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Gregory D. Racce

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Reasons Behind the Successful Entrance of Japanese Companies Into the United States Semiconductor Market Between 1976-1980

By

Gregory D. Raece

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Table of Contents

List of Tables

Chapter One

Introduction

In recent years there has been increased interest in examining what appears to be a steady decline in the United States' economic prowess. The U.S. position is often envyingly contrasted with that of seemingly more successful countries whose economies are on a more positive track. The most notable of which is Japan, quite arguably the world's most amazing present-day economic power. Even more impressive than Japan's current accomplishments has been its remarkably swift recovery from post-war devastation. The results of this recovery are clear, with each of the following having shown considerable growth; national income, growth of tertiary industries, and international trade surplus. Although the results are undisputed, the reasons behind Japan's success still leads to a great deal of disagreement amongst scholars. This paper will attempt to answer this question on Japan's success in one of its leading industries, semiconductors.

In particular, it will examine how the Japanese semiconductor industries were able to gain a foothold in the previously unchallenged United States market. This entrance took place between the years 1976- 1980 in a battle over 16 kilobyte (16K) and 64 kilobyte (64K) microchips. Japan's victory was significant for two reasons; first, it served as a signal to the rest of the world that Japan was now one of its major economic powers. Second, it was a painful reminder to a declining U.S. electronic industry.

For each country success in producing semiconductors is crucial for the following reasons.

1) Semiconductors are an important structural technology upon which a number of other electronic products are based.
2) New industries, such as semiconductor equipment, are created, thus generating employment, income, etc...
3) Semiconductors provide an important basis from which new scientific technologies can be developed.
4) They increase national security by allowing a country to not have to rely on others for strategic military parts.
5) Generates income and employment.

The above issues are crucial areas that will periodically be alluded to throughout the course of this examination. The main purpose of this paper will be to examine the reasons behind the Japanese semiconductor success. Although it is impossible to determine the exact outcome rendered by any one action, it is possible to hypothesize on the effect of a repeatable trait. It is from these traits that an acceptable explanation of the semiconductor question can be answered. It is my belief that Japan's success was due to a combination of the following situations which occurred in both the U.S. and Japan.

In the U.S., Japan was able to sell its chips as a result of;

1) The U.S semiconductor companies inability to produce sufficient amounts of chips to meet the growing demand

created by the U.S. electronic firms.

2) Deteriorating product quality on the part of U.S. companies as a result of insufficient investment into production equipment and semiconductor technology research.

In Japan, the following were crucial to its growing industries;

1) The diverse nature of Japanese semiconductor firms allowed them to better withstand the debilitating effects of recession and thereby keep a sufficient stream of investment constantly flowing into their firms.
2) The Japanese firms actually produced a much higher-quality product than did its U.S. counterparts.
3) The Japanese firms had access to loans at much better rates than their American competitors, this was important in their decisions to invest more in production equipment and new technologies.

In conjunction with this it will be important to look at the Japanese government and determine exactly what type of role it played and whether or not it was instrumental in affecting the outcome of the Japan's success. The importance of this will be to determine whether or not critics who claim Japan's government is the crucial player in high-tech industries are justified in their opinion.

Chapter Two

History of the Semiconductor

Before beginning with the examination it is essential to discuss the products and innovations which formed the core of the U.S.-Japan battle. The word 'semiconductor' is an all-purpose term that describes a wide array of electronic devices. Common to each of them is that they are all created with metals which have the following three characteristics:

1) That they become better conductors with increases in temperature.
2) They display the photovoltaic (photoelectric) effect. When a voltage is applied, electrons become excited and are able to cross electrical barriers within the material.
3) A change of conductivity will occur with electric input. (Braun & Macdonald, p.15)

The semiconductor device credited with revolutionizing the state of electronics was the germanium transistor invented by the team of John Bardeen, Walter Brattain, and William Shockley at Bell Laboratories during 1947 (Webbink, p.4). The benefit of the transistor was, simply enough, that it could transfer or amplify resistance. To better understand this, an excerpt from John Brattain's first demonstration describes exactly what this instrument could do. He wrote, "This circuit was actually spoken over, and by switching the device in and out, a distinct gain in speech level could be heard and seen on the scope presentation with no noticeable change in quality... It was determined that the power gain was on the order of a factor of eighteen or greater." (Warshofsky, p.23) The importance of the transistor was that it was able to effectively replace vacuum tubes while at the same time being both smaller and more reliable.

The next significant innovation came during 1954 when Texas Instruments' George Teal created the first silicon transistor (Braun & Macdonald, p.55). This was an improvement over the germanium transistor which companies found, "...difficult to produce (reliably) and even harder to make with identical characteristics; life expectancy was uncertain and the transistors seemed inclined to deteriorate rapidly under temperature and humidity conditions which were far from extreme." (Ibid, p.54)

Four years later, again at Texas Instruments, the integrated circuit (IC) was invented by Jack Kilby (Webbink, p.6). The significance of this circuit was that it combined the transistor, resistor, capacitor, and distributed capacitor onto one individual piece of semiconductor material (Warshofsky, p.28). After only a few years of modifications, the IC had revolutionized the electronics industry by allowing instruments such as computers to be built smaller, more reliable, and more efficient than ever before (Ibid, p.29). It was this particular innovation which the industries of today are now competing. The importance of the IC is that,

First, it made it technically and economically feasible for the semiconductor manufacturers to integrate their operations vertically so as to produce entire end products such as electronic calculators and watches; in a similar vein, end equipment producers were able to develop their own IC manufacturing capability. The two developments blurred the traditional distinction between component and equipment manufacturing. Second, the product differentiation of individual IC's encouraged the entrance of new producers into the industry who previously would have found it difficult to compete with the established component manufacturers in the discrete devices market. (U.S. Semiconductor Industry-U.S. Dept. of Commerce, ITA, p.11)

The final revolutionary semiconductor device that will be referred to in this paper is the microprocessor. Created by Intel in 1971, this device is the programmable brain found inside all computers (Borrus, p.35). According to M. Morris Mano, "Its purpose is to interpret instruction codes received from memory and perform arithmetic, logic, and control operations with data stored in internal registers, memory words, or Input/Output interface units." (Mano, p.333) The significance of this device was that it could allow items such as computers and calculators to be built within price and size ranges reasonable for sale to the general public.

