**Discussion Paper Series No.164**

# Modularization for Product Competitiveness

## - Analysis of modularization in the digital camera industry -

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**October  2004**

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Focusing on the digital camera industry with high Japanese competitiveness in IT industry, entrants are analyzed in detail as to how growth was achieved after the period of market introduction and particularly from the view of modularization and platform strategies of leading companies. As a result, the involvement of indicators such as product production, development lead-time, and price with the strategies of modularization and platform was analyzed.

Keyword:

Product Development, Modularity, Product Platform, Vertical Integration, Product Strategy

## Table of contents

## 1. Introduction

The IT device industry has continued rapid progress since the 1990s. Within the industry, Cellular phones, Digital still cameras (denoted here as Digital cameras), Large-display TVs, DVD players, Personal computers, Car-navigation systems, and the like have accomplished growth on a world-wide scale. It seems that there is a common pattern in the development process of these IT industries. One cannot deny that these industries' growth depended on cooperation and competition between entrants' product strategies such as modularization and platform adoption with regard to product structure.

This paper has focused on the Japanese digital camera industry, which is considered to have a high level of industrial competitiveness. It has analyzed what kind of product strategies companies have implemented in the industrial growth process and, moreover, what strategies were successfully or poorly implemented. Moreover, this paper will discuss the types of sources of industrial competitiveness for Japanese companies that developed these industries.

### 1-1 Preceding Research on Modularization

Research to ascertain product strategy from the viewpoint of modularization has been done extensively in recent years. First, the existing research on industrial structure, market growth, product production and modularity that constitutes the basic concept of this paper is surveyed here.

Modules have an extremely long history to the extent that descriptions of modules are noted in which wheels, hubs, bearings, and a gasoline tank are standardized by the mass-production method developed by Henry Ford (Swan, 1914). A half-century later, the concept of "Modularity" was widely recognized through the discussion of product efficiency brought by modularization in the watchmaker analogy (Simon, 1962) and mass-customization advocated by Starr (Starr, 1965). In the 1990s, detailed research on modularization by Ulrich and others started, and the concept of an interface between modules was advocated (Ulrich and Tung, 1991). Numerous results were reported such as detailed research on shortening of product development lead time (Thomke and Reinertsen, 1998), on managing both mass customization and low cost (Pine, 1993; O'Grady, 1999), and on influencing product innovation (Baldwin and Clark, 2000). However, problems with modularization research have become obvious. First is that the interpretations, definitions, and viewpoints regarding modules are not uniform among the researchers. For example, researchers turning their viewpoints to product development management regarded modules as common, standardized, and compatible components and have pointed out the misdistribution of innovative activities among many organizations (Galsworth, 1994; Sanchez and Mahoney, 1996; Schilling, 2000; Baldwin and Clark, 2000). With technology theory, however, a module is understood as a design manual for product development and its product development management is treated as a given condition. For example, the module is defined as the kind of product feature, product demand, or material (Smith and Eppinger, 1997; Newcomb, Bras and Rosen, 1998; Stone and Wood, 2000). Thus, there have been a large number of attempts to define a module from a common viewpoint, irrespective of management theory or technology theory (Brusoni and Prencipe, 1999; Baldwin and Clark, 2000; Fixson, 2003; Schilling, 2002; Sturgeon, 2002; Sako, 2003), but the current situation is one where most have not specified common definitions. Two factors for the existence of different viewpoints of management and technology mentioned above have been noted.

First is the industrial peculiarity in a module argument. The fact that the definition of a module differs substantially between products requiring assembly and small electric designed with a high density is unavoidable in the combination of hardware and software, or hardware itself. For example, numerous pieces of industry-specific research have been reported such as modularization of an automobile (Sako and Murray, 1999), modularization of an elevator as heavy machinery (Mikkola, 2001), a personal computer (the following, personal computer) (Fine, 1998; Baldwin and Clark, 2000), and an electronics product (Sturgeon, 2003), although definitions regarding modules are not uniform.

Another problem with the modular definition is the existence of several viewpoints for specification of a module (Fixson, 2003). The definition of a module can be broadly analyzed from three viewpoints of system, class, and product life cycle. A system viewpoint is for the purpose of analyzing the product architecture and understanding the connection between modules and their interfaces as a product structure element (Ulrich, 1995; Garud and Kumaraswamy, 1995; Schilling, 2000; Baldwin and Clark, 2000). Product architecture is a concept showing the relation between product feature and product structure, namely, the constituent elements of a product, (Ulrich, 1995; Baldwin and Clark, 2000; Fujimoto, Takeshi and Chingtao, 2001; Aoki and Ando, 2000). The class viewpoint indicates that if modularization is further advanced higher-class modules are formed commercially, which is expressed by the term "platform" in many papers. That is, skillful product development is defined as forming a platform by combining limited parts and united modules so as to form a product family that flexibly and quickly suits customer needs (Hyer and Wemmerlov, 1984; Nobeoka and Cusmano1994; Meyer and Lehnerd, 1997; Robertson and Ulrich, 1998; Gonzalez-Zugasti, Javier, Otto and Baker, 2000; Gawer and Cusumano, 2001). Finally, the viewpoint of product life cycle is defined differently as three stages, development (modularity in design [MiD]), use (modularity in use [MiU]), and production (modularity in production [MiP]) (Sako and Murray, 1999; Baldwin and Clark, 2000). The current product structure is too complicated to be entirely designed by one person, and modularization can be promoted in relation to organization structure (Brusoni and Prencipe, 1999). In other words, a product development organizational structure is a view related to the modular design of a product (Henderson and Clark, 1990; von Hippel, 1990). However, important factors regarding modularization as seen from the point of view of the user are additional features, upgradability, and the diversity of options at the time of purchase (Pine, 1993; Sako and Murray, 1999; Yu, Javier, Gonzalez-Zugasti and Otto, 1999). Finally, the discussion of modularization includes the most practical problem of formation of a supply chain with regard to product manufacturing (Sturgeon, 2002), and selection of commercially procurable modules becomes a requirement when procuring modules or utilizing outsourcing (Whilhelm, 1997).

In the above portion, the genealogy of research in modularization has been described. In this paper, the digital camera industry is examined by using the concept of "Modularization" and "Platform" to clarify how a company establishes modules and implements product differentiation in a limited range of selection to heighten competitiveness.

## 1-2 The Purpose of this Paper

This paper aims to analyze the digital camera industry for the purpose of proving the important role played by modularization in the phase of the firm's product development and product manufacturing. The digital camera industry has grown into an enormous industry producing more than 50 million units per year after market introduction in 1995. In that time, many innovations such as small lens composite technology, optical element technology, and digital-image-processing technology have been brought about. The purpose of this paper is to analyze through the concept of modularization how those innovations were shared and spread among entrants and how they were then reflected in corporate earnings.

This paper takes up the issue of "modularization” and “commoditization." Commoditization refers to a situation where it becomes impossible to gain excess profit by product differentiation in a market, and conversely the process that comes to obtain excess profit from a commodified product is called "de-commoditization" (Christensen and Raynor, 2003). Then, the following hypotheses are set up.

Hypothesis 1: If a main module market is formed and entrant companies proceed with formation of a similar platform, commoditization is promoted.

Hypothesis 2: Homogenization of a product is governed by the product performance of main modules. That is, homogenization becomes marked as the horizontally specialized structure of the industry progresses.

