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Introduction

The semiconductor industry typifies the reversal in industrial dominance between Japan and the US in the 1980's and the re-reversal that occurred in the 1990's. From the 1970's to the 1980's, Japan's trade surplus with the United States increased conspicuously in many industries, such as the steel, color TV, automobile manufacturing, machine tool and semiconductor industries, and this resulted in much trade friction. In the 1990's, however, the 're-reversal' of this industrial dominance between Japan and the US suddenly became the focus of attention. It is difficult to claim that such a re-reversal has occurred in the steel or machine tool industry and it is even doubtful that it has occurred in the automobile industry, although, to be sure, the US auto manufacturing has experienced a notable rejuvenation. As far as the color TV industry is concerned, American manufacturers have all but disappeared. In contrast, in the semiconductor industry, many US companies, including Intel, have achieved excellent results, while Japanese companies struggle in the face of severe competition and a price decline in DRAM product lines. The semiconductor industry, therefore, most typifies this re-reversal in industrial dominance between Japan and the United States. This paper will discuss the actual current status of this re-reversal between Japan and the US and the factors that have brought it about.

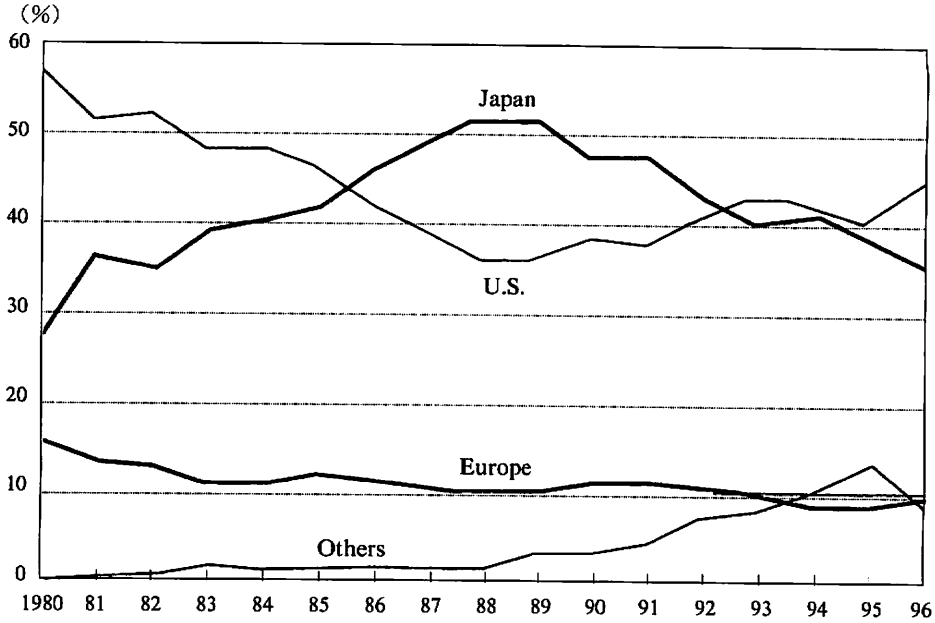
1. Reversal and the factors behind it

(1) Process of reversal between Japan and the U.S.

The dominating position that was held by US semiconductor companies, which created and developed the industry, was first threatened in the latter half of the 1970's. In 1975, the United States accounted for 58% of global IC production. This share began to sink gradually, decreasing to 50 percent in the early 1980's, and to 47 percent in 1984. As the European production share also decrease, it was Japanese that threatened the dominance of the US industry. Between 1975 and 1984, Japan's share of IC production increased from 19 percent to 36 percent[1]. The production share of semiconductor manufacturers by nationality revealed a similar trend. As shown in Figure 1, the share of the US companies continued to decline while that of Japanese manufacturers continued to rise since the mid-1970's, finally reversing their shares by the mid-1980's. This trend was reflected in company rankings by total sales, where Japanese companies monopolized the top three positions (Table 1).

It is, however, the reversal of market share for MOS memory circuits, especially

Figure 1 Market Share of Semiconductor Companies by Country



Source: *"IC guide Book"*, p. 18.