Returning to ICs, there existed during this period two predominant methods of producing these chips. The first type of chip invented was of the bi-polar variety which consisted of layers of silicon each having distinctive electrical characteristics (Kimura, p.39). The second type, invented in 1962, was the metal-oxide silicon (MOS) integrated circuit in which only the surface is 'active' (Ibid, p.39). The difference between the two in terms of performance was described by Bob Johnstone as, "Bipolar devices are faster and can handle higher voltages than MOS devices but they take up more 'silicon real estate' than MOS devices. Bipolar devices are also power-hungry and beyond a certain level of integration, tend to melt. MOS allows more components to be packed into an IC." (Johnstone, p.81) It was in this MOS field that Japanese firms concentrated their resources and were able to compete against the United States. Therefore, this paper will examine MOS devices and the memory chips created using this process.

The particular chip in which Japan was most successful producing was the dynamic random access memory microchip (DRAM or RAM) (Kimura, p.42) A description of this device says, "DRAM microchips require that stores of information be electronically refreshed periodically, and static random access memory ICs do not require refreshing. Static RAM ICs are more technologically complex than dynamic RAM ICs because static RAM ICs require more active elements to form a static cell than dynamic RAM ICs for a given level of integration." (Ibid, p.45) In order to better understand the storage capacity of these devices, Peter Lewis stated that, "Eight bits makes a byte, which is roughly the equivalent of one letter or numeric character. About a thousand bytes (1,024) make up a kilobyte, or K." (Warshofsky, p.39) The chips that will be examined in this paper, the 16K RAM and 64K RAM are those that can store roughly 16,000 and 65,000 bits of information respectively (Webbink, p.40).

Success in semiconductor production is determined by a firm's ability to produce a larger number of products while at the same time managing to keep defects low. If a company is successful at this, they will then be able to create a cheaper product because the cost to produce will naturally decrease as more is created. Great profit in the semiconductor industry usually is not the result of new breakthroughs since the rate of innovation within the industry is so great that competitors are usually able to achieve the same results within only a small amount of time. The company that does not invest in research will soon find itself either rapidly becoming antiquated or helplessly dependent on acquiring licensing from other companies who do develop new technologies. On the other hand, if a company ignores its production facilities it fails to fully capitalize on its invention because it is unable to produce, and then sell its product. It is within the happy medium between these two that the Japanese firms have been able to place themselves. Uenohara gives a brief yet accurate account of Japan's semiconductor industry when he says, "Although (it) has not made any significant breakthroughs in the form of basic discoveries and inventions, it has contributed to realizing the broader potential of the new semiconductor technologies." (Uenohara et al, p.15)

The production of the RAM chip itself is extremely difficult due to the fact that it is very susceptible to defects. Almost all of these are attributable to contamination from outside sources such as components from nearby chemicals, factory personnel, production processes, and equipment (Kern, p.1887). Contamination can occur in any amount greater than 'one atom of impurity per million atoms of silicon'(Webbink, p.42). Because of this, companies with a 'cleaner' production system are able to better compete than a company who might have a technically more advanced product but is unable to produce it without high contamination rates.

What is striking about the previously discussed technologies is that they were all invented in the United States. This point should not be overlooked since it is a psychologically important variable for both the American semiconductor industry and the U.S. government. Not only is it a matter of pride to be able to claim semiconductor superiority, but it is also expected that the U.S. should remain superior in this field solely because it was they who created it. For many companies, this line of reasoning is used when attempting to acquire help from the government in blunting the efforts of foreign firms attempting to enter the U.S. market. Upon further investigation though, this argument is not entirely true since research has been taking place in Japan for nearly the same amount of time as that of its U.S. counterparts. This is important because it helps disprove the claim that the Japanese semiconductor industry is an entity that was rapidly created by the government. In actuality, the Japanese semiconductor industry was founded by private corporations who would only later (late sixties- seventies) receive salient government assistance. To prove this is it will first be necessary to examine the history of the Japanese semiconductor industry.

Surprisingly, almost all of the current major Japanese semiconductor companies entered the industry during in the 1950s

(Uenohara et al, p.14). During this period these companies were focused on trying to recreate the transistor developed by the Bell Laboratories team (Kimura, p.51). The first Japanese transistor was built by Makoto Kikuchi who created it not by using scientific documentation from the Bell Lab discovery but from an account in Newsweek magazine (Warshofsky, p.61). This type of scavengering was a good representative example of Japanese research at the time. Their research was basically comprised of learning about a discovery, managing to get a sample of it, then trying to understand its principles by dissecting and examining it. It was not until they received licensing from U.S. firms that the Japanese companies were able to begin producing U.S. technologies, one example of this was the germanium transistors which Japan began manufacturing in 1956. In only a relatively short amount of time Japan, in 1959, had become the largest transistor producer in the world, selling 86.5 million units (Kimura, p.51). The Sony Corporation (created in 1946) was licensed the rights to build Bell's transistor for only $25,000, this deal, "...ranks among the greatest bargains in history." (Warshofsky, p.62) This particular occurrence was important because it was an early indicator of the success Japan could have in producing electronic items. It shows that they had the capability to quickly catch up with other more technologically-advanced companies and somehow manage to surpass them. This type of success contributed to a growing feeling of security among this industry's investors whose money would later prove invaluable. It was also a warning to U.S. firms that they would have to be extremely careful in licensing technology for the reason that they might very well be creating their biggest competitor.