Hypothesis 3: De-commoditization cannot be realized by technical innovation without platform changes. That is, technology must be "black-box" accompanied by changes in architecture in order to obtain excess profit.

In Hypotheses 1 and 2, the relationship between product development in a firm, industrial structure, and market structure is discussed from the viewpoint of modularization and platforming. The issue of black-box handling of technology is considered in Hypothesis 3. Although many companies entered the digital camera industry, a digital camera consists of standard modules such as lenses, CCD, image-processing engine, liquid crystal display, power supply, and memory card. Specifically, how product development is achieved with this limited combination will be clarified. Namely, the purpose of this paper is the positive analysis of the product strategy of a company in a situation where the module market has been established.

## 2. Analytical Framework

There are two reasons to select the digital camera industry. First, it has a high level of global competitiveness and analysis of the entrants' product strategy seemed to be an optimal example for the study of competitiveness in product development. Moreover, the digital camera industry is comparatively new and it was possible to acquire data that could be comprehensively and objectively analyzed such as current market prices and specifications for all of the marketed products. Furthermore, the development of constituent technology and the parts market such as diversification of OS [1], improvement in microcomputer performance, increase in memory capacity, and the miniaturization of liquid-crystal high-resolution displays are similar to other IT products, and are highly likely to be a launch pad for research in the IT industry as a whole. First, an outline of the digital camera industry and the definition of topics for analysis like "Module" and "Platform" are described in this section.

### 2-1 Outline of the Digital Still Camera Industry

In October 1988, a prototype called DSP-1 was announced by Fuji Photo Film and commercially produced with the model name DSP-100 three years later. At almost the same time, Kodak released two models called DC 3/32 and DCS200ci with a built-in hard disk through cooperation with Nikon. [2]. Then, a model called VC-1000 was released onto the market by Olympus in October 1993. These four companies had five models positioned as initial models of digital cameras. The environment of the digital camera industry those days was one in which the immaturity of the personal computer market for recording, reproducing and printing digital camera images became an inhibitor to the spread of digital cameras, and APS camera[3]. The digital camera market rapidly expanded when Casio released a low-priced model with 250,000 pixels called QV-10 in March 1995. Then, the all of the main firms entered the market during the three years from 1995 to 1997 and 564 models were released commercially by 2003.

### 2-2 Analytical Viewpoint

In this section, the mechanism for analysis of the product architecture changes in the digital camera industry will be established. An issue here is the difficulty of analyzing all 564 models with a study inquiring down to the design level, i.e., components used, software structure, and OS, to analyze the digital camera's product architecture.

Inquiring down to the cost structure of all products in order to investigate the market value is difficult in reality. This research attempted to analyze the entrants' strategy by obtaining product specifications and applying an index representing the changes in product competitiveness, by investigating actual market prices, and by indicating the relative product value for the industry as a whole. In conventional research, the product value, i.e., cost factor, has not been subject to analysis since the variable cost and expense of the product itself could not be represented because they are heavily influenced by the firm's fixed costs, distribution channels, and corporate strategy. However, acquisition of price information has become easier through progress in information technology, so these aspects were used as data for value analysis. Therefore, this paper, analysis has proceeded with analysis based on the data created from product specifications, current market price, and industry statistics[4].

### 2-3 Modular Structure of a Digital Camera

The composition of a typical digital camera is shown in Fig. 1. As shown in Fig. 1, a digital camera largely consists of modules such as lenses, an optical element (CCD or CMOS[5]), image-processing engine, liquid crystal display, power supply, and external memory card. The figure showing in Fig. 1 is conceptual and there are some variations in actual products. For example, the digital camera feature used in cellular phones forms a module incorporating a single focal lens and an optical CMOS element. In a compact digital camera, a lens module is formed consisting of a CCD module and lens unit combining several lenses and a finder, and an optical platform is formed in conjunction with the CCD module. However, lens, the finder, and optical element are modularized in the case of a digital single-lens reflex camera, a higher-level model, but a platform is not formed. Thus, a digital camera consisting of the same modules also forms different platforms through their combination.

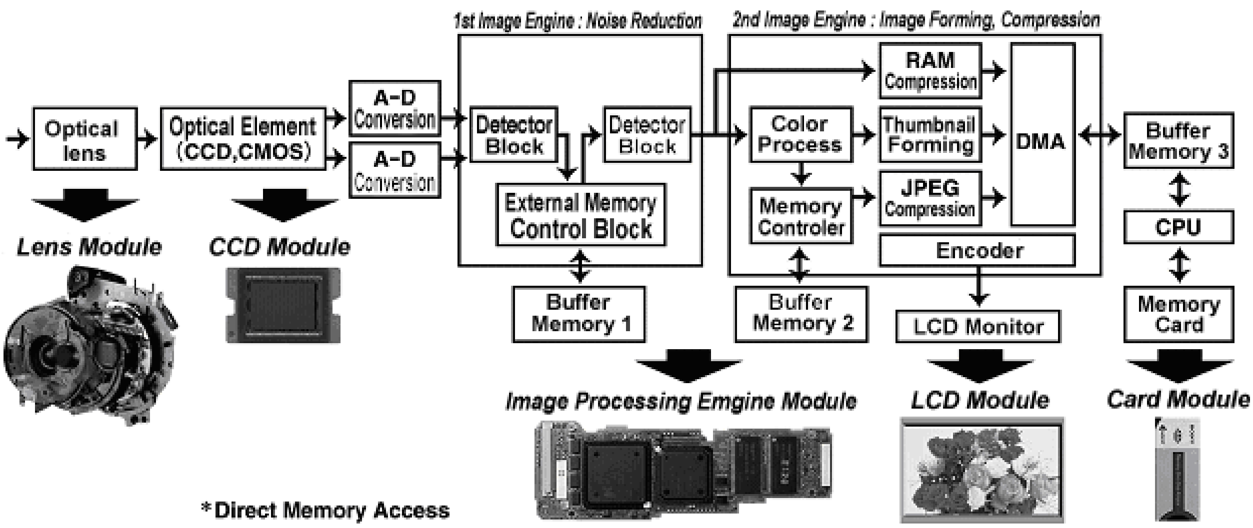
## 3. Analysis of Modularization Process

In this section, analysis proceeds from two viewpoints. First, hypotheses are examined based on study data for Canon, a leading company in the digital camera industry, and then the digital cameras of about 30 companies with 564 models that were marketed from 1995 to 2003 are analyzed again.

### 3-1 Canon's Modularization Strategy

Canon's full-scale entry into the digital camera market started with the

Fig. 1 Modular structure of a digital camera



PowerShot series released in October 1996. The product development dynamics described in terms of the module are shown in Table 1. Canon released 43 models in eight years from 1996 to 2003. Descriptions in Table 1 are described as chronologically as possible. When the same lens and optical element are combined in certain digital camera series and other modules have the same specifications, they are expressed as a "Platform."

For example, four platforms (shaded) are noted in Table 1. These four platforms are the IXY series of the compact product group, the PowerShot A10 series of the standard type using AA batteries, the PowerShot A100 series with a single focus lens and low price, and the higher-class PowerShot S series. Although they have different specifications, each series has the same platform, so the exact same structure can be observed within the series.