Table 1 Semiconductor Company Rankings by Year

	1981	1986	1989	1992	1995	1996	1997
1	TI (US)	NEC (JPN)	NEC (JPN)	Intel (US)	Intel (US)	Intel (US)	Intel (US)
2	Motorola (US)	Hitachi (JPN)	Toshiba (JPN)	NEC (JPN)	NEC (JPN)	NEC (JPN)	NEC (JPN)
3	NEC (JPN)	Toshiba (JPN)	Hitachi (JPN)	Toshiba (JPN)	Toshiba (JPN)	Toshiba (JPN)	TI (US)
4	Hitachi (JPN)	Motorola (US)	Motorola (US)	Motorola (US)	Hitachi (JPN)	Motorola (US)	Motorola (US)
5	Toshiba (JPN)	TI (US)	Fujitsu (JPN)	Hitachi (JPN)	Motorola (US)	TI (US)	Toshiba (JPN)
6	NS (US)	Philips (EU)	TI (US)	TI (US)	Sansei (KRA)	Hitachi (JPN)	Hitachi (JPN)
7	Intel (US)	Fujitsu (JPN)	Mitsubishi (JPN)	Fujitsu (JPN)	TI (US)	Sansei (KRA)	Sansei (KRA)
8	Matsushita (JPN)	Matsushita (JPN)	Intel (US)	Mitsubishi (JPN)	Fujitsu (JPN)	Fujitsu (JPN)	Fujitsu (JPN)
9	Philips (EU)	Mitsubishi (JPN)	Matsushita (JPN)	Philips (EU)	Mitsubishi (JPN)	Mitsubishi (JPN)	Philips (EU)
10	Fair Child (US)	Intel (US)	Philips (EU)	Matsushita (JPN)	Gendai (KRA)	Gendai (KRA)	Mitsubishi (JPN)

Source: *"IC guide Book"* 1997, p. 18, *"Semiconductor Data Book"*, 1998.

DRAM, that was most convincing in regard to the reversal between Japan and US industrial dominance. Intel developed the 1K DRAM in 1970 and until the mid-1970's, US companies were unchallenged in this market. However, the situation changed drastically after Japanese semiconductor companies, which used to produce primarily ICs for consumer products, entered the memory market for computers. As is well known, new product generations of DRAM, featuring higher degrees of integration, appear every three years. Japanese semiconductor companies began to increase their market share in 16K DRAM, surpassed their US rivals in 64K DRAM, and finally accounted for 90 percent of the global market in 256K DRAM production. On the other hand, the DRAM market share for US companies decreased to around 50 percent by the end of the 1970's, and to less than 10 percent by the mid-1980's when the 256K DRAM prevailed[2].

The reversal between Japan and the US in the DRAM market was particularly

noteworthy for two reasons. First, US semiconductor companies, which had developed by focusing on ICs for military and industrial applications, rapidly lost market share and were almost annihilated in the memory IC market, one of the main products for such applications. Trade friction between Japan and the United States in the IC industry occurred as early as the latter half of the 1970's when the United States still held a trade surplus with Japan in this industry. It must have reflected a sense of crisis on the part of US semiconductor companies, with respect to the rapid growth of Japanese companies producing DRAM.

Second, the reversal of dominance in this industry was felt to be a serious matter because DRAM used to be considered a technology driver. As DRAM required the most advanced minute processing technology, it was believed that companies with technological advantages in this area were prerequisite for semiconductor technology as a whole[3]. The sense of crisis triggered by the threat that Japanese semiconductor companies would take a dominant position in an extensive IC product line prevailed among political as well as business circles in the United States and resulted in the establishment of SEMATIC (Semiconductor Manufacturing Technology Institute)[4].

(2) Factors leading to reversal

What were the factors resulting in the reversal of industrial dominance in the area of DRAM production? Competitive advantages in the production of memory IC, including DRAM, stem from proficiency in the use of advanced minute processing technology rather than the capacity to design breakthrough-type products. The reversal of these particular characteristics regarding DRAM production was the result of product quality, cost-competitiveness, and capital investment. However, as will be discussed in more detail later, cost-competitiveness is a function of how quickly a new product generation is embarked upon, and quality control. Therefore, reversal should be attributed to two factors, namely, quality control and capital investment.

Two measures of product quality are defect ratios after shipment and yield ratios during the manufacturing process. Hewlett Packard released data in 1980 that proved the difference between Japanese semiconductor companies and their American counterparts in terms of defect ratios after shipment. The company evaluated memory ICs made by Japanese companies and US companies for several years, and discovered that ICs from Japanese companies consistently demonstrated lower defect ratios. Best US company had defect ratios six times as high as the best and three times as high as the worst Japanese manufacturer. The defect ratio of the worst US company was as much as twenty seven times as high as that of the best Japanese company. Later, Xerox announced a similar comparison result between Japanese and US semiconductor companies[5].

Data also exist that demonstrated a considerable difference between Japanese and US semiconductor manufacturers in terms of yield ratios during the manufacturing processes. Finan and LaMont (1985) show that, at the first stage of 64K DRAM generation, the yield ratio in the diffusion process of US semiconductor companies was 40 percent while that of the Japanese companies was 52 percent. Similarly, yield ratios in the assembly process of US companies was 90 percent whereas that of Japanese companies was 95 percent. In the case of 256K DRAM, which required precise process control including control of clean rooms, the difference between Japanese and

US companies widened. At one point, the overall yield ratio in the whole manufacturing process from diffusion to assembly of US companies was 17 percent and that of Japanese companies was 54 percent[6].

