Asian Journal of Technology Innovation 14, 2 (2006)

Organizational Behavior of Established Firms to a Disruptive Innovation[1)]

: The Case of NEC's Behavior in the Japanese Laptop Computer Industry

Jong-Hyun Wi

Faculty of Business Administration, Chung-Ang University
702, Sangdo-dong, Dongjak-gu, Seoul,156-871, Korea (jhwi@cau.ac.kr)

Summary

This paper analyzes organizational behavior of an established firm when disruptive innovation, a change in product architecture, occurs on a previous product. For the analysis, the paper analyzes and compares the behavior of an established firm through product trajectories between NEC (an established firm) and Toshiba (a new entrance) in the Japanese laptop computers industry. An established firm that has developed and produced a previous product is difficult in adapting to a disruptive innovation due to accumulated immense knowledge through a previous product.

By using regression model in the product trajectory analysis, the paper analyzes the behavior of established firms. Product trajectory means a pattern of product strategy shown in a series of products.

Two facts found in the paper are as follows. First, though NEC was able to develop a laptop computer at the same time with Toshiba, it was restricted by the resources of a previous product in the early stage. Second, possibility of learning trap in the adapting process was found. The paper found the risk that too much commitment in one evolution stage would prohibit the adapting behavior in the next evolution stage.

Key Words: change in product architecture, behavior of established firms, product trajectory, disruptive innovation, NEC

1. Introduction

The purpose of this paper is to analyze the adapting behavior of an established firm when a change in product architecture occurs on a previous product. For the analysis, the paper analyzes

1) I appreciate two referee's constructive and insightful comments. Their comments were very helpful to improve my study.

product trajectories of an established firm. The paper compares the product trajectories between NEC (an established firm) and Toshiba (a new entrant firm) in the Japanese laptop computers industry and shows the characteristics of an established firm's adapting behavior facing a change in product architecture.

The concept of product architecture is a design of physical components and functions that are arranged in the product development process (Ulrich, 1995). A product trajectory is a pattern of product strategy shown in traits of products. An established firm that has developed and produced a previous product has difficulty in adapting to a change in product architecture. As an established firm has accumulated immense knowledge through a previous product, the knowledge prevents an established firm from adapting to a change in product architecture (Henderson and Clark, 1990; Christensen, 1997; Christensen et al., 1996; Cohen and Levinthal, 1990; Wi, 2004; 2002).

Various kinds of knowledge concerning product technologies, management know-how of production process and development organizations are accumulated inside established firms. These kinds of knowledge are the origin of core competence until a change in product architecture occurs. However, as soon as a change in product architecture occurs, the knowledge become a origin of core rigidities (Leonard-Barton, 1992).

For example, Christensen (1997) and Christensen et al. (1996) argued the failure of established firms in American hard-disk drive (HDD) industry. According to the research, those firms failed to adapt to a change in HDD architecture because they were restrained by the customer power of the previous HDD product. Henderson and Clark (1990) also argued that the failure of established firms in the semiconductor photolithographic alignment industry was due to the rigidities of information filters and information channels in the organization. Anderson and Tushman (1986) emphasized the factor of different product technologies in explaining an established firm's failure.

The researchers mentioned above held that the knowledge accumulated in established firms became an obstacle that prevents a firm from adapting to a disruptive innovation such as a change in product architecture (Leonard-Barton, 1992; Abernathy, 1978; Hannan and Freeman, 1977; Cohen and Levinthal, 1990). Therefore, organizational management about how to adapt and control such a change is essential for an established firm to sustain and reconstruct competitive advantages when a change in product architecture occurs.

However, there are few researches analyzing the process of an established firm's adapting behavior in a change of product architecture. Though prior researches such as Henderson and Clark (1990) and Christensen (1997) showed the results that established firms had difficulty in adapting to a change in product architecture, they did not analyze the process of adapting

behavior of established firms. Without this analysis, it will be difficult to find how to manage an organization of established firms and what is the correct strategy of established firms to adapt to the change.

In this paper, adapting process of an established firm will be analyzed by examining NEC and Toshiba in the change from desktop computers to laptop computers and the restricting factors of an established firm will be re-examined also.

2. Data and Research Method

By using the method of the product trajectory analysis, this paper analyzes the process of adapting behavior of established firms. Product trajectory means a pattern of product strategy shown in series of products. The method of analyzing technological trajectory is a powerful tool for examining the behavioral process when firms take different paths of innovation (Dosi, 1982; Pavitt, 1984; Vangelis, 2002). However, this paper applied this method of technological trajectory to analyze firm's traits of products and a firm's behavior.

For mapping one product in a product trajectory, first of all, main functions which have trade-off relationship must be found out. Information processing and information portability are the main functions of laptop computers and also in a trade-off relationship. The function of information processing is the general function of a computer, which consists of sub-functions such as input of information, transformation of information, output of information, etc. The function of information portability is the characteristic of laptop computers, which means the degree of information mobility from one place to another.

In mid-1980s, several components required in light and small-sized laptop computers were restrained by heavy technological constraints. For pursuing the function of information portability, the function of information processing had to be suppressed. On the contrary, raising the functional performance of information processing meant suppressing the function of information portability.

For example, HDD and display were examples of those kinds of constrained components. In the case of display, the weight of a plasma display was about 1kg, the LCD with a back-light of cold cathode was about 800g, and the high reflective LCD was about 500-600g. As a plasma display required a considerable amount of power (15W-30W), AC power cable was essential in operating a laptop computer. In contrast, a laptop computer with LCD display worked in comparatively small amount of power (8W), thus allowed a battery as a power supply. In addition, if HDD were added to a laptop computer, the functional performance of information

processing increased, though a laptop computer gained weight and required a larger amount of power supply.

As a result, a firm which sought a laptop computer with a high speed of information processing like a desktop computer had to include a HDD and a plasma display inside a laptop computer. On the contrary, a firm that sought a laptop computer with high portability had to set a LCD display and no HDD inside a laptop computer.

For determining the degree of functionality of information portability, the weight of a laptop computer is a useful measure. However, measuring the degree of functionality of information processing required more complex proxy variable and needed several steps described below.