Adoption of such a platform started in 2000 and has been continued in current products. In Table 1, "Price" expresses the market price per 1 million pixels and its decline by year is indicated. "Product development lead-time" decreased from 140 weeks in 1996 to 50 weeks in 2000 during formation of the first platform, finally decreasing to 40 weeks in 2003. In order to investigate how Canon's digital camera production, overseas production, and development lead-time are related to product development factors such as ratio of outsourcing for modular components, platform, and in-house technical contribution, these eight factors are indicated in Table 2 in a timeline from 1996 to 2003. Although Canon depended on OEM for twenty percent of manufacturing in 1997, the entire quantity was manufactured by the firm after that time. Total output reached 1 million units in 2000, overseas production started in 2001, and the ratio rose quickly to 44% in 2003. Thus, the correlation coefficient between indices was calculated in order to investigate factors for substantial changes in indices regarding production and product development. Since none-parametric data such as the platform ratio and the level of in-house technical contribution are included in indexes, the Pearson's correlation coefficient was determined and is shown in Table 3[6].

Table 1. Product Modularization and Platforming by Canon

| Product Name | | Lens | | Optical Element | | Other Modules | | | | | Release | Period | Price | Lead-time |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Series | Model | Focal length | F-value | Size | Pixels | Filter | Card | LCD | Engine | Power | M- Y | Months | ¥10000 | Weeks |
| PowerShot | 600 | 10 | F2.5 | 1/3 | 57 | Comp. | PC3 | X | DVC | NiCd | Oct. 1996 | | 22.46 | 140 |
| PowerShot | 600N | 10 | F2.5 | 1/3 | 57 | Comp. | PC3 | X | DVC | NiCd | Feb. 1997 | | 22.46 | 140 |
| PowerShot | 350 | 8 | F2.8 | 1/3 | 35 | Comp. | CF | 1.8Mini | DVC | AA | Mar. 1997 | | 19.94 | 140 |
| PowerShot | A5 | 5.4 | F2.5 | 1/3 | 81 | Comp. | CF | 1.8TFD | DVC | NiH | Apr. 1998 | | 9.23 | 140 |
| PowerShot | A5zoom | 4.3-8.75 | F2.6-4.0 | 1/3 | 81 | Comp. | CF | 2.0TFD | DVC | NiH | Oct. 1998 | | 10.47 | 140 |
| PowerShot | Pro70 | 3.5-10.8 | F2.0-2.4 | 1/2 | 168 | Comp. | CF | 2.0PS | DVC | NiH | Nov. 1998 | | 9.40 | 140 |
| PowerShot | A50 | 3.5-10.8 | F2.6-4.0 | 1/2.7 | 131 | Comp. | CF | 2.0PS | 1st | NiH | Apr. 1999 | None | 6.09 | 140 |
| PowerShot | S10 | 5.4-10.8 | F2.8-4.0 | 1/2 | 211 | Comp. | CF | 1.8PS | 1st | NiH | Oct. 1999 | | 4.26 | 140 |
| PowerShot | S20 | 4.0-8.0 | F2.8-4.0 | 1/1.8 | 334 | Comp. | CF | 1.8PS | 1st | NiH | Mar. 2000 | | 2.99 | 50 |
| PowerShot | Pro90 | 5.5-22.2 | F2.8-3.5 | 1/1.8 | 334 | Comp. | CF | 1.8PS | 2nd | Li | Feb. 2001 | | 4.79 | 50 |
| PowerShot | G1 | 5.4-10.8 | F2.0-2.5 | 1/1.8 | 334 | Comp. | CF | 1.8PS | 2nd | Li | Oct. 2000 | | 3.44 | 50 |
| PowerShot | G2 | 5.4-10.8 | F2.0-2.5 | 1/1.8 | 410 | Prmry | CF | 1.8PS | 2nd | Li | Sep. 2001 | | 2.80 | 50 |
| PowerShot | G3 | 7.2-28.8 | F2.0-3.0 | 1/1.8 | 410 | Prmry | CF | 1.8PS | Digic | Li | Nov. 2002 | | 2.20 | 50 |
| PowerShot | G5 | 7.2-28.8 | F2.0-3.0 | 1/1.8 | 530 | Prmry | CF | 1.8PS | Digic | Li | Jun. 2003 | | 1.70 | 40 |
| IXY DIGITAL | 0 | 5.4-10.8 | F2.8-4.0 | 1/2.7 | 211 | Comp. | CF | 1.5PS | 2nd | Li | May. 2000 | | 3.55 | 50 |
| IXY DIGITAL | 200 | 5.4-10.8 | F2.8-4.0 | 1/2.7 | 211 | Prmry | CF | 1.5PS | 2nd | Li | May. 2001 | | 3.41 | 50 |
| IXY DIGITAL | 200a | 5.4-10.8 | F2.8-4.0 | 1/2.7 | 211 | Prmry | CF | 1.5PS | 2nd | Li | Apr. 2002 | 37 | 2.99 | 50 |
| IXY DIGITAL | 320 | 5.4-10.8 | F2.8-4.0 | 1/2.7 | 320 | Prmry | CF | 1.5PS | Digic | Li | Oct. 2002 | | 1.56 | 50 |
| IXY DIGITAL | 30 | 5.4-10.8 | F2.8-3.9 | 1/2.7 | 320 | Prmry | CF | 1.5PS | Digic | Li | May. 2003 | | 1.41 | 40 |
| IXY DIGITAL | 300 | 5.4-16.2 | F2.7-4.7 | 1/2.7 | 211 | Prmry | CF | 1.5PS | 2nd | Li | Apr. 2001 | | 4.03 | 50 |
| IXY DIGITAL | 300a | 5.4-16.2 | F2.7-4.7 | 1/2.7 | 211 | Prmry | CF | 1.5PS | 2nd | Li | Apr. 2002 | None | 3.27 | 50 |
| IXY DIGITAL | 400 | 7.7-22.2 | F2.8-4.9 | 1/1.8 | 410 | Prmry | CF | 1.5PS | Digic | Li | Mar. 2003 | | 1.46 | 40 |
| IXY DIGITAL | L | 6.4 | F2.8 | 1/2.5 | 420 | Prmry | SD | 1.5PS | Digic | Li | Oct. 2003 | | 0.95 | 40 |
| PowerShot | A10 | 5.4-16.2 | F2.8-4.8 | 1/2.7 | 130 | Prmry | CF | 1.5PS | 2nd | AAx4 | Jun. 2001 | | 3.83 | 50 |
| PowerShot | A20 | 5.4-16.2 | F2.8-4.8 | 1/2.7 | 211 | Prmry | CF | 1.5PS | 2nd | AAx4 | May. 2001 | | 2.65 | 50 |
| PowerShot | A30 | 5.4-16.2 | F2.8-4.8 | 1/2.7 | 130 | Prmry | CF | 1.5PS | 2nd | AAx4 | Mar. 2002 | 21 | 2.91 | 50 |
| PowerShot | A40 | 5.4-16.2 | F2.8-4.8 | 1/2.7 | 211 | Prmry | CF | 1.5PS | 2nd | AAx4 | Mar. 2002 | | 2.36 | 50 |
| PowerShot | A60 | 5.4-16.2 | F2.8-4.8 | 1/2.7 | 210 | Prmry | CF | 1.5PS | Digic | AAx4 | Mar. 2003 | | 1.43 | 40 |
| PowerShot | A70 | 5.4-16.2 | F2.8-4.8 | 1/2.7 | 330 | Prmry | CF | 1.5PS | Digic | AAx4 | Mar. 2003 | | 1.21 | 40 |
| PowerShot | A80 | 7.8-23.4 | F2.8-4.9 | 1/1.8 | 410 | Prmry | CF | 1.5PS | Digic | AAx4 | Oct. 2003 | None | 1.10 | 40 |
| PowerShot | A100 | 5 | F2.8 | 1/3.2 | 130 | Prmry | CF | 1.5PS | 2nd | AAx2 | Mar. 2002 | | 1.91 | 50 |
| PowerShot | A200 | 5 | F2.8 | 1/3.2 | 210 | Prmry | CF | 1.5PS | 2nd | AAx2 | Jun. 2002 | 11 | 1.52 | 50 |
| PowerShot | A300 | 5 | F3.6 | 1/2.7 | 330 | Prmry | CF | 1.5PS | Digic | AAx2 | Apr. 2003 | | 0.76 | 40 |
| PowerShot | S30 | 7.1-21.3 | F2.8-4.9 | 1/1.8 | 330 | Prmry | CF | 1.8PS | 2nd | Li | Dec. 2001 | | 2.72 | 50 |
| PowerShot | S40 | 7.1-21.3 | F2.8-4.9 | 1/1.8 | 410 | Prmry | CF | 1.8PS | 2nd | Li | Oct. 2001 | 15 | 2.43 | 50 |
| PowerShot | S45 | 7.1-21.3 | F2.8-4.9 | 1/1.8 | 410 | Prmry | CF | 1.8PS | Digic | Li | Oct. 2002 | | 1.59 | 50 |
| PowerShot | S50 | 7.1-21.3 | F2.8-4.9 | 1/1.8 | 530 | Prmry | CF | 1.8PS | Digic | Li | Mar. 2003 | | 1.32 | 40 |
| EOS | D30 | | | APS | 325 | Prmry | CF | 1.8PS | 1st | Li | Oct. 2000 | | 11.02 | 50 |
| EOS | EOS1D | | | 35mm | 448 | Prmry | CF | 2.0PS | 2nd | NiH | Dec. 2001 | | 16.74 | 50 |
| EOS | D60 | DSLR | | APS | 650 | Prmry | CF | 1.8PS | 2nd | Li | Mar. 2002 | None | 5.08 | 50 |
| EOS | 1Ds | | | 35mm | 1140 | Prmry | CF | 2.0PS | Digic | NiH | Nov. 2002 | | 8.77 | 50 |
| EOS | 10D | | | APS | 650 | Prmry | CF | 1.5PS | Digic | Li | Mar. 2003 | | 3.08 | 40 |
| EOS | KISS | | | APS | 650 | Prmry | CF | 1.8PS | Digic | Li | Sep. 2003 | | 1.85 | 40 |