Japan's transistor success also is important because it establishes a vital foundation from which a higher-level semiconductor industry was to be built upon. No industry dealing in this type of advanced product could be created during any short period of time. This industry needs the experience that can only be acquired after years of research in which each mistake and success has been painstakingly examined, reexamined, questioned, understood, and only then put into production. Since Japan was involved so early on it was able to acquire the knowledge necessary to build a successful semiconductor industry. This casts doubt onto the argument stating Japan's government 'created' an industry in a field which they saw potential promise.

Throughout most of the 60s, the Japanese firms were consistently behind their American counterparts in terms of technological achievements. This was mainly the result of the Japanese firms inability to successfully develop and then compete in the silicon transistor market (Uenohara et al, p.14). To these industries' credit, they also lacked the domestic demand for the kind of devices that the U.S. received from its military and computer sectors (Kimura, p.51). It would not be until the development of the Integrated Chip market in the late 1960s that Japan was able to pursue a field in which it could be a world technological leader. It is at this point in which some of the events that take place are extremely important in affecting the Japanese entry into the U.S. market in the late 1970s. The first will be grouped into an examination which will look at conditions within the U.S. semiconductor industry since 1970.

Chapter Three

United States Semiconductor Industry 1970-1978

One of the events contributing to Japan's eventual victory was the inability of the U.S. firms to satisfy the world's semiconductor demands. This was the result of a number of factors, most of which were directly attributable to the 1974-75 recession. This particular recession created a situation of,

> Unprecedented inventory liquidation, high money rates, soaring inflation, all harmonized to induce a catatonic state in the industry that dropped employment levels to new lows, closed plants, stifled capital formation, and impacted vital research and development programs. (Industry leaders cautious, p.1)

The recession was the result of rising industrial costs due to the Oil Embargo and also to conditions created by the end of the Vietnam War. For the semiconductor industry this resulted in a sharp decline in production and demand during the 1975 economic year. Within the United States semiconductor/electronic component production decreased from (using 1967=100) 145.1 in 1974 to 112.1 in 1975 (Webbink, p.5). U.S. semiconductor exports dropped from the 1974 level of 1,247,498 thousands of dollars to 1,053,495 in 1975, while imports of semiconductors declined from 961,338 in 1974 to 802,687 during 1975 (U.S. Semiconductor Industry, U.S. Dept of Commerce-ITC, p.68).

A decrease was also apparent in the quantity of shipments of integrated circuits, from 2,122 million dollars of product in 1974 to 1,712 million in 1975 (Ibid, p.39). In effect, a decrease of roughly nineteen percent. As a whole, the average selling price of integrated circuits dropped roughly 30% in the course of only one year (Ibid, p.51). Other bad news for the U.S. firms came in a drop in their net earnings after taxes as a percent of sales.

Table 1. Net Earnings after Taxes as a Percent of Sales

Year	Semiconductor Manufacturing	All Manufacturing Industries
1972	5.0%	4.3%
1973	7.4%	4.7%
1974	6.1%	5.5%
1975	3.9%	4.6%

Source: United States Industry, Department of Commerce, p.57

Looking at the chart it is apparent that semiconductors, although they usually had good years, tended to feel the effects of recessionary years much greater than did other industries. This particular recession was on a much greater scale than any other the semiconductor industry had yet to face. John R. Opel, president of IBM, felt that the 1974-75 recession affected his industry differently then the one in 1970-71 because its presence was worldwide rather than simply a U.S. phenomenon (Industry leaders cautious, p.1). This observation can be deemed correct when the figures on the Japanese market are also examined. The total production of Integrated Circuits in Japan decreased a total of 6.2 percent, 125.5 Yen billion in 1974 to 117.6 Yen billion in 1975 (Semiconductor Industry, OECD, p.114). From these figures a

Japanese slowdown is apparent, but not nearly as damaging as that which the United States firms suffered. Their ability to weather this economic storm is one of the most important reasons for the latter success the Japanese semiconductor industry would enjoy. Before examining this, it is important to explain why this difference occurred. In order to do this, some of the unfortunate influences that affected the U.S. market will be looked at.

In addition to the slowdown in the worldwide semiconductor industry, many of the U.S. firms were saddled with expenses which prior to the recession had seemed secure investments. The most important of them was labor. Labor costs rose during a year in which the industry found its net earnings decline sharply.

Table 2. U.S. Domestic Semiconductor Industry Manufacturing Costs (% of total)

	1972	1973	1974	1975
Value of output	100.0	100.0	100.0	100.0
Payroll	33.5	31.6	32.1	38.3
Cost of Materials, Fuels, etc.	32.7	35.8	38.5	34.9
Capital Expenditures	6.0	8.8	10.5	9.0
Other	27.8	23.8	18.9	17.8

Source: The Semiconductor Industry, Douglas Webbink, p.14

In fact, during this recession year (in which semiconductor output decreased by nearly 22 percent) semiconductor employment only dropped about five percent (Ibid, p.96). The effect of this was that it helped drain valuable capital from the semiconductor firms who truly needed it for research purposes, materials, and capital expenditures.

One additional labor problem the semiconductor industry began to experience during the early 1970s concerned the tendency of individuals to leave their firm for the purpose of starting their own company. The problem this created was discussed by Fred Warshofsky;

> It saps the original company of some of its best talent, and the small start-up companies they create are too small and financially weak to compete in the industry now that large economies of scale and huge capital investments are required. and so the entrepreneurial spirit that is the great strength of Silicon Valley is suddenly conceived by many experts to be its Achilles heel. (Warshofsky, p.44)

This situation is best reflected in the fact that between 1969-75 a total of twenty-five new semiconductor companies were formed (Borrus, pp.30-31). The founders of these companies were made of former employees from the following firms; Fairchild, National Semiconductor, IBM, Nortec, Texas Instruments, Signetics, Hewlett-Packard, General Instruments, Mellonics, Monsanto, American Microsystems (Ibid, p.30-31). For all practical purpose these major companies basically were the United States semiconductor industry, and the defection of their most talented members did nothing to help them grow.