Generally measuring the functionality of information processing in PC is not easy. There is a way to use benchmark test to measure the speed of PC's information processing. But it is just a method used mainly in testing a PC as a mechanical system (for example, performance of CPU), and also it includes only a part of the entire functions that users evaluate. Furthermore, as current benchmark standard changes every year, it is not easy to use the results gained by benchmark tests.

In this paper, the price of a laptop computer on initial sales is assumed as reflecting the value of all functions. The price can be broken down into the value of each component. This paper adapted log p as a dependent variable of regression model. From 1986 to 1990, the price of desktop PC rapidly went down. Compared with desktop, however, laptop was comparatively high priced product and the price was stable. For example, J-3100 by Toshiba was an expensive machine, 7,000 dollars at that time of market launching. Furthermore, the paper just adapted the initial laptop price to prevent the problem of pricing down[2].

In the mid of 1980s, the components used in realizing the function of information processing were CPU, HDD, display, memory, etc. However, in the regression analysis, only CPU, HDD, and display were statistically significant. Accordingly, the prices of CPU, HDD and display-contrast, display-plasma or LCD gained from regression were aggregated. The aggregated prices are used as a proxy variable that shows the functionality of information processing.

This process of the estimation is as follows.

1. The prices and specs of 33 laptop computers sold during 1986- 1990 were collected.
2. The regression model of prices and specs was set as follows.

2) Also color display was very expensive at that time. The variable of color display has been put into regression model.

$$\text{Log}\,p = \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + k + \varepsilon$$

Log p : logarithm of the price

X_1 : dummy variable of CPU (below 286 CPU is 0、above 386 CPU is 1)

X_2 : HDD dummy variable (existence of HDD is 1)

X_3 : contrast of display

X_4 : dummy variable of display type (LCD is 0、plasma is 1)

k : constant

ε : residual

The result of regression can be found in table 1. Log p was estimated by the model and was used as a proxy variable showing the functionality of information processing.

Table 1: Results of Regression Analysis

No. of samples=33

Independent variables	Coefficient	Standard Error	t statistics
Intercept	2.46	0.03	80.28***
CPU	0.07	0.03	1.89*
HDD	0.18	0.03	6.26***
Display-contrast	0.01	0.00	2.85**
Display-LCD or plasma	0.17	0.04	4.73***

Notes: dependent level is log p, Adjusted R2=0.78, F=30.20***, *: p<0.1, **: p<0.01, ***: p<0.001

3. Next, every laptop computer sold by NEC and Toshiba was classified into a product series and a representative model of the best performer was selected from each series. As a result, 6 laptop computers according to each company were chosen (names of these were described in Appendix) and those laptop computers were mapped on the figure of product trajectory. Vertical axis of the product trajectory is the proxy variable of the functionality of information processing, and horizontal axis is weight.

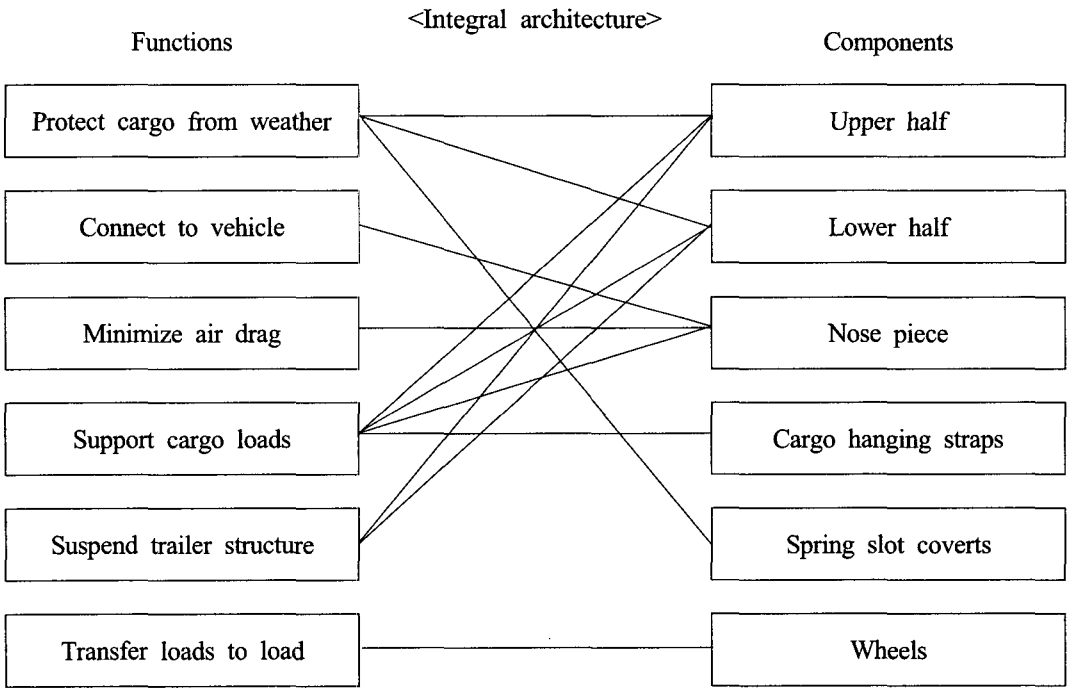
3. A Change in Product Architecture in Laptop Computers