(Note) The data in the table was provided by Canon. DSLR in "lens" is an abbreviation for "Digital Single Lens Reflex" camera with an exchangeable lens. The size of the "Optical Element" is in inches. PS in "Liquid Crystal" is abbreviation for "Poly Silicon." With regard to the "Image-Processing Engine," DVC is an abbreviation for Digital Video Camera, with specialized engines for the 1st, 2nd, and 3rd generations, and Digic is the brand name of the 3rd generation. "Price" shows the market price in 10000 Yen per 1 million pixels. In "Filter," "Comp." is an abbreviation for Complimentary and "Prmry" for Primary.

Table 3 indicates that the total output depends largely on the amount of production overseas and is negatively correlated with the development lead-time and outsourcing ratio, i.e., the development lead-time and outsourcing ratio decrease, and total output increases with a higher platform ratio and greater in-house technical contribution. Next, development lead-time is negatively correlated with the platform ratio and level of in-house technical contribution, i.e., development lead-time decreases when the platform ratio increases and level of in-house technical contribution ratio increase. Next, the price index decreases when development lead-time decreases (positive correlation) and when the level of in-house technical contribution increases

Table 2. Changes in Canon's digital camera production and product development factors

| | *1996* | *1997* | *1998* | *1999* | *2000* | *2001* | *2002* | *2003* |
|---|---|---|---|---|---|---|---|---|
| Total Production Volume（K） | 40 | 80 | 140 | 320 | 970 | 2450 | 5300 | 8920 |
| Overseas Production Ratio (%) *1 | 0 | 0 | 0 | 0 | 0 | 2 | 34 | 44 |
| In-house Production Ratio (%) *2 | 100 | 80 | 100 | 100 | 100 | 100 | 100 | 100 |
| Outsourcing Ratio (%) *3 | 69 | 69 | 69 | 69 | 69 | 68 | 69 | 67 |
| Price Index (¥10K /1million pixels) *4 | 22.46 | 21.2 | 9.7 | 5.18 | 3.33 | 3.33 | 2.26 | 1.26 |
| Platform Ratio (%) *5 | 0 | 0 | 0 | 0 | 25 | 63 | 60 | 45 |
| In-house technical contribution (%) *6 | 23 | 23 | 23 | 23 | 31 | 32 | 31 | 33 |
| Development Lead-time (week) *7 | 140 | 140 | 140 | 140 | 50 | 50 | 50 | 40 |

(Note) Data in the table was provided by Canon. *1: Production overseas is at the corporate factories in Malaysia, Zhuhai (China), and Taiwan. *2: Received OEM supply from Matsushita Electric only in 1997. *3: Variable cost structure consists of the lens unit (23%), liquid crystal panel (14%), CCD (17%) and ASIC (8%), other parts (9%), memory (4%), and accessories such as adapter and battery (25%). The lens unit and ASIC were produced entirely by Canon, with the CMOS to partially substitute for the CCD produced in-house starting in 2001. *4: Price index is the market price (10,000 yen) per the number of pixels (units of 1 million pixels). *5: Platform Ratio means the ratio of products by platform in Table 1 of the products sold that year. *6: In-house technical contribution represents "Black Box" technology that is the company's particular technology, such as the image-processing engine "Digic" introduced in 2000. In this table, it indicates the ratio of modules with these two technologies in the total variable cost. *7: Development lead-time expresses the period from planning to the start of production.

(negative correlation) .

Here, hypotheses are tested using the case of Canon. First are hypotheses 1 and 2, but the conditions of commoditization are an increase in the production volume and decrease in price. The results of correlation analysis indicate requirements to increase the production volume; in order to increase the total production volume, a firm has to increase production overseas, to reduce product development lead-time, and to decrease the module outsourcing ratio while forming platforms and actively using in-house technology. To establish a competitive price, requirements are reduced product development lead-time and active use of in-house technology. Thus, the Canon case affirms hypothesis 1 that, if a main module market is formed and entrants proceed to form a similar platform, commoditization is promoted. Next, improvement in the performance of main modules and the horizontal specialization cannot be discussed with regard to hypothesis 2. Finally, hypothesis 3, regarding the relationship between excess profit and "black-box" handling of technology, is likely to be affirmed based on the results of the level of in-house technical contribution contributing to total output and reduced development lead-time[7].