This difference between yield ratios had a marked influence on competitiveness including cost advantages and profitability. Finan and LaMont (1985) explain that although Japanese semiconductor companies spent more on material and equipment, they were compensated by higher yield ratios, and thus gained advantages over their US competitors regarding cost per defect-free IC chip. Of course, every manufacturer can ultimately improve yield ratios with time. This is known as the learning curve and claims that production costs will be reduced by 30 percent because of improved yield ratios when the cumulative production volume is doubled. The crux of the matter is how early semiconductor companies can realize high yield ratios in the early stages of a product generation. A cyclical pattern in price of memory IC, typically DRAM, is generated because prices can be maintained at higher levels in the beginning stage because of a discrepancy between supply and demand, but fall sharply when supply rises following increased capital investment. Therefore, semiconductor companies which can obtain profits before prices decline become the winners for that generation of DRAM. US semiconductor companies, which lagged behind Japanese rivals in mass production of 256K DRAM and in improvement of yield ratios, were annihilated in memory IC. In terms of cost competitiveness, appreciation of the US dollar against the yen during the Reaganomics era was another burden for US semiconductor companies.

How did the difference in quality control between Japanese companies and their U.S. counterparts come about? Some researchers have attributed this difference to the location of assembly plants. Seeking a labor cost advantage, US semiconductor companies established assembly plants in Southeast Asia, but quality control proved insufficient. In contrast, Japanese semiconductor companies, restrained by the practice of long term employment, maintained domestic assembly plants and automated the assembly process in order to cope with the steep rise in labor costs. In this way, differences in the location of assembly plants is said to have resulted in differences of quality achieved by Japanese and US manufacturers[7]. However, this explanation does not account for the difference in yield ratios in the diffusion process.

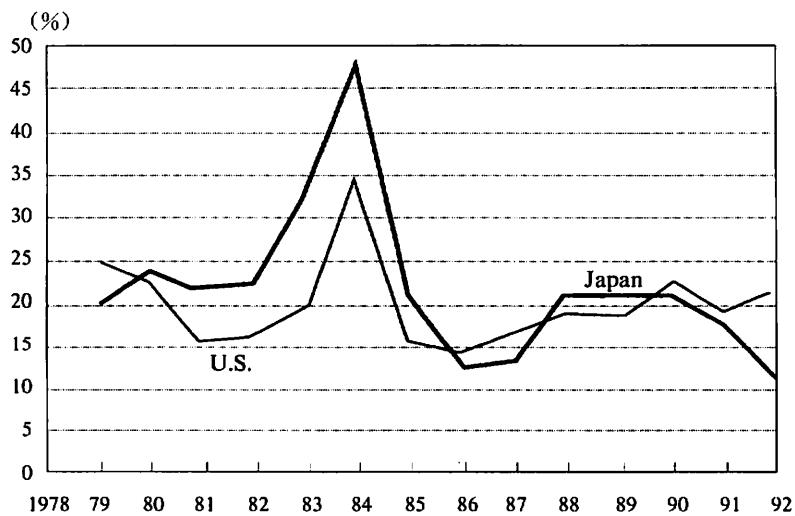
More fundamentally, differences in quality were attributed to the different extent to which importance was attached to management, and especially quality control on the shop floor[8]. A higher degree of IC integration required stricter controls over manufacturing processes and clean rooms, greater material and water purity, and more meticulous improvements in equipment and production processes. Such characteristics differentiated Japanese semiconductor companies from their US counterparts. The disparities in quality control also stemmed from differences between the engineers and technicians. In Japan, engineers and technicians remained with the same companies for longer durations, were better acquainted with their equipment, acquired broader skills, made more persistent efforts to improve results, and applied stricter quality controls. Furthermore, materials and production equipment were steadily improved through close and long-term trade relationships between semiconductor companies and materials producers as well as equipment manufacturers. This also led to differences in the ability to achieve quality control at shop floor. These characteristics were observed in various manufacturing sectors as well as the semi-

conductor industry[9]. The general Japanese manufacturing industry characteristic of attaching importance to management of the production shop floor and to product quality resulted in their advantages in memory IC, including DRAM.

Another critical factor accounting for the difference in competitiveness was the capability for raising funds for capital investment and for R&D[10]. As the degree of IC integration increased and precision processing technology became more and more advanced, so the amount of investment in production equipment and clean rooms rose drastically. Furthermore, the most advanced memory ICs produced new generations in three-year-cycles, rendering expensive equipment immediately obsolete. In addition, the periodic "silicon cycle" is reflected in the semiconductor market slump and the accompanying sharp decline in prices. Competition in the semiconductor industry thus began to take on aspects of match-up involving scale and strength. Under such conditions, Japanese semiconductor companies maintained heavy investment in plant and equipment. Figure 2, which compares investment ratios (ratio of investment in plant and equipment in the current year to amount of sales in the previous year) between Japanese and US companies, reveals that Japanese semiconductor companies had much higher investment ratios from the beginning to the mid-1980's, a period in which the disparity in DRAM competitiveness between Japanese and US companies became conspicuous.