Demand and labor questions were not the only areas in which difficulties arouse, perhaps the most devastating was the loss of confidence the semiconductor industry had among its investors. Due to observations made on the 'natural' reaction of the semiconductor industry to fluxuations in the economy, the industry managed to acquire the reputation of being 'very sensitive to recessions' (Webbink, p.39). In other words, a risky investment. As far as the stockholder's own interests were concerned, the dividends they could expect to receive greatly fluctuated.

Table 3. Net Income After Taxes as a Percent of Stockholder's Equity for Selected Semiconductor Companies and for All Manufacturing- 1970-1975

Year	All Semiconductor Cos.	All Manufacturing Cos.
1973	21.87	12.84
1974	17.97	14.83
1975	8.02	11.42

Source: Douglas Webbink, The Semiconductor Industry, p.178

It must be pointed out that the only reason the semiconductor industries showed a positive number in 1975 was due to the great success of the four leading companies. When looking at those firms which recorded total sales between $25 million to $100 million, their total net income as a percent of stockholder's equity was a negative number, -9.96 percent.

In addition to this, a number of people believed there did not exist a spectacular future in the items semiconductors form an integral part of. For instance, in the August 1978 issues of Radio-Electronics there appeared the following editorial by Art Kleiman;

The home computer, however, is directed toward the masses. Here the industry is looking for mass volume sales and is touting the home computer as a home appliance able to solve a host of problems for the homeowner. Who is the industry trying to fool? Does the industry really expect John Q. Public to take the computer home, learn to program it, interface it and use it to solve problems? The same John Q. Public that calls a service technician only to discover that the line cord isn't plugged into the wall outlet? And what sort of problems does the industry expect the home computer to solve? Can anyone name a single application that is more meaningful to the home-owner than a $1000 solar energy converter? The silence is deafening. To put the home computer in perspective, it's a solution looking for a problem. (Kleiman, p.14)

As a result of this investor concern, the semiconductor industry suffered a wound which, remaining unhealed, would later make it unable to challenge the Japanese. Specifically, this damage was the overall decline in technological research and equipment investment in an industry where success is dependent on high amounts of each. When examining statistics on U.S. investment in their plants and plant improvement this trend is starkly apparent.

Table 4. Integrated Circuits: U.S. investment in plants and plant improvements (excluding production equipment) in thousands of dollars

	1974	1975	1976	1977	1978
U.S. investment	135,217	102,562	123,916	127,189	172,783

Source: U.S. International Trade Commission, Competitive Factors Influencing World Trade in IC, p.104

Concerning investment in IC production there was no regression but rather a slowdown of funds.

Table 5. U.S. Investment in the Production of Integrated Circuits (thousands of dollars)

	1974	1975	1976	1977	1978
U.S. investment	276,135	296,938	353,067	383,036	505,419

Source: U.S. International Trade Commission, Competitive Factors Influencing World Trade in IC, p.105

In fact, the minimum investment required to produce semiconductor wafers rose from two million dollars in 1972, to five million dollars by 1976, and up to ten million dollars by 1978 (Semiconductor Industry-OECD, p.39). Added to this, there existed a variable market characterized by intense price competition among firms. The result was that a number of companies chose to cut their losses by leaving the consumer product market altogether (Borrus, p.34).

The year 1978 was of utmost importance to the semiconductor industry because it was when the 4K MOS RAM chip was being phased out in favor of the more powerful 16K MOS RAM. Even though the U.S. industry had suffered a setback due to the recession two years previous, it still held a commanding 65 percent total of the worlds' MOS production (Gregory, p.196). Yet by the end of the 16K RAM's life span in 1982, its market would be under the complete control of Japanese producers. To better understand the situation that occurred, it is imperative that the Japanese industry between 1970-78 be examined. The purpose of this will be to look at some of the actions taken by the Japanese which enabled them to best use to their advantage the shortcomings of the U.S. firms.

Chapter Four

Japanese Semiconductor Industry 1970-76

For the Japanese firms the period between 1970-76 was characterized as a 'catch-up' stage with their competitors in the U.S.. This seemed an especially daunting task since Japan began this period suffering from a trade imbalance with the United States totalling 18,664 million yen (Semiconductor Industry-OECD, p.115). In 1970, its total production earned the Japanese firms a total of 47,410 million yen (Kimura, p.55). This number gains significance when compared with the semiconductor production totals of 1975, 104,746 million yen worth (Ibid, p.55). This nearly three-fold increase shows that the Japanese firms were making great strides in their production totals. However, almost all of that increase was made up of sales within Japan and not from any substantial increase in exports to the U.S..

One of the most notable contracts the Japanese firms maintained was with Nippon Telegraph and Telephone (NTT) (Weinstein, Uenohara, and Linvill, p.55). The importance of this role was;

In the early 1970's, NTT's need for large quantities of 16K RAMs was a major stimulus to the Japanese semiconductor industry, and NTT established quality standards that were very high even for Japan, where high quality is expected. quarterly reports to NTT's suppliers kept them informed on the performance of their products, and the suppliers did all they could to meet NTT's rigid specifications even when the costs were exorbitant, because they knew this would pay off in the long run. (Ibid, p.55)

It was extremely crucial in giving Japan an edge since it was gaining experience in the 16K field while the world-wide standard was still 4K. Japan was, in effect, placing a good deal of its technological eggs into a very promising, yet not immediately profitable, future market. The NTT contract played a role similar to that of the space and defense contracts the U.S. government provided for its semiconductor companies (Ibid. p.110). The contract helped stimulate research within the companies that lead to the development of new technologies and capital investment which eventually resulted in increased production at lower prices.