Table 3. Correlation Coefficient Between Canon Product Development Factors (Pearson's Correlation Coefficient)

| | Volume | Overseas | In-house | Lead-time | Outsource | Price Index | Platform | Technology |
|---|---|---|---|---|---|---|---|---|
| Total Volume | 1.000 | **. 964**** | .275 | **-.743*** | **-.799*** | -.600 | **.718*** | **.765*** |
| Overseas Production | **.964**** | 1.000 | .223 | -.627 | -.636 | -.505 | .620 | .635 |
| In-house Production | .275 | .223 | 1.000 | -.377 | -.204 | -.595 | .346 | .375 |
| Development Lead-time | **-.743*** | -.627 | -.377 | 1.000 | .586 | **.757*** | **-.910**** | **-.997*** |
| Outsourcing | **-.799*** | -.636 | -.204 | .586 | 1.000 | .447 | -.549 | -.646 |
| Price Index | -.600 | -.505 | -.595 | **.757*** | .447 | 1.000 | -.649 | **-.754*** |
| Platform | **.718*** | .620 | .346 | **-.910**** | -.549 | -.649 | 1.000 | **.916**** |
| Technological Contribution | **.765*** | .635 | .375 | **-.997**** | -.646 | **-.754*** | **.916**** | 1.000 |

(Note) Significance Level: **1% *5%

### 3-2 Modularization of the Digital Camera Industry

The functional information obtained from the specifications of a digital camera is limited. Table 4 indicates the typical changes in the features of a digital camera. As understood from Canon's example in Table 1, the purpose of this work is to analyze the relationship between the features of Fixed-lens and Digital Single-lens Reflex cameras. Here, items that can be judged by dichotomy are discussed, and Price per number price of pixels is not discussed since it is continuous value[8]. First, a conversion system is a system for processing image data captured by the digital camera and it has marked tendencies from complementary to primary colors[9]. A lens system can be classified as a fixed-lens or single-lens reflex camera. Although there was a technical problem with the combination of a large diameter lens and a small CCD element in that distortion arose on the edges of the picture, technology for design of an independent large CCD element was established centering on an

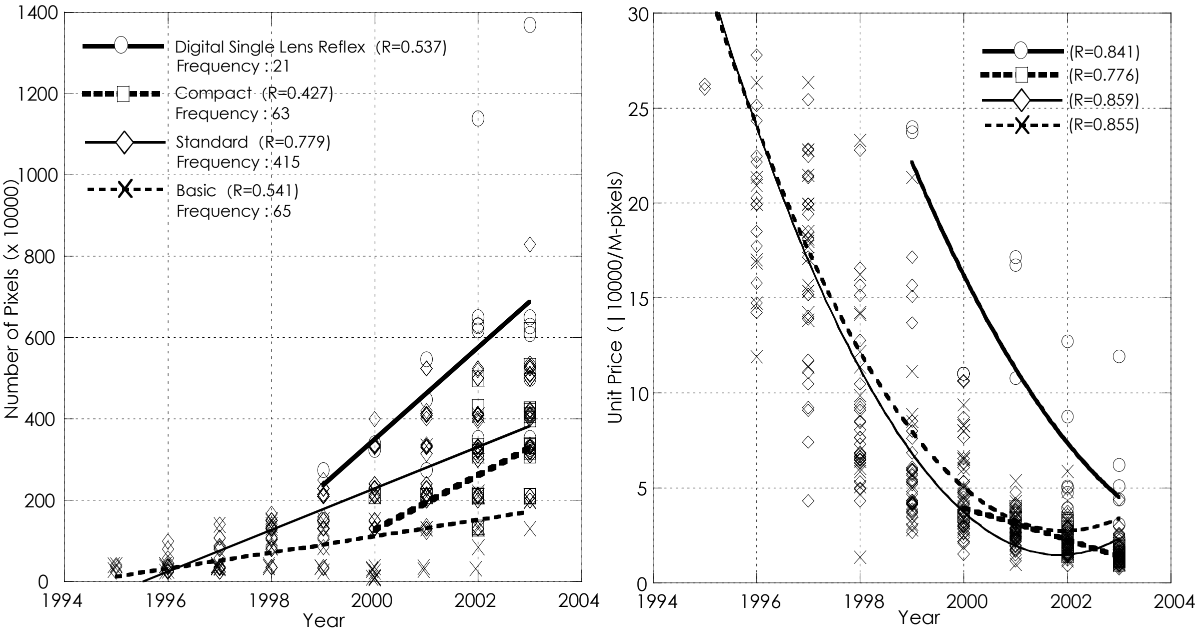
Table 4. Changes in a Digital Camera’s Main Specifications

| Year | Filter | | Lens | | Memory | | Finder | | Monitor | | Power | | Interface | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Com. | Prim. | Fixed | SLR | Inside | Card | Other | Optical | None | LCD | Exclusive | Standard | Exclusive | USB |
| 1995 | 6 | 1 | 7 | 0 | 4 | 3 | 2 | 5 | 5 | 2 | 3 | 4 | 7 | 0 |
| 1996 | 21 | 7 | 27 | 1 | 14 | 14 | 9 | 19 | 10 | 18 | 6 | 22 | 28 | 0 |
| 1997 | 32 | 14 | 46 | 0 | 15 | 31 | 19 | 27 | 6 | 40 | 9 | 37 | 45 | 1 |
| 1998 | 29 | 18 | 47 | 0 | 2 | 45 | 12 | 35 | 2 | 45 | 13 | 34 | 47 | 0 |
| 1999 | 22 | 35 | 55 | 2 | 2 | 55 | 8 | 49 | 2 | 55 | 18 | 39 | 46 | 11 |
| 2000 | 28 | 51 | 77 | 2 | 9 | 70 | 17 | 62 | 10 | 69 | 29 | 50 | 16 | 63 |
| 2001 | 25 | 66 | 88 | 3 | 6 | 85 | 15 | 76 | 9 | 82 | 37 | 54 | 6 | 85 |
| 2002 | 14 | 84 | 92 | 6 | 5 | 93 | 21 | 77 | 1 | 97 | 55 | 43 | 2 | 96 |
| 2003 | 0 | 109 | 96 | 15 | 0 | 111 | 23 | 88 | 1 | 110 | 60 | 51 | 2 | 109 |
| total | 177 | 385 | 535 | 29 | 57 | 507 | 126 | 438 | 46 | 518 | 230 | 334 | 199 | 365 |
| Fixed lens | -.083 | **.932**** | 1 | .690* | -.309 | **.981**** | **.834**** | **.987**** | -.211 | **.985**** | **.923**** | **.932**** | -.427 | **.910**** |
| SLR | **-.692*** | **.884**** | .690* | 1 | -.487 | **.785**** | .642 | **.752*** | -.450 | **.783*** | **.859**** | .505 | -.568 | **.795*** |

(Note) Significance Level: **1%, *5%, Com.: Complementary, Prim.: Primary optical apparatus company in 2001. Numerous digital single-lens reflex cameras were commercially released in 2003.Specifications for memory are largely external storage media, i.e., memory cards. The finder has diversified[10]. Although the ratio of optical finders is seen here, there are also numerous non-optical types such as liquid crystal finders. A liquid crystal display monitor is a standard specification for almost all of the models in Table 4. There are two types of power supply; one is designed to use general-purpose dry cells and the other an independently designed battery. For example, a general-purpose dry cell is too large to use in a compact digital camera. Last, a USB interface became the norm in 2000.

The correlation coefficients of fixed lens and SLR cameras are shown in the last two lines of Table 4. The differences in the correlations between single-lens reflex and fixed-lens cameras are that the single-lens reflex camera has a strong correlation with both complementary and primary color conversion systems, an optical finder, and independently designed power supply; the fixed lens camera has a correlation limited to primary color conversion systems and a strong correlation with optical finders and other finders and both general-purpose dry cells and am independently designed power supply.