The different investment behavior stemmed mainly from the disparity between capital resources, and which, in turn, was attributed to the difference between corporate structures of Japanese and US companies[11]. With certain notable exceptions, such as Motorola, IBM and AT&T, most US semiconductor companies developed from venture companies that focused their activities on semiconductor products. As these companies had poor capabilities for external finance, they relied heavily upon internal funds. Their ability to invest vigorously was restricted because their profits declined sharply in the face of the rapid growth of Japanese semiconductor companies, which concentrated on memory IC. In contrast, Japanese semiconductor com-

Figure 2 Investment Ratios of Japanese and US Semiconductor Companies



Source: Itami (1995), p. 80.

panies were general electronics manufacturer giants. They had no trouble raising funds from banks and it was said that they subsidized investment in semiconductors through profits from other divisions[12].

US semiconductor companies, which lagged behind in quality control and investment in plant and equipment, were compelled to withdraw from the memory business. While there were fifteen US DRAM manufacturers in 1974, by 1986 their number had declined to only three. Japanese semiconductor companies, on the other hand, actually increased over that same period from six to seven[13]. It came as quite a shock when Intel, the company that developed the 1K DRAM, announced its withdrawal from the business in 1985, laying off 2,700 employees for two years and shutting down eight semiconductor factories[14]. Of course, as will be discussed later, Intel then concentrated on the MPU business, becoming the leading company in the re-reversal between Japanese and US semiconductor manufacturers.

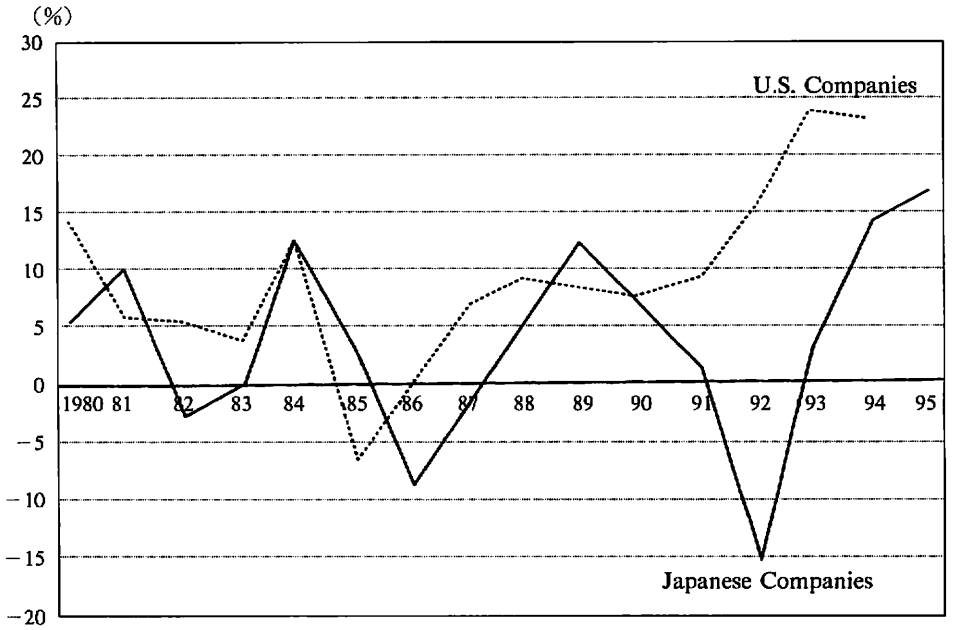
The governments of Japan and of the United States reached the Semiconductor Agreement in 1986 (revised in 1991 and abolished in 1996). This agreement contained two rather extraordinary features, namely, price controls and access to the Japanese market. Regarding the former, every Japanese semiconductor company was obliged to submit documentation related to their IC production costs to the US Department of Commerce, based upon which the Department determined a 'fair price' that could be charged by each Japanese semiconductor company. Regarding access to the Japanese market, the Japanese government encouraged Japanese companies to import semiconductors and established import promotion organizations in Japan[15]. However, by the time the agreement was reached, the circumstances within the semiconductor industry had already changed drastically. As Figure 2 shows, the investment behavior of Japanese semiconductor companies became extremely moderate around this time. In that sense, semiconductor trade friction between Japan and United States, including the agreement, was a burden for Japanese companies that constrained investment and became one of the factors behind the re-reversal of dominance in this industry in the 1990's.

2. 'Re-reversal' between Japan and the U.S. and its causal factor

Whereas 1980's was the era of reversal between Japan and the United States, the 1990's is known as the era of re-reversal. As Figure 1 shows, the gap between the Japanese and the US shares in world production widened from the mid-1980's to the end of that decade. After that, however, the gap began to narrow, and by 1993, re-reversal had finally occurred. Corporate rankings, shown in Table 1, further reveal the revitalization that occurred among US semiconductor companies. Intel maintained number one position throughout the 1990's, and TI and Motorola became numbers three and four, respectively, in 1997.