It is important to mention that NTT's demand should not be overly stressed as being the sole catalyst for Japan's success. It was important because it introduced a number of companies to future technologies, however its investment alone could not have fueled the Japanese semiconductor market. The crucial factors for the Japanese during the time before they entered world-wide 16K competition was their continued investment in plant production during the previously mention 1975 recession and also their 'superior' labor force.

Japan, like most every other country, also felt the effects of the 1974-75 recession. As was previously mentioned, its semiconductor industry production totals stumbled, resulting in Integrated Circuit production totals that were down six percent from 1974 (Semiconductor Industry-OECD, p.114). This decrease was not as great as that of the United States' 19 percent (as mentioned on page 11) for the very reason that Japan was able to reduce its dependency on exports by 21.7 percent (Ibid, p.114). Although this was instrumental in weakening the recessions impact, it brings up the question of whether or not this adjustment was carried out by the government or through some other means.

It seems unlikely that this 'softening' was due to any government action since there is nothing to show that anything concerning Japanese import requirements was changed. In fact, the tariff rate remained stable at 12 percent even when raising it was a tool easily within the government's reach (Okimoto, Competitive Edge, p.109). (It should be pointed out that this rate was only slightly higher than the U.S.' 10.1 percent but still much lower than the European Community's 17 percent) (Ibid, p.109). At the same time there was also a measurable shift in the government's focus. Responding to public demand for increased social services, funds were diverted from 'unbalanced industrial growth' to an "...increased priority for social infrastructure, pollution and other environmental control, social welfare (especially retirement and health benefits)., and housing." (Patrick, p.14)

Table 6. Growth of Budgeted Government Spending, by Category
(Percent Change from Previous Fiscal Year)

	1970	1971	1972	1973	1974	1975
Social Welfare	18.8	17.7	23.5	32.0	40.9	28.8
Government Pensions	12.4	12.0	9.9	28.3	26.5	26.6
Public Works	17.2	33.6	40.2	7.9	4.1	11.8
Roads	17.9	29.3	31.8	4.3	-0.6	0.1
Housing	20.3	34.7	29.7	22.3	29.6	19.4
Sewers	31.3	92.1	66.9	12.4	22.5	16.2
Foodstuff Control	29.2	4.6	11.1	54.0	22.3	-8.1

Source: Edward Lincoln, Japan Facing Economic Maturity, p.94

The shift towards reduced American imports seems to have instead been a natural business adjustment to what was an inability by the U.S. firms to supply their chips to Japanese electronics companies. In response to these shortages, Japanese companies thus learned at an early stage that if they were to expect a steady supply of chips they must learn to be reliant on themselves.

The importance of this 'shift' can not be stressed enough. First, it maintained a high level of confidence among Japanese industry investors because they were then aware of the fact that there was indeed a guaranteed place in the world for the Japanese semiconductor industries. Secondly, this confidence led to a steadily increasing amount of outside investment being poured into the semiconductor industry. This confidence can be best reflected by looking at rates concerning the percentage of total funds financed by outside sources to the semiconductor companies of the U.S. and Japan.

Table 7. Sources of Finance for Japan-Based Semiconductor Firms %

	Internal Funds	Equity Issues	Bond Issues	Outside Loans
1970-1972 (average)	47.2	2.9	8.8	41.1
1975-1979 (average)	55.2	7.3	10.7	26.8
1970-1979 (average)	51.2	5.1	9.7	34.0

Source: OECD, Semiconductor Industry-Trade Related Issues, p.121

Table 8. Sources of Finance for U.S.-Based Semiconductor Firms %

	Internal Funds	Equity Issues	Bond Issues	Outside Loans
1970-1972 (average)	61.8	19.6	9.4	9.2
1975-1979 (average)	79.0	6.6	8.6	5.8
1970-1979 (average)	70.5	13.0	9.0	7.5

Source: OECD, Semiconductor Industry-Trade Related Issues, p.121

With the U.S. firms forced to rely on more of their own funds, they found themselves in a position in which their investment relied on how healthy the business environment was during a particular year. When business was slow, U.S. companies experienced a smaller amount of profits and therefore could invest only a smaller amount of money into product development, production equipment, and technology research. Research that is ignored in one year will later come back to haunt a company by hindering them when new products are introduced as the industry standard progresses. Inability to invest in production equipment and product development will not allow a firm to increase its profit margins since it will not be able to capitalize on the lower costs that result from fewer defects. One reflection of trends within Japanese research concerned total semiconductor patent applications. Those in Japan increased from 4,406 in 1974 to 6,397 in 1977, while foreign applications dropped from ten to seven percent of the total (Gregory, p.206).

One example best illustrates the opinion held towards the Japanese semiconductor industries in terms of financial stability, When a large U.S. semiconductor firm asked a Japanese banker why he would lend to the Japanese company that had a high debt to equity ratio and would not lend to him, with less than 25 percent debt, the reply was, "Because I know I'll get paid by the Japanese firm. (Semiconductor Industry, U.S. Dept. of Commerce-ITC, p.24)

The author of this quote then goes on to conclude that the reason for this was that, "the Japanese government has taken the risk out of investing in target industries in Japan." (Ibid, p.24) This argument seems to be flawed because even though the semiconductor firms were given special loan considerations by the government, there existed no government program that would account for the repayment of these loans. Once Japanese semiconductor firms received money they had to undertake the policies which they felt would best help them succeed in order not only make money, but to help pay their debts back.