Fig. 2. Number of Pixels and Unit Price Changes for Each Type



To easily understand these trends, digital cameras are classified into four types: single lens reflex, compact, standard, and basic cameras[11]. Hereafter, analysis proceeds according to this classification. Figure 2 shows the changes in pixels (figure on left) and the unit price per 1 million pixels by year, and estimated regression equation (figure on right) for each type of digital camera is depicted[12]. In addition, the product names of each entrant are shown.

A digital single-lens reflex camera can be distinguished by use of a large diameter lens and large optical element with a high number of pixels and by replaceability of the lens. The number of pixels has rapidly increased from 2 million pixels in 1999 to 6.5 million pixels in 2003. The compact camera has an independently designed power supply, weight of less than 200g, and it is easy to distinguish by the specific product name. Discrimination between standard and compact cameras is based on whether a general-purpose battery is

Table 5. Optical Element Size and Degree of Concentration

| Optical Element Size | 1/1.8 | | 1/2.7 | | 1/3.0 | | Others | | No. of | Pixels | Price |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | No. | (%) | No. | (%) | No. | (%) | No. | (%) | Products | (x10,000) | (¥10,000) |
| 1995 | 0 | 0.00 | 0 | 0.00 | 2 | 28.57 | **5** | **71.43** | 7 | 36.00 | 38.60 |
| 1996 | 0 | 0.00 | 0 | 0.00 | **16** | **57.14** | 12 | 42.86 | 28 | 39.71 | 24.16 |
| 1997 | 0 | 0.00 | 0 | 0.00 | **25** | **54.35** | 21 | 45.65 | 46 | 48.52 | 16.03 |
| 1998 | 0 | 0.00 | **14** | **29.79** | **16** | **34.04** | 17 | 36.17 | 47 | 109.60 | 8.47 |
| 1999 | 0 | 0.00 | 7 | 12.28 | 8 | 14.04 | **42** | **73.68** | 57 | 160.73 | 6.51 |
| 2000 | **23** | **29.11** | **20** | **25.32** | 10 | 12.66 | 26 | 32.91 | 79 | 223.17 | 4.25 |
| 2001 | **30** | **32.97** | **30** | **32.97** | 8 | 8.79 | 23 | 25.27 | 91 | 279.96 | 3.51 |
| 2002 | **32** | **32.65** | **39** | **39.80** | 1 | 1.02 | 26 | 26.53 | 98 | 323.14 | 2.86 |
| 2003 | **23** | **21.10** | **44** | **40.37** | 0 | 0.00 | 42 | 38.53 | 109 | 384.64 | 1.70 |
| Total | 108 | 19.22 | 154 | 27.40 | 86 | 15.30 | 214 | 38.08 | 562 | - | - |
| Correlation Coefficientt (Pixels) | **.838**** | | **.906**** | | **-.889**** | | -.539 | | - | - | - |
| Correlation Coefficient (Unit Price) | -.641 | | **-.814**** | | .626 | | .595 | | - | - | - |

(Note) Significance Level: **1%, *5%

used or not. The basic type has a low price with less than 2 million pixels and is identified by a different product name than the standard type.

Table 5 indicates the relationship between changes in optical element size, the number of pixels in all products sold that year, and the average unit price to verify modularization in the digital camera industry. In total, 19 kinds of optical elements were used from 1995 to 2003. However, the actual optical element used in digital cameras is concentrated in three sizes shown in Table 5. Although a 1/3.0-inch optical element was mainly used from 1996 to 1999, a 1/2.7-inch and a 1/1.8-inch optical element were used in more than 60% of cameras after 2000. This trend is the same as that in the Canon case as shown in Table 1, and it is highly possible that platform forming by lens module and optical element is progressing not only at Canon but in the whole industry. The basis for this possibility is surmised from the Pearson's correlation coefficient among the number of pixels, change in pixel unit price, and the optical element used as shown in Table 5. First, the increase in the number of pixels becomes significant at 1% with each of three optical elements, displaying a high level of correlation. A platform is formed to increase the number of pixels within such optical element sizes; that is, optical elements recognized as an industry standard have been a major influence on the increase in the number of pixels. Furthermore, the unit price per number of pixels has a negative correlation with the 1/2.7-inch optical element. That is, the drastic price depreciation of a digital camera is related to the diffusion of the 1/2.7-inch optical elements. This fact is also completely consistent with the Canon case in Table 1.

As mentioned above, changes in the whole digital camera industry as a whole have been investigated from various angles. Hypotheses will be verified to conclude this section. First, as shown in Fig. 2, the price depreciation of digital cameras is abrupt, although its performance is improving markedly. As shown in Fig. 2 in particular, the price per million pixels had drastically fallen by 2001. That is, digital cameras except digital single-lens reflex cameras have been commoditized since 2001. In this stage, as shown in Table 5, large

1/1.8-inch optical elements are mainly used in standard types and small 1/2.7-inch ones in compact ones; therefore, as shown in Table 2, the greater part of specifications has been homogeneous. That is, the main module market was established, and when the entrants proceeded to form of a similar platform, this resulted in commoditization of digital cameras, suggesting establishment of hypothesis 1. Moreover, the phenomenon of homogenization of products, as exemplified by the number of pixels changing at the same pace in the industry as a whole, is thought to result from individual entrants forming similar platforms and using optical elements with the maximum number of pixels available on the market in combination with the development of optical elements, their main module. In other words, the hypothesis that product homogenization is governed by performance of the main module, is affirmed. Thus, results suggesting affirmation of hypotheses 1 and 2 were indicated.

## 4. Analysis of Product Competitiveness

Stated reasons for the homogenization of product specifications of digital cameras are that most modules are commonly used among by entrants and product performance is governed by the module supplier. This section discusses how entrants implement product strategy amidst competition and how product competitiveness is established. Furthermore, hypotheses are tested and the discussion is concluded.

### 4-1 Strategy Analysis of Entrants

What is the factor dominating the product competitiveness of the digital camera? In order to reply to this question, changes in specifications were investigated in the preceding section. The result is that many features became homogenized, while the number of pixels continuously increased with a fixed size of the optical element. This section discusses what product development strategy each company has created in such an industry structure.

A characteristic of the digital camera industry is that all entrants had completed commercial production in the two years from 1995 to 1997. Therefore, the digital camera industry's peculiarity is that a forerunner and a new entrant cannot be clearly distinguished. This factor is thought to be because a digital camera is a product that continues to be technologically influenced by optical and video cameras[13] and companies in both industries entered into the digital camera industry. As a result, competition became intense since both optical companies and electric companies entered the market. There were two turning points in this competition. The first was in 1999 when the digital camera overtook the APS camera with a market that had started at almost same time in terms of total production volume, and the second was in 2001 when the volume of optical cameras as a whole was surpassed. The companies that perceived this turning point are Sony, Olympus, Fuji Film, and Canon. Sony and Olympus quickly increased their new products starting in 1990. Canon provided new value with series such as compact cameras named IXY and digital single-lens reflex cameras named EOS Digital. As a result, companies that perceived these turning points increased sales.

There are three levels of customer demand in the digital camera industry. [14]. First is the demand level of 2 million pixels or less, as used primarily in web pages that would later compete with the digital camera feature of cellular phones. Next is the level for people who casually enjoy photographs, where 2 million or more pixels are required. Then, there is a demand for digital single-lens reflex cameras used by professional photographers and enthusiasts, and several features are required such as images with no distortion due to combination of large diameter lenses and resolution of 6 million pixels or more and high-speed exposure. That is, the competitive structure of the digital camera industry consists of two different vectors that coexist in the market, one that seeks successive improvements in the number of pixels and quantitative expansion with the same quality and one seeking new value creation such as with digital single-lens reflex cameras.