The difference between corporate profitability clearly reflects the re-reversal. Figure 3 shows that the earnings ratio of Japanese and US semiconductor companies followed almost the same path until the end of the 1980's, but then the gap widened considerably in the 1990's. In particular, US companies increased their profit rates in the early 1990's while their Japanese rivals experienced major deficits. Japanese

Figure 3 Profit Rates of Japanese and US Semiconductor Companies



Source: Development Bank of Japan (1996).

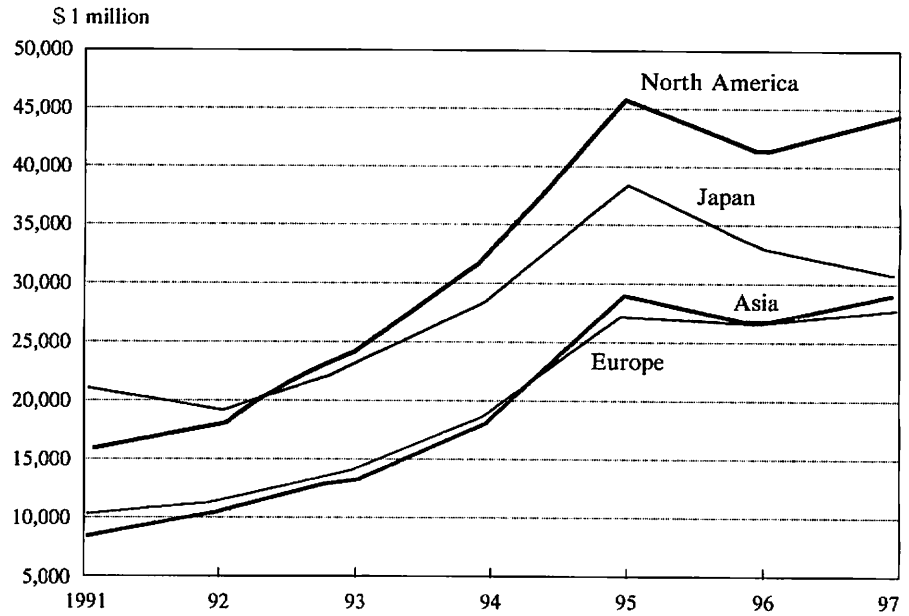
companies had a recovery in their earnings around the middle of the 1990's, but profitability deteriorated again in the latter half of the 1990's, as a result of the sharp price decline of memory, especially DRAM. Japanese companies struggled as a result, as five leading semiconductor companies, NEC, Toshiba, Hitachi, Fujitsu and Mitsubishi, reduced their investment in plant and equipment for three consecutive years from 1996 to 1998 by postponing installation of new production lines and construction of new plants[16]. This difference in profitability most clearly demonstrates the re-reversal between Japan and the United States in the semiconductor industry.

Why did this re-reversal come about? One significant factor is the gap between the growth rates of the semiconductor markets in Japan and the United States. Figure 4 shows that the growth rate of the US semiconductor market was higher than that of Japanese market in the 1990's and that the size of the US market began to exceed that of the Japanese market in 1993. The growth rate of Japanese market became negative after 1995, whereas the US market remained stable. After that the gap began to widen.

Furthermore, it is noteworthy that the semiconductor industry relies to a considerable extent on the domestic market. The Japanese semiconductor industry, in particular, depends heavily upon domestic demand. As can be seen in Table 2, the dependence of Japanese leading semiconductor companies, other than Mitsubishi, on the domestic market reached almost 60 percent. Clearly, the lower growth rate of the Japanese semiconductor market influenced the growth rate of production and the profitability of Japanese companies.

General business conditions are the most significant factor contributing to the gap in the growth rates between the Japanese and US semiconductor markets. The American economy has maintained prosperous conditions since the beginning of the

Figure 4 Size of Semiconductor Market by Region



Source: *Semiconductor Data Book*, 1995-98.

Table 2 Distribution of Market by Region for Leading Japanese and US Semiconductor Companies (1997)

(Unit: %)

	North Am.	Japan	Asia	Europa
US Companies				
Intel	44.1	9.9	19.0	27.0
Texas Instrument	55.0	21.0	9.0	15.0
Motorola	45.0	10.0	20.0	25.0
National Semiconductor	43.0	10.0	24.0	23.0
Micron Technology	66.5	2.9	13.9	16.7
Japanese Companies				
NEC		58.0		
Toshiba	21.0	60.0	13.0	6.0
Hitachi	18.0	60.0	11.0	11.0
Fujitsu	19.0	57.0	11.0	13.0
Mitsubishi	30.0	44.0	20.0	6.0

Source: *Semiconductor Data Book*, 1998.

1990's, whereas the Japanese economy has continued to stagnate since the collapse of the so-called bubble economy. Without doubt, the performances of the Japanese and US economies have had a major effect upon the growth rates of their respective semiconductor markets.