By having such a favorable borrowing climate the Japanese firms were able to strengthen their companies by investing within themselves, thus increasing their competitiveness. One portion of this investment concerned labor, which in many respects was superior to that of the United States. Unlike the U.S. semiconductor industry, there was no defection of key employees to new firms. The pleasant result of this was,

...the stability of employment in Japanese companies yields higher returns on an investment in training, which gives the company a greater incentive to offer expanded training opportunities to its employees. (Weinstein, Uenohara, and Linvill, p.60)

Therefore, not only did this help keep costs down since there is no need to keep retraining new people, but the experience employees acquired allowed them to work at a much more accurate and faster rate.

Another positive feature of the Japanese semiconductor labor force was that it was a well-trained, hard-working, and efficient group. However the determining factor behind creating successful employees is usually found within the capability of their managers. In management the U.S. and Japanese firms take different approaches about which one industry analyst commented:

I believe that one reason Japanese plants are often two or three times more productive than similar American and West German plants is the hands-on experience of Japanese managers. American and German managers spend most of their time in their offices preparing instruction manuals and issuing orders. They move in different circles from the rank and file, even eating in separate dining rooms and using separate washrooms. Japanese plant managers, by contrast, begin work earlier than their employees. They don overalls and proceed to the factory floor, where they pick up knowledge useful in improving productivity. (Makino, p.12)

Unfortunately it is next to impossible to determine the extent of the impact created by a 'superior' Japanese work force, the only factor that can be considered is that of the previously discussed long-term employment factor. Long-term employment was important to Japanese firms because it kept an unbroken stream of expertise within the company and also since it gave them the luxury of not having to expend money in order to train replacement employees.

Chapter Five

Semiconductor Industry (1976-1980)

In 1976 semiconductor technology took a step forward when the 16K MOS RAM chip was introduced to the world electronics market (Borrus, p.34). Two years later the 16K RAM would become an economically significant factor when it reached the point where it equalled that of the previously market-standard 4K RAM chip (Warshofsky, p.158). When this occurred, the 4K RAM suddenly became less desirable to electronics producers since it was not only a weaker chip, but its use was no longer economically advantageous. 1976 was important because it can be pointed to as the beginning of serious Japanese involvement in the United States semiconductor market. By serious, this refers to the fact that not only were these companies exporting their products but were doing so with a realistic ability to gain part of the U.S. market share. In order to best examine the factors which provided for Japan's entrance, it is important to keep in mind that the U.S. firms were still recovering from a recession that did more damage to them than it did to Japanese companies.

Whereas 1975 was characterized by marked reductions in production as a reaction to decreased demand, the period from 1976-1978 was a completely reversed situation. Not only had many of the problems which led to the 1974-75 recession been solved but there was renewed growth in the established IC consumer market, namely calculators and watches and also the growth of a fledgling computer industry (Borrus, p.33). Some of the notable computer-oriented companies created during this period include Apple, Tandy Computers, Microsoft, and Digital Microsystems (Scannell, p.111). In addition to these new companies, the always steadfast IBM reestablished itself as the leader of the computer industry when its 4300 computer was favorably received (Warshofsky, p.148). Non-business computer uses for semiconductors also began to appear after 1976. In 1977 Oldsmobile became the first automaker to use microchips in the engine control system of one of its cars (Alster, p.102). Other areas in which microchip demand grew were CBs and video-games where total production skyrocketed within only a few years (Competitive Factors Influencing World Trade in IC, USITC, p.102).

From all appearances, this upswing in the economy should have been a welcome blessing for the U.S. semiconductor industry. In many ways it was, both orders and production increased, pulling the industry out of its recessionary lull. Unfortunately though, the heightened demand proved to be much too great for the U.S. companies to satisfy alone. As a result, the Japanese semiconductor firms basically had an open invitation into the U.S. market. It was their ability to fully capitalize on this situation that was one of the significant events which contributed to Japan's eventual dominance of the US dRAM market. The extent of the U.S. firms' inability to satisfy 16K MOS RAM demand was apparent on a number of occasions. During 1979 IBM began shopping in Japan for

16K DRAM chips mainly because there was a shortage of these items being sold by U.S. companies (Hataye-IBM, p.18). This action was symbolically important since IBM, the figurehead of American electronics, was forced to go to Japan for the devices it needed in its products. It was, in effect, saying American companies were simply incapable of sustaining its own technological growth. In order to get semiconductors, customers in the U.S. actually had to place orders six months in advance, and even then they were not guaranteed on-time delivery (Surge in Semicon, pp.1,107). One of these victims was Mattel Electronics, who was unable to release its Intellivision video game system during the profitable Christmas shopping season solely because of the shortage in semiconductors (Mattel: CPU, p.22).

It should again be mentioned that U.S. firms also benefitted from increased demand, but that they were unable to capitalize on this demand in the manner that the Japanese companies did. This 'maximization' was in areas in which both research in next-generation technologies and product improvement benefitted. To better understand this it is necessary to look at the methods by which investment was undertaken and the effect it had on production.

Perhaps the most salient characteristic which influences investment is the economic environment in which semiconductor companies produce their product. When looking at information from the 16K era a strong argument can be made that the Japanese semiconductor companies operated in a system which was more conducive to allowing firms to grow. This economic environment will be examined as it is related to the larger financial world.

Unlike Japan, the United States firms, aside from IBM and AT&T, were comprised of a large number of individual companies who were not very diversified in terms of production. These companies were for the most part concerned mainly with creating microchips, while those in Japan could be characterized as ,"...highly diversified, vertically integrated electronic equipment manufacturers (that produced) a wide variety of home appliances, data processing, telecommunications, automotive electronics and medical equipment"(Gregory, p.96). Flaherty and Itami compiled a list in which both U.S. and Japanese firms were grouped into categories describing their business characteristics.