For example, development of digital single-lens reflex camera is completely different. First, the modules are independently designed for every product. In the Canon example, the 22.7x15.1-mm and 28.7x19.1-mm CMOS elements and 35.8x23.8-mm CCD element are developed exclusively, and they are produced commercially with independent specifications in combination with an independently designed image processing engine. Furthermore, a digital single-lens reflex camera requires high-speed exposure. A digital camera has features where an optical element captures images and writes digitally converted information to storage medium, but the feature of instantly processing enormous amounts of image information with huge numbers of pixels depends on the performance of the image processing engine independently designed by each company. Furthermore, extremely advanced integration is required such as providing raw data before filtering, designing dedicated power circuits, and anti-dust features for large optical elements. The platform has yet to be formed.

### 4-2 Role of Modularization in Competition

The competitive structure of the digital camera industry has been analyzed. Platforms were formed by combining modules for successive product improvements such as an increased number of pixels and reduced weight, and a new market, the digital single-lens reflex camera, was born. Figure 4 shows the relationship between the direction of product development and modularization. Each issue is discussed here. First, although technical development was implemented by many companies in the late 1980s, the digital camera was not intended to replace the silver hydride camera at the beginning[15]. Thus, product development in a stage where customer demands could not be satisfied required improvement of the product performance by trial and error using independently designed modules and devices, since neither the module nor the device market was complete.

Then, when customer demand was satisfied and the surplus performance was produced, the main module market was established, and horizontal specialization in the industry proceeded. Figure 4 depicts this situation, where the module market was formed and companies sought to improve performance with various module configurations from 1995 to 2000.

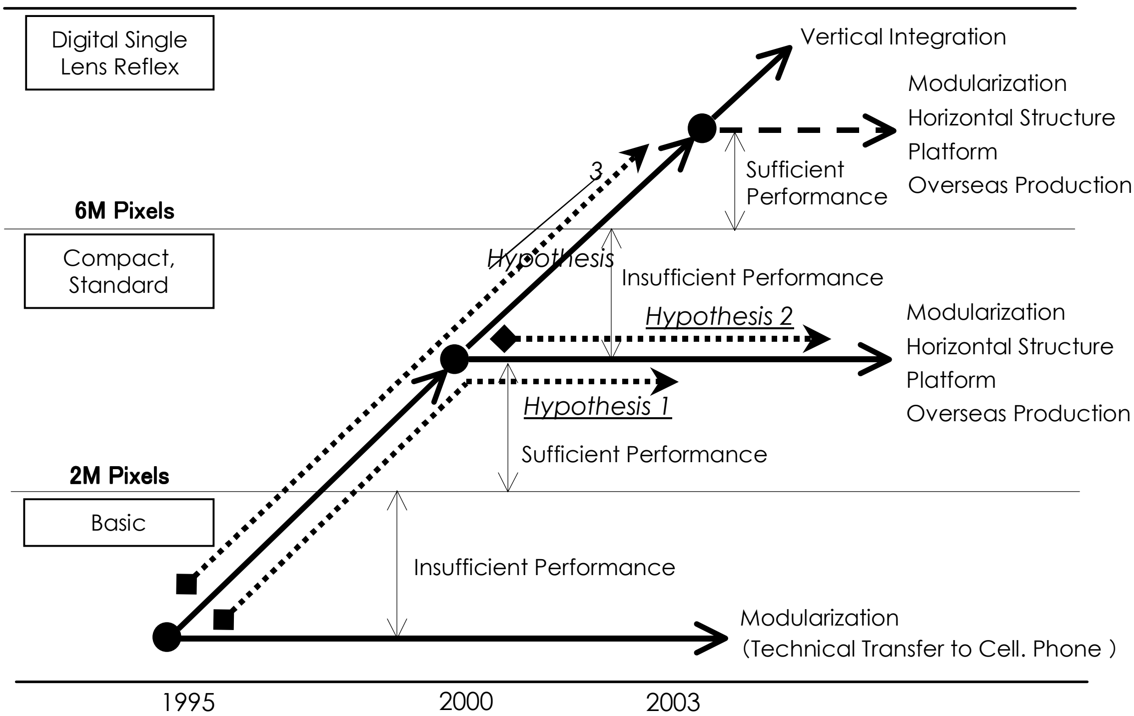
As understood from Canon's case in Table 1, a unified platform was not formed during this period. After 2000, platforms were formed by each company and product development has been proceeding in accordance with the improved performance of the module itself. Establishment of such a platform made overseas production easy, the rapid fall of the product price started due to expanded productivity, and commoditization was promoted. This situation is apparent from the rapid homogenization after 2000 in Tables 4 and 5 and Fig. 2. Therefore:

Hypothesis 1: If a main module market is formed and entrant companies proceed with formation of a similar platform, commoditization is promoted.

can be expressed by the vector of hypothesis 1 in Fig. 4.

Next, 1/1.8-inch and 1/2.7-inch optical elements, made by Sony, have a market share of 60% or more for the industry as a whole, as is obvious from the Canon case in Tables 1 and 5 that. The entrants established platforms by combining optical elements in these sizes and lens module made by Canon or Tamron and improved the number of pixels in accordance with development of optical elements after 2000. Therefore: Hypothesis 2: Homogenization of a product is governed by the product performance of main modules. That is, homogenization becomes marked as the horizontally specialized structure of

Fig.4. Product Development and Modularization in the Digital Camera Industry



the industry progresses can be expressed by the vector of hypothesis 2 in Fig.4.

Furthermore, commoditization in which the price decline becomes constant for compact and standard digital cameras with an established platform occurred after 2000 as shown on the right in Fig. 2. By extension, a price rise, or de-commoditization in other words, is not seen.

However, digital single-lens reflex cameras have displayed a relatively small price decline and have excess profit. Again, this excess profit was produced by the new market value that happened when the product architecture was reconsidered and product integration took place again in order to compensate for insufficient performance in higher-level markets.

For example, a dedicated image-processing engine was developed, an independent body structure that mounted a lens for single-lens reflex use was designed, and vertical integration of product structure had taken place in circumstances requiring compensation for insufficient performance with respect to customer demand level. That is, black-box technology such as independent lens mounting and image processing technology has yielded excess profit. Therefore,

Hypothesis 3: De-commoditization cannot be realized by technical innovation without platform changes. That is, technology must be "black-box" accompanied by changes in architecture in order to obtain excess profit.

can be expressed by the vector of hypothesis 3 in Fig. 4.

## 4-2 Conclusion

The purpose of this paper has been to inquire about the relationship between product development factors of modularization and platforming, industrial structure, and market structure, and to consider the problem of black-box technology. In the other words, the purpose of this paper is to consider the fact that, despite being in a competitive industry, Japanese firms' profit level is clearly low compared to that of other industries and firms overseas, and to examine the common idea that the black-box technology is required to maintain and improve industrial competitiveness.