Let us examine Japanese and U.S. semiconductor market trends from the demand side (Table 3). In North America, information-related equipment (including computers), which account for a large proportion of the semiconductor market, experienced remarkable growth, reaching as high as 180 percent between the years 1991 to 1997. The communication equipment segment of the semiconductor market,

Table 3 Distribution of Market Share and Growth Rate within Semiconductor Industry by Product Area

North America					
	1991 Distribution		1997 Distribution		Growth Rate
	$ 1 million	%	$ 1 million	%	%: 91-97
Consumer	807	5.2	2,705	15.3	235.2
Information	9,909	64.4	28,107	55.1	183.7
Communication	1,913	12.4	7,290	14.3	281.1
Industry	1,820	11.8	4,127	8.1	126.8
Military & Aerospace	32	0.2	825	1.6	2478.1
Automobile	895	5.8	2,797	5.5	212.5
Sum	15,376	100.0	45,851	100.0	198.2
Japan					
	1991 Distribution		1997 Distribution		Growth Rate
	$ 1 million	%	$ 1 million	%	%: 91-97
Consumer	8,864	42.4	9,642	30.0	8.8
Information	6,541	31.3	11,869	37.0	81.5
Communication	2,184	10.4	4,812	15.0	120.3
Industry	2,351	11.2	3,978	12.4	69.2
Military & Aerospace	36	0.2	32	0.1	−11.1
Automobile	953	4.6	1,764	5.5	85.1
Sum	20,929	100.0	32,097	100.0	53.4

Source: *Semiconductor Data Book*, each year.

though only a quarter of the size of the information-related segment, grew 2.5-fold during the same period. This degree of market expansion stems from vigorous investment in information and communication equipment in the midst of prosperous economic conditions. The US market for automotive semiconductors, which was a bit smaller than the one in Japan in the early 1990's, doubled in size and surpassed that of Japan in 1997. The IC market for consumer products, which used to be underdeveloped in the North America, and which is far smaller than in Japan, more than doubled.

In contrast, Japan experienced a remarkable slump in demand for consumer product ICs, at one time the largest market for semiconductors. This is attributed to the overall slump in the domestic economy, the expansion of foreign production, and the reduction in the number of parts installed in consumer products. These consumer product trends create unfavorable conditions for Japanese semiconductor companies, which have been predominant in ICs for consumer products. Of course, the market for information- and communication-related equipment ICs also saw considerable growth in Japan. The market size for information equipment ICs, in particular, surpassed that for consumer product ICs. In the US, however, the size and growth rate of the IC market for information and communication purposes surpasses that of Japan by a considerable margin.

Let us next consider the factors behind the re-reversal from the perspective of types of IC products, namely, MPU versus memory. It is often pointed out that the growth of the MPU market, with the rapid expansion of PC market in the 1990's, revitalized the US semiconductor industry, which is very competitive in the MPU

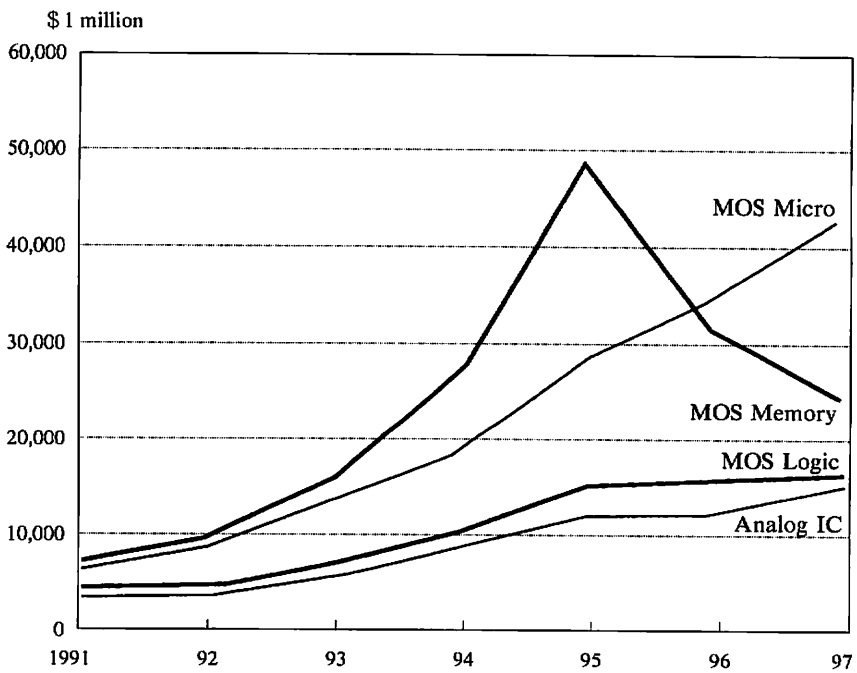
field. Japanese semiconductor companies, which concentrated on memory IC, suffered under a depressed market for memory ICs, instead. This is then said to have led to the re-reversal between Japan and the United States in the semiconductor industry. The reality, however, is somewhat more complex.