1. Heavily diversified and somewhat vertically integrated electronics firms prominent in the state-of-the-art, high-volume memory market: Fujitsu, Hitachi, Mitsubishi, NEC, Oki, and Toshiba.
2. Heavily diversified and somewhat vertically integrated electronics firms not prominent in the state-of-the-art, high-volume memory market: Matsushita, Sharp, Sony, Tokyo Sanyo.
3. Moderately diversified and not vertically integrated electronics firms: Motorola, Texas Instruments.
4. Specialized integrated circuit firms: AMD, Intel, National Semiconductor.
5. Conglomerates (heavily diversified and not vertically integrated) selling integrated circuits: Philips (Signetics), Schlumberger (Fairchild), United Technologies (Mostek).
6. Diversified and vertically integrated producers of semiconductors: AT&T, IBM. (Flaherty and Itami, p.161)

The importance of this was the stability it created within the company. Any economic downturn in a company's semiconductor department could be offset by revenues generated from profits in other sections of the company. This is important because it greatly decreases the chance of the company going under, allows for an unbroken stream of finance into long-term research projects, and also provides for a high degree of confidence on the part of outside investors. As far as production totals are concerned, when comparing the main Japanese and U.S. semiconductor producers, semiconductor divisions comprised an average of seven percent of total sales in Japan and 71 percent in the U.S. (Semiconductor Industry-OECD, p.46).

One item previously mentioned concerned the portion of financing that came from the company's internal funds. As was mentioned before, the U.S. relied on internal funding to a greater extent than Japan. The reason for this difference can be traced directly to the borrowing conditions which existed within each country. In the U.S., the discount rate increased from 6.0 percent in December of 1977 to 12.0 percent by the end of 1979 (Lincoln, p.259). The effect of this was that it, "...dried up what was once a major source of capital for computer firms." (Verity, p.29,Sect II) In Japan the comparable rate was 4.2 percent by the end of 1977 and 6.2 percent at the end of 1979 (Lincoln, p.259). An additional difficulty for small U.S. companies was that they were forced to accept short-term loans with five to seven percent additional rates tacked on (Verity, p.29, Sect II). As a result, the average Japanese producer was able to operate with a 9.3 percent cost of capital while the American companies were at 17.5

percent (Cook, p.103). After examining these numbers, there does not seem to be any question as to why Japanese investment grew. It simply had access to money at much better rates and therefore the decision to invest was easier for them to make, simply because they had less to pay back.

Table 9. Semiconductor Capital Spending (Millions of Dollars)

	Japanese Firms		U.S. Firms	
	Capital Spending	% of Sales	Capital Spending	% of Sales
1976	$238.6	21.3%	$306.0	9.0%
1977	179.4	14.1	413.4	10.6
1978	453.2	18.2	650.1	13.6
1979	656.3	22.4	887.1	13.4
1980	956.2	24.9	1,299.8	15.4
1981	1,046.7	25.1	1,424.0	17.8
1982	1,301.0	27.8	1,188.4	14.8

Source: Howell, Noellert, et. all, The Microelectronics Race, p.218

No matter how much money a company receives, success is not entirely guaranteed. Instead, the important item used in determining is that the proper things be invested into. For the Japanese semiconductor companies, the improvements they authorized within their own firms were what ultimately produced better products. Unlike the U.S. firms, the Japanese companies chose to follow a conservative approach when producing their chips. By conservative this refers to,

Japanese engineers described three design features to illustrate how they had 'designed quality into the chip.' First, they were more liberal than their U.S. counterparts in the use of border areas; this was expensive, but by leaving more space, they were able to avoid certain bonding problems. Second, they claimed to have made an important breakthrough in the packaging process.

Heretofore, the two choices in packaging had been hermetic, which is very reliable but expensive, and plastic. The Japanese developed a new plasma nitride passivation technology that made plastic more reliable. (According to the Japanese, American experiments along the same line produced products that were too thin and often defective, not comparable in quality to the Japanese packaging.) Third, the conservative design of Japanese chips was said to have made it easier to deal with the problem of alpha particle immunity, which was a cause of soft errors. (Those which do not actually change the physical make-up of the semiconductor and therefore are much more difficult to detect since they give no outward symptoms of being incorrect.) The Japanese developed a technology to overcome the alpha particle problem by overcoating the chip. (Weinstein, Uenohara, and Linvill, p.52)

The Japanese strongly believe that the only acceptable defect ration is none, while U.S. companies agree that at least some are to be expected and therefore permitted.

Life tests, environmental tests, function tests and failure origin tests are carried out in great number, over and over again, at all stages from design to development through production. Using this so-called failures in time standard (FITS), Japanese semiconductor manufacturers consider 15 to 30 failures per billion hours of operation to be high quality, while 100 failures are rated good. (By comparison, the U.S. space industry sets 2 failures per billion hours of operation as standard). (Gregory, p.200).

What this type of production resulted in was a markedly higher quality on the part of Japanese producers. One survey conducted concerning the quality and reliability of Japanese and U.S. RAM circuits found that the average rejection ratio for 16K RAMs made in Japan was 0.87 percent, while that for U.S. firms was twice as high at 1.70 percent (Semiconductor Industry-Paris, p.124). Once these defected chips had been weeded out the next concern was their reliablity at performing their specified jobs. For Japanese RAM circuits, the reliability levels measured (in percent of failures per thousand hours) was strikingly low at 0.027 percent (Ibid, p.124). The comparable rate among U.S. products was almost five times higher, at 0.125 percent (Ibid, p.124). From this statistic we can truthfully claim that the Japanese chip was actually better than the American one.