This paper focused on the concept of a module and analyzed it. Specifically, the modules used in the digital camera industry are very uniform, and entrants are competing while establishing similar platforms using lens modules, optical elements, image-processing engines, liquid crystal modules, power supply, and memory cards. However, such competition will leave product specifications with the technology of the module supplier at the stage when the platform is formed, and as a result, product differentiation from other companies will become difficult using the same modules. Therefore, when modularization progress and platforms are established, the product will be commoditized since product differentiation becomes difficult, and corporate profits will suffer (Christensen and Raynor, 2003). Although this paper indicated that corporate profits will suffer due to modularization despite being in such a strong industry, how should a company face the problem of such commoditization? This paper showed there were three countermeasures to this problem. First, with regard to production, the rate of external procurement to variable cost should be decreased, in-house/independent technology should be utilized, and development lead-time should be reduced. Second, with regard to the price decline, development lead-time should be reduced and the rate of modules using in-house/independent technology to variable cost should be lowered. Third, platforms should be established and in-house/independent technology should be utilized to reduce the development lead-time.

To conclude the discussion, in order for a company to gain a high profit it should first handle module technology essential to platform formation by other companies as "black box" and actively use its own products. Second, in order to satisfy requirements to ensure profit it should specify higher-level customer markets and combine different modules or revamp modules themselves and create a completely new product architecture.

Footnote:

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1 This Software offers the fundamental functions commonly used among many application software, and manages the whole of computer systems. It is also called "Basic Software." By using the function offered by OS, the software programmer can save the time and effort of development, and can unify the operability of application. There are two types of OS, one is for personal computers and another embedded type used for many electric equipment.

2 This information became clear in an interview with the research and development division of Kodak, where the digital camera has been under development since the 1980s.

3 APS: Advanced Photo System also known as a "new system camera." APS is the common protocol of five companies, Kodak, Fuji Film, Canon, Minolta, and Nikon. The film used in this camera is different from a conventional camera. It is compact and in cartridge form. The film records data electromagnetically unlike a conventional camera. It was also possible to print messages and to record print types (C, P, and H) for individual photos in addition to the usual date function、 Furthermore, photography conditions could be recorded for individual photos and suitable correction was also possible during printing. It was also technically possible to record voice data, but this did not become a big market since the digital camera came to market before this feature was adopted in products.

4 These product specifications for recent models were collected from various media such as catalogs, technical magazines, and the homepage of each company. The market price is the accumulated data understood as the unit price, ¥10000 per million pixels, as was collected from volume discount stores and mail order sites. Compensation via a price index has not been applied. The market price fluctuates sharply when the model is older; therefore, prices in March and December, when sales are active, were referred to as much as possible. The data for the shipping volume of each company and market share data were provided by the Japanese Camera Association.

5 CCD: Charge Coupled Device. The CCD is the element that transforms optical energy into an electric signal and converts an optical image into electronic format. It is a main part of a digital camera. CMOS: Complementary Metal Oxide Semiconductor. Compared to CCD, CMOS has advantages in that it operates with about $1/10^{th}$ of the electric power and at a lower voltage, and combination with peripheral circuits is also possible. Although it had a disadvantage of less sensitivity compared to CCD, improvement has been proceeding. Lower power consumption and miniaturization are expected for new imaging elements in digital cameras.

6 Correlation is a situation where data accumulates in the first and third quadrants when two average values(x,y) become the origin of the coordinate axes (0.0) and axes are drawn. It is possible for the correlation between two variables to also be shown by covariance since covariance is influenced by measurement units as well as distribution, although comparison with other joint distributions with differing distribution cannot be performed. Thus, covariance is divided and normalized by the standard deviation (sx, sy) of two variables, and the index not depending on a measurement unit is defined as r=sxy/sxsy as Pearson's correlation coefficient. Pearson's correlation coefficient takes a value between -1 to 1; data is aligned on a straight line rising to the right on a correlation diagram when a correlation coefficient is 1, and conversely, it is aligned on a straight line leading down to the right when the correlation coefficient is -1. The above-mentioned correlation coefficient is a linear correlation coefficient when two variables are interval scales or ratio scales.

7 Although Canon's case was taken up in this chapter, study of Sony, Nikon, and Sanyo was also conducted. Sony has established six platforms since 2000 and Nikon has established three platforms since 2001, and it seems that the same analysis results as for Canon will be obtained.

8 The number of pixels in a digital camera expresses the number of elements used that are light-receiving portions of the CCD. The number of elements changing light into electronic signals is an important aspect that measures the performance of the digital camera. When the number of pixels is larger, a larger number of pixels receive and convert light into data, and more information can be records. When the digital camera was firstly released on the market, a model with 300,000 pixels was mainstream. Now, however, models carrying a high-pixel CCD with over 3 million pixels called

"Megapixel" models are standard.

9 CCD used in digital cameras can basically only record black and white images. Therefore, a filter is also used and color is reproduced. Every element in CCD is equipped with a filter and Primary Color Filters reproduce colors in images by allowing light of the respective color R (red), G (green), or B (blue) to pass.

A filter is equipped with a complementary filter to complement RGB. Since a complementary filter uses complementary colors, the amount of light passing through and increases, so it has the advantage of increased sensitivity, but it also has a disadvantage in that complicated data processing is needed to reproduce color. In contrast, a primary color filter has the advantage of vivid color, so complicated data processing is unnecessary although sensitivity is not high. A tendency in recent years has been an increasing combination of large caliber lenses and a primary color filters.

10 An optical finder means the window of the camera to look through during photography. Although it is simply called a "finder" in a silver halide camera, it is called an "optical" finder in order to distinguish it from an LCD monitor since a liquid crystal display monitor can be used as a finder in a digital camera. Here, the filter operating with the image to photograph, i.e., the finder where the image can be seen through the lens, is called an "optical finder." An example is a finder where the image in the finder also appears to be magnified when zooming in. In contrast is an electronic finder, which attaches a liquid crystal display and projects the picture actually captured.

11 When a chi-square test was performed on each type of digital camera with regard to the weight and the number of pixels, it became significant with 0.5% probability of asymptotic significance. Therefore, such a classification can be judged to be statistically significant.

12 The market price here uses the value that averaged the sticker price per 1000 yen at a volume retailer. These sticker prices are collected from two or more price comparison Web sites. The difference in the digital camera market price among volume retailers is small, and there is comparatively little variation.

13 Indicates a camera that uses silver halide film. It is normally called an optical camera, but a digital camera is also optical. Since such a name was used by the Japanese Camera & Imaging Products Association, this distinction has been followed.

14 This was confirmed at an interview with the Japanese Camera Association. Industry statistics here were created by classification of cameras as those with less than or more than 2 million pixels. In addition, a level of 6 million pixels or more has been requested by users of optical single-lens reflex cameras according to survey results from the Japanese Camera Association.

15 Companies such as Fuji Film, Sony, and Kodak conducted technical development aimed at a technical breakthrough in digital cameras in the latter half of the 1980s. An interview was conducted in May 2004 with Mr. Nanai, former director of Kodak's digital camera research and development from the end of the 1980s to the birth of the digital camera in 1995. "At the time, no one thought that digital camera technology would catch up to the image quality of silver halide film. However, we thought that there were special uses such as studio use, so development was actively implemented. Kodak had developed a 1 million-pixel CCD earlier than other companies but was not able to take the lead in the digital camera industry in spite of its advantageous position. The sales and profit from silver halide film were enormous at the time while the sales of the first digital camera were extremely small by contrast because of its rough appearance." That is, the early digital camera was not meant so to replace the silver halide camera but was developed for special uses.

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