Figure 5 shows, in terms of shipments by semiconductor category, that until 1995, the growth rate of MOS memory IC, including DRAM, was much higher than that of MOS micro IC, including MPU and MCU (micro control unit). It clearly reveals the contrast between the reduction in the memory market and the expansion of the micro market after 1995. Although this contrast accounts for the difficulties experienced by the Japanese semiconductor industry in the latter part of the decade, it fails to explain re-reversal that took place in the first half of the 1990's.

The method that this analysis uses to contrast the prosperous US semiconductor industry with the depressed industry in Japan is also too simple. As Figure 6 shows, among US companies, the rate of profit to sales of Texas Instruments, National Semiconductor and Micron Technology, whose ratio of memory IC to total production is high, or used to be high, revealed almost the same trend as Japanese companies in the 1990's. In contrast, Intel, Motorola and AMD, which emphasized logic ICs, recovered profitability rapidly in the 1990's. From the standpoint of profitability, this situation does not point out a re-reversal between Japanese and US companies, but rather, the difference between logic-centered and memory-centered producers.

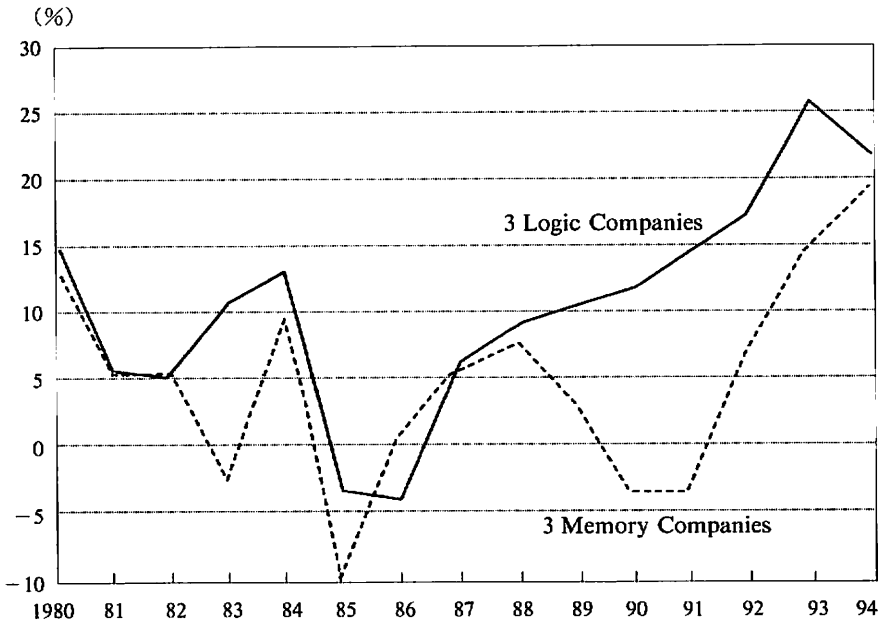
Although the memory IC market grew larger than the micro IC market until the mid-1990's, the profitability of both Japanese and US memory-centered companies deteriorated. This is mainly attributed to the price decline of memory IC that resulted from excessive competition and oversupply, mainly of DRAM. Market expan-

Figure 5 Size of Semiconductor Market by Products



Source: *Semiconductor Data Book*, 1995-98.

Figure 6 Profit Rates of US Semiconductor Companies by Main Product



Source: Development Bank of Japan (1996).
Note: 3 Logic Companies: Intel, Motorola, AMD; 3 Memory Companies: TI, NS, Micron.

sion in the mid- 1990's temporarily eliminated oversupply and returned profitability to these companies. It was a transient situation, however, and a shrinkage of the memory market led to oversupply again in the latter half of the 1990's. For a two-year period beginning in 1996, the price of DRAM declined to one tenth, resulting in the deterioration of business for memory-centered companies[17].

There were two reasons for the oversupply of DRAM. One was that, unlike US semiconductor companies, none of the Japanese memory manufacturers withdrew from DRAM production, even during the frequent "silicon cycles." The other reason was the entry of Korean semiconductor companies, including Samsung. Notably, Korean semiconductor companies invested aggressively in plant and equipment, while Japanese companies curbed their investment because of the Semiconductor Agreement between Japan and the United States itself, and the circumstances that led to it in the first place.

It is also inaccurate to claim that US semiconductor companies have strong advantages in the production of MPUs. As Table 4 shows, only Intel accounts for an overwhelming MPU market share, even among US companies. Intel's monopolistic position derives from the fact that its MPUs are the de facto standard in IBM compatible PCs. This exclusivity stems not only from Intel's advantageous R&D capabilities but also its strategy regarding intellectual property rights[18]. In terms of MPUs, it is not a situation of re-reversal between Japan and the United States, but rather a situation where Intel is clearly a winner.