The inferiority of American products as being the crucial factor in choosing a producer by a large company was first brought up by Hewlett-Packard chairman David Packard, whose company discovered that Japanese rejection levels for chips was around 0.1 percent while those from American firms are around 0.6 percent (Halper, p.83). He stated that,

> When it comes to the fact that we can't get products from (U.S. suppliers) that perform anywhere near as well, we have no choice but to go to the Japanese. (Ibid, p.83)

This opinion was also voiced by other industry leaders, Doug Malone of GTE stated,

> I do concur with Packard. I'm very concerned. The quality (of Japanese parts) is indeed very good. It's getting better. The quality from the domestic suppliers is eroding somewhat. Domestically, we've lost the formula. They're doing what we did 20 years ago and doing it very well. (Ibid, p.83).

As for prices, the semiconductor industry is subject to what is known as a 'learning curve'. The learning curve is an economic phenomenon in which prices decrease (usually by 25-35 percent) as total production doubles (Kimura, p.49). During the lifespan of the 16K RAM, this adjustment swung into full effect in 1980, when prices during just one quarter fell from $4.00 to $2.50 (Weinstein, Uenohara, et al., p.72). This combination of declining quantities of devices being produced and higher Japanese product quality made it very difficult for U.S. semiconductor consumers to continue refusing to use Japanese devices. As a result of this and higher product quality, Japan was able to control 43 percent of the U.S. 16K RAM market by the beginning of 1980 (Borrus, p.106).

In terms of new-technologies research, Japan once again showed no signs of letting up. However during this time there were also signs of reinvigoration in the U.S. as its research totals began to increase.

Table 10. Semiconductor Research and Development Spending

	Japanese Firms		U.S. Firms	
	Capital Spending	% of Sales	Capital Spending	% of Sales
1976	$164.7	14.7%	$227.8	6.7%
1977	199.8	15.7	300.3	7.7
1978	375.9	15.1	384.3	8.0
1979	427.8	14.6	470.0	7.1
1980	483.8	12.6	624.6	7.4
1981	621.3	14.9	776.0	9.7
1982	725.4	15.5	875.3	10.9

Source: Howell, Noellert, et. all, The Microelectronics Race, p.219

Between 1976-80 research continued in a number of areas within different companies, but the one that received the greatest publicity was Japan's Very Large Scale Integration (VLSI) program. This program was organized in 1976 by the Japanese Ministry of

International Trade and Investment in order to link together private Japanese semiconductor firms for the purpose of creating new generation 64K chips (Cook, p.101). The fact that this program did exist and that it did do a number of positive things for the Japanese semiconductor industry is often viewed by many in the U.S. as being 'government intervention'. Something that was considered nothing less than unfair assistance. Upon closer examination it can be shown that the most useful result of this program was that it improved on a number of processes that had previously been invented in the U.S., such as electronic beam lithography, plasma etching (Weinstein, Uenohara, et al., p.51).

In fact, of all the new technologies created as a result of this program, only 'evaluation technology for oxide and nitride layers by liquid crystal' was considered to be an industry breakthrough (Ibid, p.39). The project as a whole can be described as a number of competing companies who without government guidance simply would never have come together since they each distrusted the other (Naohiro, p.42). Once they were working together, this distrust still persisted. The firms were unwilling to send their most valuable employees to the project simply because they did want the other companies to gain their valuable research knowledge. As a result of this the only research which took place was basically that which was generally known. The companies invested their time into looking at existing technologies and finding out ways in which they could be improved.

Chapter Six

Conclusion

By the time the Japanese firms were getting ready to compete in the 64K RAM market they were already a strong actor. Their involvement in this particular microchip continued the policies they had previously followed, being continued investment into both their own production systems and research. The result of this was that they were constantly improving in an industry where this type of behavior is eventually rewarded. The purpose of this paper was to try and better understand the reasons behind Japan's success in the United States semiconductor market. As was mentioned at the beginning and seen throughout this paper, Japan's entrance was the result of actions in the United States as much as those in Japan.

Japan succeeded in making a quality product in a manner that many analysts do not usually consider. There existed no dynamic new innovations or huge government subsidies that served to propel the Japanese toward eventual semiconductor domination. Instead, the real reason seems to have been much less exotic. The Japanese succeeded because they created a superior product by doing a better job than their opponents in investing within their firms. During the recession years, the Japanese companies still managed to keep funding flowing into areas in which they saw future promise. They also were able to keep this investment within their own firms through an employment system which encouraged continued service with the same company. Whether or not the Japanese companies would have been able to compete in the American market had the U.S. firms been doing the same type of quality job is questionable. Nevertheless there is no denying the fact that the U.S.'s inability to capitalize on its own market demands was a window of opportunity which the Japanese used fully.

The most serious problem the U.S. firms faced was that they were very much isolated from one another and were forced to compete on their own. This was especially reflected in the high percentage of internal funding they had to rely on. Although the U.S. government had labeled this a strategically crucial area in which success was imperative it did not do anything to make the consumer market easier for these firms to become involved in. This was especially apparent in the extraordinarily high borrowing rates these firms were subject to. For the U.S. firms, the recessionary year 1975 was another contributing factor to its decline. Since the U.S. firms were so heavily reliant on their own financial fortunes, this economic downturn resulted in what appears to have been a break in their investment programs. The result of this was that it left them unable to fully capitalize on the unexpected boom in demand that would occur soon afterward. The importance of this examination is that it serves to better explain the reasons behind decline in at least one of the United States' industries. Much too often the blame is unfairly shifted from a domestic source to one located overseas, namely Japan. In this case the attributes that led to the United States' problems could very easily have been averted if it had only been able to receive a small amount of assistance from the government. Rather than large defense contracts this industry would probably have done better in the commercial sector if it had received assistance in such areas as investor guarantees and discounted rates on semiconductor investment. Hopefully the actions taken in future semiconductor technologies will be undertaken by those in the U.S. who are aware of their industry's history and the lessons it teaches.

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