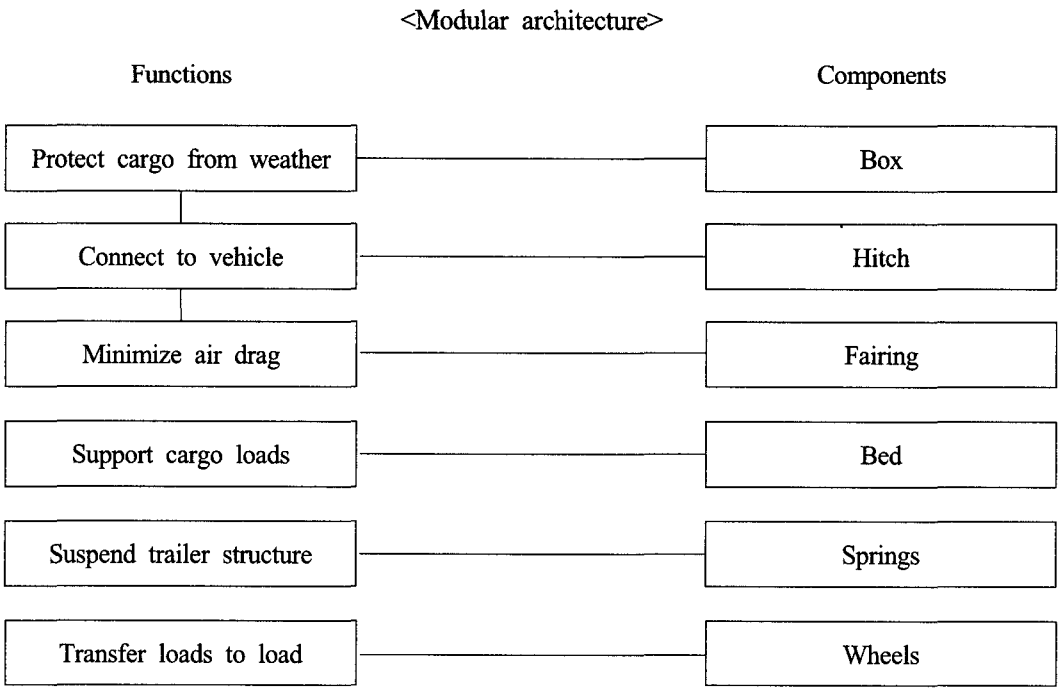
In the paper, previous product is defined as a product which has been sold before a change

in product architecture and new product is a product which is developed in the midst of the change. An established firm means the one which has developed and produced a previous product and accumulated knowledge through that. A new entrant firm is the one that has not experienced to concern a previous product or that have terminated the development of a previous product in the midst of the change.

The concept of product architecture is defined as a design of physical components and functions that are arranged in the product development process. Product architecture consists of three factors, which are an arrangement of functions, correspondence of functions and components and the specification of interface between interacting components (Ulrich, 1995). In other words, product architecture is the scheme or design rule that consists of a hierarchical structure (Ulrich, 1995; Fujimoto, 1997; Clark, 1985; Baldwin and Clark, 2000).

Product architecture can be classified into two types. One is an integral architecture, the other is a modular architecture. Shown in figure 1, integral architecture has a complex corresponding relationship between functions and components and has high functional interdependency and structural interdependency. Modular architecture shows a simple relationship between functions and components and has low functional interdependency and structural interdependency due to a de-coupled specified interface (Ulrich, 1995; Gopfert and Steinbrecher, 1999).





Source: Ulrich (1995 p.421, 422).

Figure 1: Two Types of Product Architecture

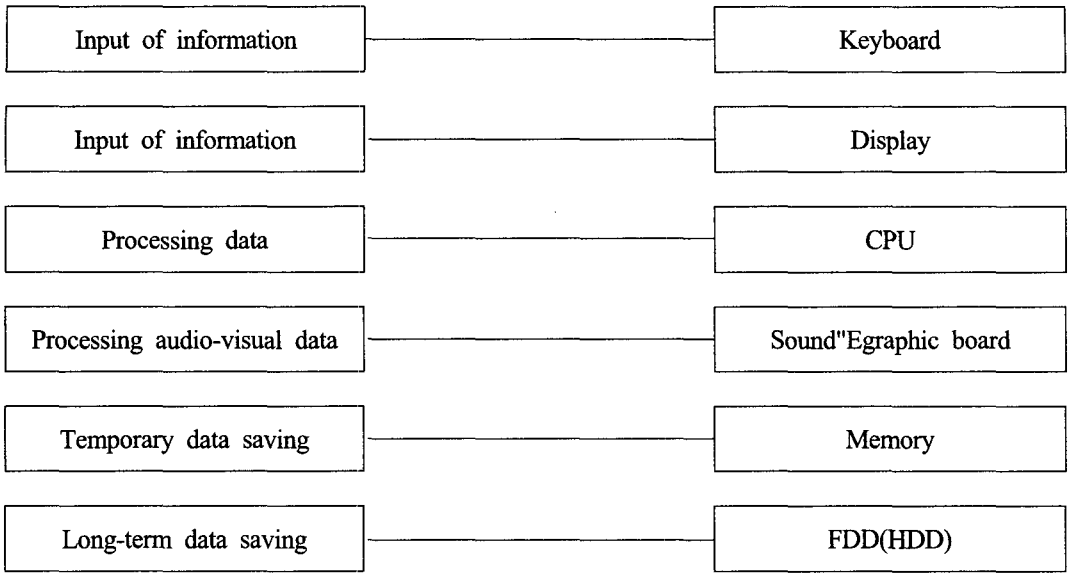
An automobile is an example of integral architecture. In case of designing a brake of an automobile, the arrangement with suspension and steering becomes essential. If the fitness between these components is lost, the risk in turning a car rises high.

A desktop computer is an example of modular architecture. Components of a desktop computer show low functional interdependency and structural interdependency. In addition, the interface between components is specified. For example, the components such as HDD, mouse, monitor, keyboard are separated and independent functionally and structurally (Wi, 2002a; 2002b; 2001a).

A change in product architecture is a disruptive one in the corresponding relationship between functions and components when new functions or new components are combined into a previous product. The change occurs by driving forces such as an appearance of new technology or new needs of users.

