the concept of "open innovation" to be effective, the accumulation and advanced utilization of big-data is an absolute necessity. In other words, the combination of business model creation, accompanied by the accumulation of big data and its advanced utilization, can make the arguments of *market-driving* more plausible, and make the *accuracy* of demand articulation more enhanced. As far as business model itself is concerned, the *experimentation* and *simulation* of alternative business models becomes possible with the sheer existence of *big-data*. These are necessary conditions for IoT to be brought into a reality.

Endnotes

1) According to Webster's dictionary, articulate comes from the Latin articulare. The word "articulate" has two conflicting meanings: (1) to divide into parts; and (2) to put together by joints. Thus, the word encompasses two opposite concepts: analysis (decomposition) and synthesis (integration). In fact, both are necessary in technology development, and the heart of the problem concerning technology development is how to manage these conflicting tasks.

2) Included are: a device displaying numerals and letters, a window curtain, still-picture display equipment, and a display panel for airplane pilots.

3) This combination of technology and market strategies was not unique in Japan. The differentiation strategies of US manufacturers were different. Since they went forward to "programmable calculators," a further thinning was not their major concerns. *Source*: Numagami (1999)

4) Although the U.S. government was the primary customer for the semiconductor industry in the early stage of IC technology, its influence on the market decreased significantly in the years that followed. In 1963, the share of the federal government was 35.5 %, in 1970, 20.6 %, in 1972, 11.9 %, and in 1973, 5.8 %.

5) This assertion is based on the author's interview (in 1986) with Dr. Yoshiyuki Takeishi of Toshiba Corporation, who led this association on behalf of the industry. He was a vice director of the association.

6) In the face of huge ex ante uncertainties concerning the uses of new technological capabilities, Rosenberg points out that private firms can depend upon the market

mechanism, and that it encourages exploration along a wide variety of alternative paths. He also asserted: In the early stages when uncertainties are particularly high, individuals with differences of opinion need to be encouraged to pursue their own hunches or intuitions. Indeed, the achievement of technological progress, in the face of numerous uncertainties, requires such ex ante differences of opinion (Rosenberg, 1994).

[7)] As part of its exit from the semiconductor manufacturing equipment industry, General Signal put GCA up for sale in January 1993 and, unable to find a buyer, shut it down by the summer of that year.

[8)] These include an extended recession in Japan, the rising value of the yen, trade agreements in which Japan conceded that imports should account for 20% of its domestic semiconductor market, competition from low-cost Korean makers of memory chips, and the continued dominance of U.S. semiconductor companies in the microprocessor market.

[9)] In October 1994, SEMATECH invested about $8 million in Silicon Valley Group Lithography Systems (SVGL). In 2001, however, ASML (being independent from Philipps of Netherland in 1984), had acquired SVG. By acquiring several important technologies from SVGL, ASML has now become the world-largest lithography manufacturer. Source: Takahashi, T. (2006): *The History of Lithography*, National Science Museum, Tokyo.

[10)] Although he described explicitly, Gaddis did not have a chance to document how the nuclear weapons had been *accidentally* destructive and *suicidal* in their implications. Meanwhile, Graham Allison documented how we have become aware of these implications by the experiences at Cuban missile crisis, which occurred in the time period from October 16th to 28th in 1962. *Source*: Allison, G. and Zelikow (1999): *Essence of Decision: Explaining the Cuban Missile Crisis*, Second Edition, Longman, New York.

[11)] For identification of a most appropriate model, we will use the criterion developed by Akaike. The AIC (Akaike information criterion) is developed for measuring the degree of fitness of nonlinear regression analysis. The smaller AIC value means a better fitness.

[12)] It is based on the interview with Mr. Shike, conducted by the coauthor of this paper, Shibata, T. in December 2014.

[13)] We are told that Mr. Shike responded by saying that Alexander Graham Bell had not clearly understood what kinds of businesses would be brought about with the development of the telephone.

[14)] Indeed, Mr. Shike was recruited to Komatsu Co. as an executive officer in 2014.

[15)] In page 109 of the author's book, "Emerging Patterns of Innovation," (Harvard Business school Press, 1995): a cyclical process of research, development, production, and distribution is called an *innovation cycle*. Our review of the history of optical fiber development in Japan revealed that the leading innovators at each stage came from different industrial sectors while collaborating in joint research across industry boundaries. Furthermore, each time a change in leaders occurred, dramatic improvements in technological development were made. Therefore, the innovation cycle should be thought of as multilayered, because high-tech R&D is carried out simultaneously in a wide variety of industries.In this multilayered structure, changes in leaders could be taken to mean that leaders move from an innovation cycle in one industry to a new innovation cycle in a different industry, solving technological problems as they go. The innovation cycle, then, becomes a *spiral innovation model* with three-dimensional cycles. The essential feature of this innovation model is the one-to-one correspondence between technological approach and industrial sector. Each industry tries to solve a problem using specific technological competencies accumulated in its industrial sector. Therefore, the high-tech R&D process is interindustry competition, instead of interfirm competition within a given industry.

Competing interests
The authors declare that they have no competing interests.

Authors' contributions
TS made an interview to Mr. Chiaki Shike of the Big Rental. Both authors read and approved the final manuscript.

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