And not least significant is the difference between corporate strategies, namely, the choices concerning product orientation and IC product lines that determined the profitability of semiconductor companies. Many US semiconductor companies have

Table 4 Company Ranking by IC Products (1997)

	DRAM		MPU		MCU	
Rank	Company	Share(%)	Company	Share(%)	Company	Share(%)
1	Samsung	11	Intel	80	Motorola	23
2	NEC	9	IBM	4	NEC	13
3	Micron	9	AMD	3	Intel	11
4	LG	7	Motorola	2	Hitachi	11
5	Hyundai	7	Syrix	1	Mitsubishi	10
6	Hitachi	7			Matsushita	8
7	TI	6			Philips	6
8	Mitsubishi	6			Lucent	3
9	Toshiba	5				
10	Fujitsu	5				

Source: *Semiconductor Data Book*, 1998.

specialized in specific IC product lines. The success of Intel is a typical case. Another example is Texas Instruments, which abandoned the general business sector to specialize in digital signal processors (DSP), achieving a remarkable recovery in its rate of profit after suffering difficulties until the mid- 1990's. During rapid technological development, concentration upon specific product lines creates competitive advantages.

3. Conclusions and Prospects

The situation in the semiconductor industry in the 1990's is best viewed not as re-reversal between Japan and the United States but as a contrast between the prosperity of companies, including Intel and Motorola, which produce mainly micro or logic IC, and the deterioration of business for companies that depend largely on memory IC. Similarly, there is the contrast between companies that specialize in specific product lines and those that seek to diversify their IC business, such as the leading Japanese semiconductor companies, or Texas Instruments before it abandoned broad product lines.

Current strategies focus on reducing the reliance on memory and selecting new fields activity. Regarding the selection of new fields, most US companies already concentrate, or are planning to concentrate on specific product lines where they enjoy competitive advantages. Leading Japanese companies are divided into two groups. One group, made up of companies such as NEC, will maintain diversified product lines including DRAM, while other companies such as Fujitsu and Mitsubishi intend to concentrate on new, promising products.

One of the promising products which will help to reduce the reliance on memory is system LSI. This is the integration of various IC functions, such as micro controller, memory, image processor, into a single chip. System LSI is projected to see rapid growth, since it is expected that it will be applied in a wide variety of products: digital consumer appliances including digital televisions, personal computers and peripherals, digital cameras, next generation information networking equipment, and various household appliances. It is possible that Japanese semiconductor companies will lead the system LSI sector, since they have maintained broad IC lines, including micro

controllers and memory, they operate the most advanced precision processing technology, and have accumulated advanced technology in consumer electronics equipment, including image processing. Actually, at the present stage, Japanese semiconductor companies precede rivals utilizing their own advantages mentioned above[19]. In the forthcoming era of system LSI, semiconductor companies with broad, comprehensive technology may have an advantage, as Intel or Micron Technology, which specialized in a particular product area, did in the 1990's.

It is too early to project that Japanese companies will be the only winners in the system LSI business. First of all, various Japanese semiconductor companies with similar levels of technologically might expand the system LSI business, creating fierce price competition, and producing the same low-profit, rapid growth situation that befell the DRAM business. Secondly, some US semiconductor companies have enormous advantages in fields comprise the broad technology of system LSI. Examples include MPUs for the PC, an area where Intel has monopoly power, and DSPs, where US companies, including Texas Instrument, account for 90 percent of the world market share. In addition, various US venture companies, own original design technology for system LSI. For these reasons, Japanese and US semiconductor companies may develop various kinds of alliances to exploit the growing system LSI business, which requires broad technological resources and huge investments in plant and equipment.

In the semiconductor industry of the future, it may not be productive to rigidly classify and contrast companies as "Japanese" or "US." Of course, this author does not insist that differences in corporate strategy or organization between Japanese and US companies will disappear, but rather, that it may be nonsense to compare competitiveness between these companies on the basis of national origin.

Notes

1 Sasaki (1987), p. 76.
2 Arai (1996), pp. 145-146.
3 Koezuka (1996), pp. 72-73, pp. 102-103, and Itami (1995), p. 128.
4 Warshofsky (1989), ch. 10, and Tani (1994), pp. 172-175.
5 Okimoto (1984).
6 Sasaki (1987).
7 Itami (1995), pp. 124-126, and Okimoto (1984).
8 Sasaki (1987), p. 86.
9 Itagaki (1994).
10 Itami (1995), pp. 79-85.
11 Itami (1995), pp. 2-93, and Okimoto (1984).
12 Many argument this point, but we have not reliable evidences.
13 Arai (1996), p. 146.
14 Amano (1993), pp. 25-30.
15 Sato (1991), pp. 118-122.
16 *Japan Economic Journal*, 21 Jan. 1998.
17 *Japan Economic Journal*, 20 June 1998.
18 Jackson (1997).
19 *Japan Economic Journal*, 23 April 1998.

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