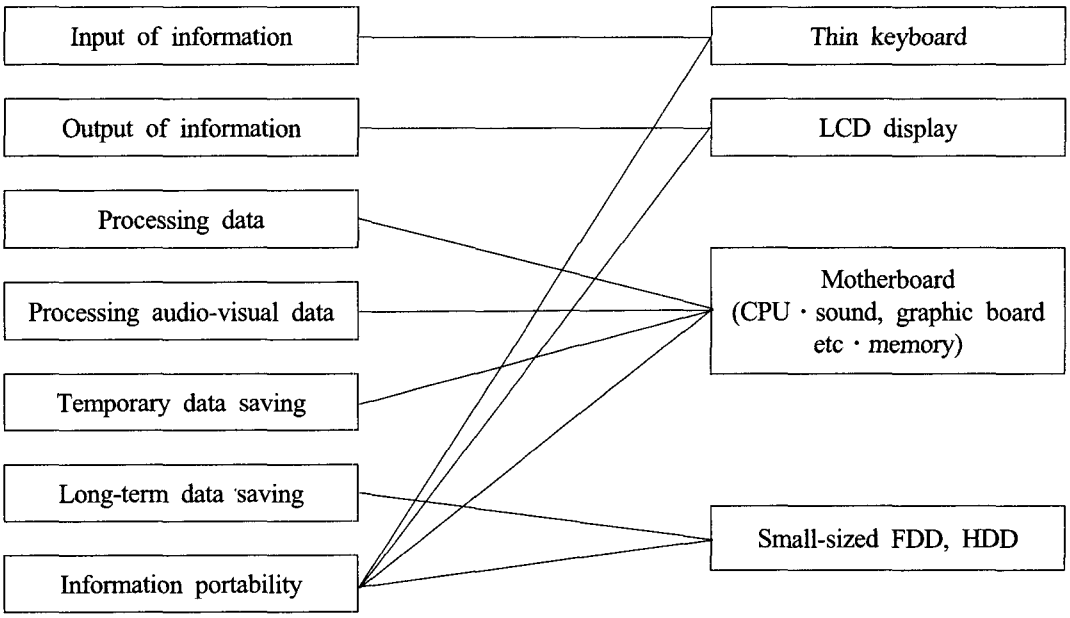
The change in PC architecture means transformation from desktop computers to laptop computers. In detail, it is a transformation from modular architecture of desktop computers to integral architecture of laptop computers. These two kinds of architecture are shown in figure 2.

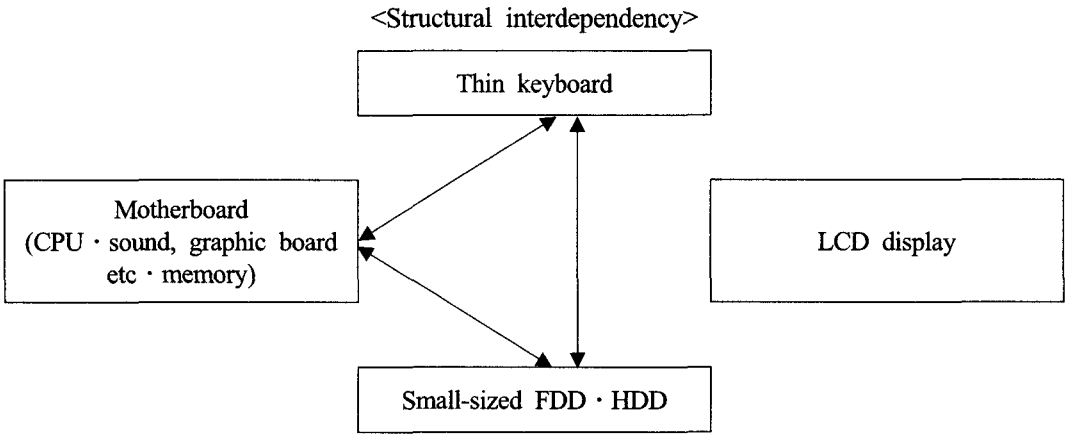
<Product architecture of desktop computers : modular architecture>



<Product architecture of laptop computers : integral architecture>

<Functional interdependency>





Note: arrows mean a higher interdependency

Figure 2: Comparison of the Product Architecture between Desktop Computers and Laptop Computers

The upper part of figure 2 shows the product architecture of desktop computers and the lower part shows the product architecture of laptop computers. Six functions (input of information, output of information, etc) are introduced as the functions of a desktop computer. The components are physical elements which realize the six functions of a desktop computer, and each is a self-contained element which realizes the functions intended by product developers (Wi, 2002).

Those functions and components of a desktop computer have a corresponding relationship of modular architecture. The components of a desktop computer show low structural interdependency, functional interdependency, and the interfaces between components are specified.

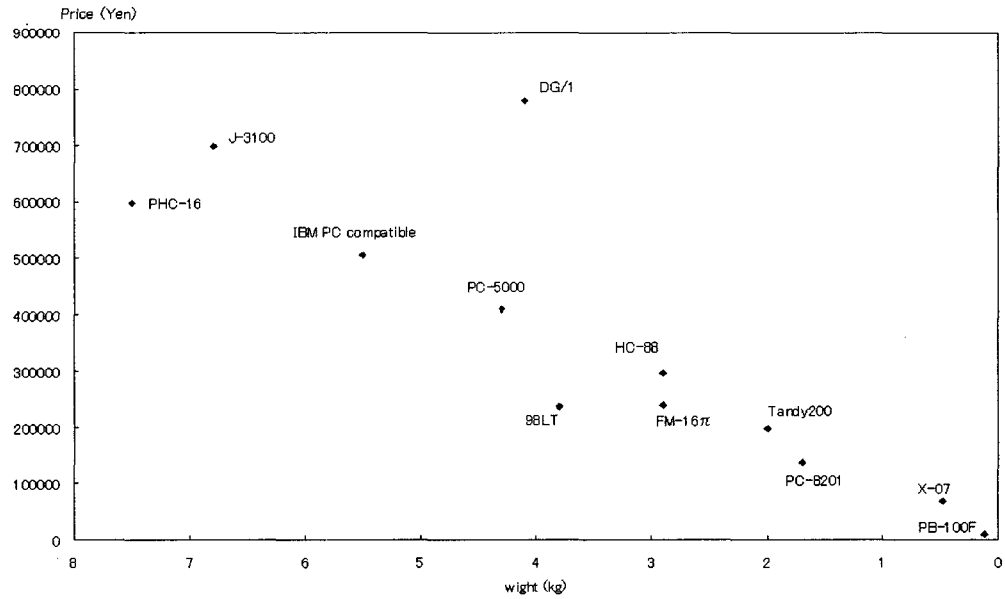
However, when the new function of information portability is added, desktop architecture is changed dramatically. As shown in figure 2, the product architecture of laptop computers becomes that of integral architecture due to a complex corresponding relationship between functions and components and high functional interdependency and structural interdependency. For example, motherboard is an integrated new component and it is engaged in realizing 4 functions, such as processing audio-visual data, temporary data saving, information portability, etc. In addition, structural interdependency in laptop computers rises high. As weight and space of hardware are restrained heavily, the components of laptop computers have to fit into the narrow hardware unit.

When a change in product architecture takes place, various interpretations and product concepts concerning a new product appear. The interpretations and product concepts become to settle down with an appearance of dominant design.

Extremely varied interpretations about the usage of laptop computers appeared in the early stage of laptop evolution. At that time, although each firm recognized that laptop computers were different from desktop computers, they did not have a clear image of what was a laptop computer. Some firms interpreted a laptop computer as a word-processor, other firm interpreted as a portable communication tools.[3)]

Laptop makers also showed differences about target consumer. For example, a firm interpreting laptop computers as an office tool developed a laptop computer with a superior function of information processing and an inferior function of information portability. On the other hand, a firm interpreting a laptop as the tool used by salesman developed a laptop computer with a superior function of information portability and a inferior function of information processing.

As the result of firm's choice in developing a laptop computer, various kinds of laptop computers appeared in the Japanese market. Figure 3 shows these various laptop computers. In the Figure 3, the price of 98LT is significantly lower than that of J-3100 because of HDD and plasma display. As HDD and plasma display were expensive components in the early 1980s, firm that tried to develop a laptop with a superior function of information processing had to embed HDD and plasma display into laptop.



Source: Wi (2001b, p. 111)

Figure 3: Appearance of Various Laptop Computers

3) Wi (2002), p. 28.

4. Product Trajectories of Laptop Computers (NEC and Toshiba)

The paper analyzes NEC's (an established firm) adapting behavior comparing that of Toshiba (a new entrant). NEC started desktop computer business from 8 bit-PC, PC-8001, in the early 1980s, and set up the de-facto, standard in desktop computer industry by the 16 bit-PC, PC-9801. NEC have made up 40% market share and dominated the Japanese desktop market. As a result, NEC accumulated huge amount of knowledge concerning desktop computers. Accordingly, NEC is well suited for analyzing an established firm's adapting behavior to a change in product architecture.

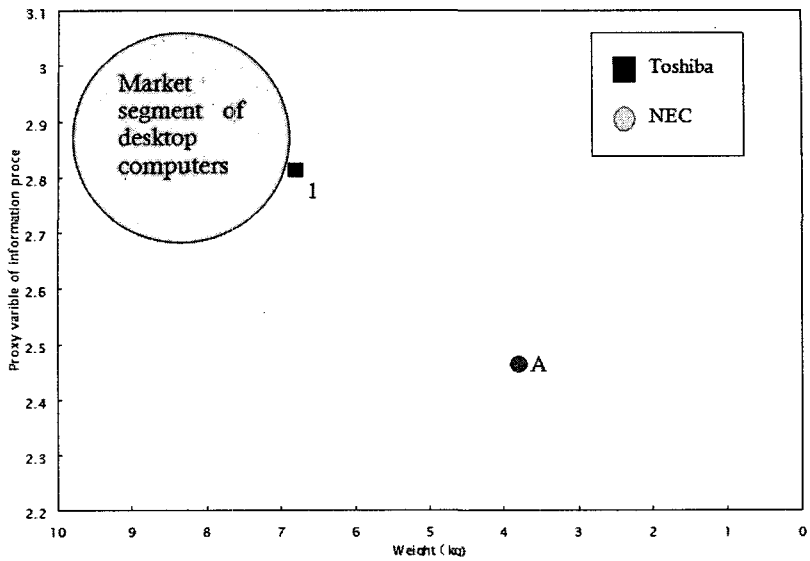
Compared to NEC, Toshiba failed to enter the desktop computer business in the early stage. Toshiba seemed that it had no way but to get virtually withdraw from the market. For this reason, Toshiba was considered as a new entrant in laptop computer business. This difference on initial condition between NEC and Toshiba was important. Even though Toshiba had the power to decide a laptop strategy for it's PC division, NEC's division for laptop was restricted by the power of desktop division.

In addition, When NEC sold laptop computer 98LT, Toshiba introduced a laptop computer J-3100 at the same time to the Japanese market. NEC had evolved in product competing with the product of Toshiba. Total market share of NEC and Toshiba was 70% in 1987, 56% in 1988 and 90% in 1990. The laptop market in the late 1980s can be defined as an oligopolistic market. According to these reasons, it is reasonable to analyze the NEC's adapting behavior by comparing that of Toshiba.

Three stages in product trajectories were observed in the adapting process of NEC and Toshiba from the appearance of laptop computers to the settlement of dominant design. Stage 1 is the period that each firm tries to develop a new architecture product. Stage 2 is the period that each firm changes the functional combination of new product through observing and learning from user's response. Stage 3 is the period of converging to the dominant design that each firm tries to move quickly to the dominant design.

4.1 Stage 1 (New Product Development)

Stage 1 is the period that each firm develops and sells a new product corresponding to the change in product architecture. Interactions between laptop makers and users begin through these new architecture products.



Product Code	Period of sale	Product name (Toshiba)	Product name (NEC)
1	Oct,	1986 J-3100	
A	Oct, 1986		98LT

Figure 4: Product Trajectories at the Stage of New Product Development

Shown in Figure 4, Toshiba sold a laptop computer, J-3100, near the market segment of desktop computers. J-3100 was the product focused on the function of information process. On the contrary, NEC introduced 98LT, which was focused on the function of information portability.

In this trajectory, the fact that NEC was able to develop and sell a laptop computer in the early stage can be found. Contrary to the prior research, NEC succeeded in developing and selling laptop computers. The reason is that development organization of laptop computers within NEC was separated from the organization in charge of desktop computers. In NEC, though the unit (Johoshori business unit[4]) in charge of desktop computers was not able to develop a new architecture product, another unit (NEC Yonezawa[5]) had accumulated technologies and experiences concerning laptop computers. Using this knowledge, NEC (Johoshori business unit)

4) Johoshori means information process in Japanese. Johoshori business unit had taken charge of computer related products from mainframe computers to desktop computers.

5) NEC Yonezawa is a plant name. NEC Yonezawa was located in Yonezawa city, Japan and subsidiary of NEC which produced mainly communication tools and peripheral devices.

was able to develop a new laptop computer in the early stage of product architecture change.

The differences in laptop's strategies and initial condition in desktop market were the reasons why NEC and Toshiba's chose different market position. Before appearance of laptop, NEC was a leader, but Toshiba was a minor maker in Japanese desktop market. In addition, NEC's desktop was the cash- cow business at that time. Therefore, NEC was trying to protect desktop PC business instead of launching a laptop on the position which was far from desktop domain. On the contrary, Toshiba had tried to penetrate NEC's desktop market through pinning its laptop position very close to NEC's desktop. In this sense, Toshiba's laptop had dual role, gaining laptop market and desktop market.

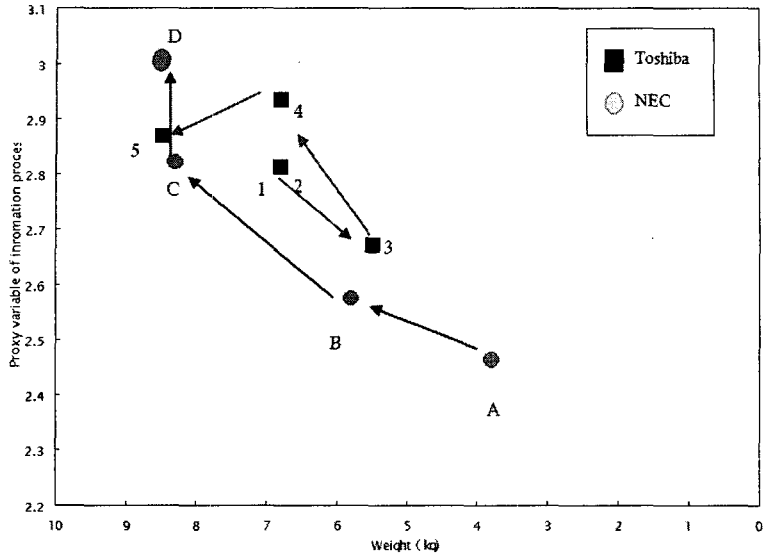
The other reason NEC developed a laptop computer focused on the function of information processing was that Johoshori business unit held the role of product planning. Though NEC Yonezawa played a pivotal role of engineering and developing a laptop computer, the role of deciding specs of a laptop computer remained in Johoshori business unit who tried to protect desktop market segment and decided the laptop computer's specs not to overlap desktop market segment. It was 98LT, which was focused on the function of information portability. Through pursuing portability, 98LT had to sacrifice the compatibility with NEC's desktop, which was de facto standard in Japanese market.

As a result, laptop users did not support NEC's product. Market shares of each laptops were 19% (NEC) and 50.6% (Toshiba) during 1986- 1987. Market shares of desktops were 42% (NEC) and 4.3% (Toshiba) at the same time.[6] On these data of market share, it is confirmed that users of laptops supported more the function of information processing than the function of information portability.

4.2. Stage 2 (Learning from Users' Response)

Stage 2 is the period that each firm had tried to change the functional combination of laptop computers. Firms which have sold laptop computers in various market segments attempt to move into the market segment where user's support was confirmed.

6) At that time, Toshiba had ended the development of desktop computer. The market share 4.3% includes sales of unsold desktop computers, peripherals such as a monitor.



Notes: Product 1 and product 2 are overlapped in the figure. Product 2 is a improved product of product 1

Product Code	Period of sale	Product name (Toshiba)	Product name (NEC)
1	Oct, 1986	J-3100	
A	Oct, 1986		98LT
2	Jul, 1987	J-3100GT	
3	Oct, 1987	J-3100SL	
4	Dec, 1987	J-3100SGT	
5	Jan, 1988	J-3100GX	
B	Feb, 1988		9801LV
C	Oct, 1988		9801LS
D	Mar, 1989		9801LX

Figure 5: Product Trajectories at the Stage of Learning from User's Response

Toshiba developed 4 kinds of similar laptops one after another for 15 months after selling its initial product J-3100. They were the products 2, 3, 4, 5 in figure 5. Toshiba developed these laptops, focusing on the high functionality of information processing.

After sales of product code 5 by Toshiba in figure 5, NEC transformed its product strategy from producing a laptop focused on the function of information portability to making it focused on the function of information process. That is to say, NEC stopped developing 98LT series

and moved to the new laptop, 9801-LV.

Figure 5 shows the NEC's transition of product strategy. NEC started from product A and moved its product to the points, B (9801-LV), C (9801-LS), and D (9801-LX). At this point, as product C and D of NEC were sold at the same market segment where Toshiba's products already settled, 1, 2, 4, 5 were positioned, there was no way but to compete with each other.

4.3. Stage 3 (Converging to the Dominant Design)

Stage 3 is the period that each firm moves to the market segment where dominant design product has emerged. As a dominant design appeared, each firm was able to take a clear image of a new product. Therefore, they tried to adjust their products to the functional combination of a dominant design product.

NEC and Toshiba competed in the same market segment showing different strategy in 9801-LX5C (product E of the figure 6) and Dynabook (product 6 of the figure 6). Toshiba moved to Dynabook, a notebook computer,[7] which emphasized the function of information portability whereas NEC developed a colored-display laptop, which emphasized more the function of information process.

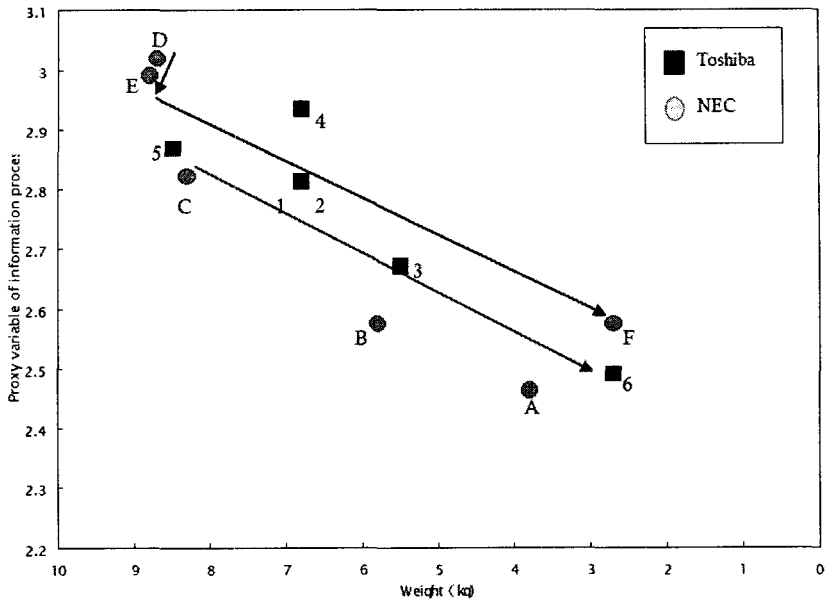
Dynabook succeeded in setting up the dominant design of laptop computers. NEC was delayed for 6 months later in developing a notebook computer, 9801N, than Dynabook. NEC was late in switching over to the notebook computer. The knowledge gained in the stage 1 obstructed the rapid switching to the notebook computer. As NEC has learned the user's support toward the function of information processing through stage 1, NEC stuck to the knowledge through stage 2.

As a result, when each firm had to choose between a notebook computer and a colored-display laptop, NEC chose a colored-display laptop and that made NEC late for moving to the notebook computer.[8]

---

7) A notebook computer is a dominant design of laptop computers. It is a product of letter-sized, about 3kg, and having an integrated feature of keyboard, monitor, and display. Notebook computers are a part of laptop computers.

8) In Figure 4, Toshiba's laptop computer (J-3100) was superior in information processing and heavier than that of NEC (98LT). In Figure 5, Toshiba also tried to enhance the function of information processing, except one time. And in Figure 6, the two firms' final products (Dynabook and 9801N) had the same weight. NEC seemed to have a contradictory product strategy such as a change, information portability --> information process --> information portability. At the early stage, both firm acknowledged that the ideal type of laptop was a small portable sized one like Dynabook. However, limit of component technology prevented firms to realize an ideal laptop. After all, Toshiba chose a function of information processing rather than that of information portability. Toshiba was able to maintain desktop compatibility. However, NEC chose the function of information portability and sacrificed that of information processing. Strictly speaking, NEC's 98LT was not PC product due to lack of compatibility with NEC's desktop.



Product Code	Period of sale	Product name (Toshiba)	Product name (NEC)
1	Oct, 1986	J-3100	
A	Oct, 1986		98LT
2	Jul, 1987	J-3100GT	
3	Oct, 1987	J-3100SL	
4	Dec, 1987	J-3100SGT	
5	Jan, 1988	J-3100GX	
B	Feb, 1988		9801LV
C	Oct, 1988		9801LS
D	Mar, 1989		9801LX
6	Jun, 1989	Dynabook	
E	Jul, 1989		9801LX5C
F	Nov, 1989		9801N

Figure 6: Product Trajectories at the Stage of Converging to the Dominant Design

After 9801N (98note) sold by NEC, the main segment was changed completely to that of a notebook computer. Laptop computers with various specs began to converge on notebook computer market.[9] One of the characteristics in the laptop evolution process was that it took a short term in evolution process. It took only three years for proceeding of the three stages

(from Oct. 1986 to July 1989). It was very short time in product innovation including users' response. The term on Toshiba and NEC's competition was very short. However, if including other makers' laptop products at Figure3, the period of laptop PC evolution proceeded about 8 years from 1982 to 1989.

It is also important that laptop was not born through the radical innovation, but through change of product architecture. The change in product architecture means adding new attributes to old product. Therefore, product evolution process sometimes ended in very short time. Especially IT products sometimes evolved rapidly during a very short period.

5. Discussion and Conclusion

This paper adapted the case of laptop computer industry to analyze the behavior of an established firm to a change in product architecture. The following two points became clear by this analysis (see table2).

First, though NEC succeeded to acknowledge new market and developed a laptop in the early stage, it was restricted by the power to protect the market segment of a previous product. Though NEC Yonezawa had accumulated technologies concerning a laptop, it did not hold the product planning function of laptops. As NEC Johoshori which was restricted by organizational inertia and current customers (Christensen, 1997; Christensen and Bower, 1996; Anderson and Tushman, 1986; Henderson and Clark, 1990) decided laptop's functional combination, NEC failed in the early market.

However, the fact is important that NEC, even though it was an established firm, held the unit that accumulated resources and know-how concerning laptop in the early stage. In short, the problem was not that NEC as a firm was not able to accumulate resources of laptops, but that it failed in controlling and was suppressed by the established unit, NEC Johoshori business unit, which was in charge of the previous product. In other words, the failure of a laptop, 98LT was the result of NEC's lack of capability on managing 'an established unit' and 'a new entrant unit' inside a firm.

The organization of modern big business are consisted of independent units (Chandler, 1962;Weick, 1976) and each unit accumulates different knowledge concerning its own products. Therefore, when a change in product architecture occurs, the adapting capabilities become different

9) After dominant design established, NEC caught up Toshba in laptop market. Brand power and software compatibility with NEC's desktop were the main reasons of NEC's recovery.

in each unit inside a firm. Managing these units (a unit charging a previous product and other units of no relationship with a previous product) to create an innovative product becomes essential.

NEC's case mentioned above shows that it is very important to consider whether the object of analysis is a diversified firm or a specialized firm, and whether analysis is on a firm or a unit (division) inside a firm for discussing the failure of established firms.

The second point this paper made clear is the possibility of a learning trap in an established firm. NEC was late for switching over to the notebook computer. When NEC developed the laptop computer 9801-LX5C, which was focused on the function of information processing, Toshiba concentrated its resources on developing Dynabook, the notebook computer with the enhanced function of information portability.

Researchers who analyzed learning in the innovation process emphasized that the important role of knowledge gained by learning. (Shintaku, 1994;Nonaka and Takeuchi, 1994). Shintaku (1994) argued that accumulating knowledge by dynamic full line strategy was important to lead rapid technological progress. He discussed that a firm should develop various products flexibly to gain the related knowledge in technologically turbulent period.

However, a new fact concerning learning in a change of product architecture was found in the analysis. In the case of NEC, the knowledge gained in the learning process obstructed the adaptation. Because user's support toward its early product was weak, NEC did excessive learning in the process of absorbing user needs. When each firm had to choose between a notebook computer and a colored-display laptop, NEC chose a colored-display laptop and was late for moving to the notebook computer. It was a learning trap.

The characteristic of learning in a change of product architecture was similar with the concept of learning from exploration by March (1991). Contrary to learning from exploitation, learning from exploration has several characteristics that uncertainty of return by learning is high and knowledge gained by learning becomes commonplace rapidly.

The paper made clear the fact that there is a risk of learning trap in the changing process of product architecture. In the period of a change in product architecture, contradictory functions in a new product coexist and various combinations of functions are tested through market.

The paper pointed out the risk of adapting behavior that is based on too much commitment to the knowledge gained in one stage. Because the knowledge gained in one stage of the changing process may prevent an established firm from adapting the next stage.

Table 2: Comparison Facts Found in This Paper to Previous Research

	Previous research 1 (Tushman & Anderson, Henderson and Clark, etc.)	Previous research 2 (Christensen)	This paper
Established firms do not risk to explore (disruptive technology)	No, they don't risk	No, they don't risk	Yes, NEC did
Failure of new market recognition by established firms	No, they don't recognize	No, they don't recognize	Yes, NEC knew the potential market
Performance of trial	N.A.	N.A.	low
New factor of establihed firm's restriction	Technology or information filter channel	Customer power	Managing capabilities of multi division
Analysis leverl	A firm	A firm	A unit(division) inside a firm

References

Abernathy, W. (1978), *The Productivity Dilemma: Roadback to Innovation in the Automobile Industry*, The Johns Hopkins University Press.

Anderson, P. and Michael T. (1986), "Technological Discontinuities and Organizational Environments," *Administrative Science Quarterly*, Vol. 31, pp. 439-465.

Baldwin, C. Y. and Kim B. C. (2000), *Design Rules: The Power of Modularity*, MIT Press.

Chandler, A. D. Jr. (1962), *Strategy and Structure*, MIT Press.

Christensen, C. M. (1997), *The Innovator's Dilemma*, Harvard Business Press.

Christensen, C. M. and Bower, J. (1996), "Customer Power, Strategic Investment and the Failure of Leading Firms," *Strategic Management Journal*, Vol. 17, pp. 197-218.

Christensen, C. M., Suarez, F. and Utterback, J. M. (1996), "Strategies for Survival in Fast-changing Industries," *Working Paper*, Harvard Business School, July 16, No. 97-009.

Clark, K. B. (1985), "The Interaction of Design Hierarchies and Market Concepts in Technological Evolution," *Research Policy*, Vol. 14, pp. 235-251.

Cohen, M. W. and Levinthal, D. A. (1990), "Absorptive Capacity: A New Perspective on Learning Innovation," *Administrative Science Quarterly*, Vol. 35, pp. 128-152.

Fujimoto, T (1997), *The Evolution Theory of Production System*, Yuhikaku (in Japanese).

Gopert, J. and Steinbrecher, M. (1999), "Modular Product Development: Managing Technical and Organizational Interdependence," *Mimeo*, pp. 213-224.

Dosi, G. (1982) "Technological Paradigms and Technological Trajectories," *Research Policy*, Vol. 11, pp. 147-162.

Hannan, M. T. and Freeman, J. (1977), "The Population Ecology of Organizations," *American Journal of Sociology*, Vol. 82, pp. 929-964.

Henderson, R. M. and Clark, K. B. (1990), "Architectural Innovation: The Reconfiguration of Existing Product Technologies and the Failure of Established Firms," *Administrative Science Quarterly*, Vol. 35, pp. 9-30.

Leonard-Barton, D. (1992), "Core Capabilities and Core Rigidities: A Paradox in Managing New Product Development," *Strategic Management Journal*, Vol. 13, pp. 111-225.

March, J. G. (1991), "Exploration and Exploitation in Organizational Learning," *Organization Science*, Vol. 2, pp. 71-87.

Nonaka, I. and Takeuchi, H. (1995), *The Knowledge-Creating Company : How Japanese Companies Create the Dynamics of Innovation*, Oxford University Press.

Pavitt, K. (1984) "Sectoral Patterns of Technical Change: Towards a Taxonomy and a Theory, *Research Policy*, Vol. 13, pp. 343-373.

Shintaku, J. (1994), *Competitive Strategy of Japanese firms*, Yuhikaku (in Japanese).

Ulrich, K. (1995), "The Role of Product Architecture in the Manufacturing Firm," *Research Policy*, Vol. 24, pp. 419-440.

Soutaris, V. (2002), "Technological Trajectories as Moderators of Firm-level Determinants of Innovation," *Research Policy*, Vol 31, pp. 877-898.

Weick, K. E. (1976), "Educational Organization as Loosely Coupled System," *Administrative Science Quarterly*, Vol. 21, pp. 1-19.

Wi, J. H. (2004), *Organizational Strategy for Innovation*, Shinzansha.(in Japanese)

Wi, J. H. (2001a), "The Adapting Process to a Change in Product Architecture through Mobilizing and Recombining of Resources inside a Firm," *Keizaigakukenkyu (Research of Economic)*, Vol. 43, pp. 43-56 (in Japanese).

Wi, J. H. (2001b), "The Organizational Management of an Established Firm in Adapting to a Change of Product Architecture," *Sosikikagaku* (Organizational Science), Vol. 35, pp. 108-123 (in Japanese).

Wi, J. H. (2002), "Organization Strategy of Established Firms for Adapting to a Change in Product Architecture: The Dynamic Management of Subunits inside an Organization," *Annals of Business Administrative Science*, Vol. 1, No.2, pp. 1-8.

Appendix: 12 Laptop PCs Specifications

	98LT	Dynabook	9801N	9801LV	J-3100SL
CPU	V50	80C86	V30	V30	80C86
Display	LCD	STNLCD, 2gradation	BLSTNLCD, 8gradation	LCD, 8gradation	STNLCD, 2gradation
HDD	no	no	no	no	10M HDD
weight	3.8kg	2.7kg	2.7kg	5.8kg	5.5kg

	J-3100GT	9801LX	J-3100GX	9801LX5C	9801LS
CPU	80286	80286	80286	80286	386SX
Display	Plasma, 2gradation	BL LCD, 8gradation	Plasma, 4gradation	STN color BL	Plasma, 8gradation
HDD	20M HDD	40M HDD	40M HDD	40M HDD	40M HDD
weight	6.8kg	8.3kg	8.5kg	8.7kg	8.8kg