Comparison of China and Japan's Economic Development in the Semiconductor Industry

Rundong Ke
Bard College, rk859@bard.edu

Comparison of China and Japan's Economic Development in the Semiconductor Industry

Rundong Ke

Bard College, Annandale-on-Hudson, NY

May 2012

ABSTRACT

While Japan marked its success in surpassing the U.S. to dominate the semiconductor industry in 1986, the Chinese semiconductor industry transformed from a small sector into a global competitor. This thesis tracks and compares the developmental histories of this industry between China and Japan and analyzes the differences in government policy, economic systems, comparative advantage and trade policy in both countries, in order to ascertain the two countries' industrial development strategies and governments' impacts on the semiconductor industry.

This analysis finds that Japan's development strategy targeted a knowledge- and capital-intensive industry (semiconductor industry, in this case) by providing preferential assistances while deliberately keeping that market protected from foreign competitions to ensure that the industry had a high volume and a profitable base. When the Japanese achieved the economy of scale and cost competitiveness and gained enough production experiences, Japan expanded the market share by aggressive pricing and ultimately dominated the foreign market. On the other hand, China's development strategy went from a protectionist strategy in a command economy—learning from the Japanese model—which focused on cultivating large state-owned enterprises to be national champions and protecting the market from foreign competition, to an export-oriented strategy in a relatively more market-oriented economy which encouraged foreign investment and leveraged China's labor-abundant comparative advantage by cooperating with foreign firms.

Table of Contents

DEDICATION

To what doesn't kill me that make me stronger…

ACKOWLEDGEMENT

I would like to express my appreciation to my advisor, Professor Dimitri Papadimitriou, who has offered me continuous support and guidance. His broad knowledge impressed me and made me long for further studies in the development histories and economic systems of developing and developed countries, such as China and Japan. This work will be my first step to pursue my passion for understanding the world and making the world a better place.

I would also extend my gratitude to Professor Sanjaya DeSilva and Professor Alex Chung who sit on my senior project board and provide many detailed instructions during midway. Also I hope to express many appreciations to Tamar Khitarishvili who inspired my passion to study in the macroeconomics and international trade theories, Andrew Pearlman who provided advices to me in my freshman and sophomore year, and Susan Rogers who helped to improve my writings during my undergraduate years. Finally, I want to thank my previous instructors, Professor Tamas David-Barrett, Professor Christine Wong, Professor George Bitsakakis and Professor Silvia Palano at Oxford University, who have inspired me to think about the different economic systems and developmental histories among different countries.

Additionally, I want to thank my friends Dimin Xu, Sining Leng, Sicong Zhang, Siyao Du, Michelle Yuan, Mengyao Li for continuous academic and professional help.

I give my special appreciation to Justin Zhou for personal and professional help during my final year at college.

At last but not least, I want to give my most sincere appreciation to my parents, Jisheng Ke and Fujing Ma, for supporting my pursuit to study abroad and giving me freedom to do things that I like.

I.1 Overview Introduction

China has been regarded as the most important emerging economy in the world. Since 2010, China ranks as the world's second largest economy after the U.S. It has been the world's fastest-growing economy, with consistent growth rates of around 10% over the past 30 years. Among China's major industries, China's electronics information industry has grown three times faster than the national GDP growth rate and has grown faster than the machinery manufacturing and metallurgy industries (People Daily). However, the value added ratio (amount of value added/total sales * 100%) of the electronics industry in China is only 23.4%, compared with the whole national average of 27.1% (Economic Operation Report of China Electronic Information Industry 2007). The main reason is that China's role in the global electronics industry remains an assembly base, which relies on overseas electronic components and parts. Up until now, China still bears the impression of "copycat" and "made in China".

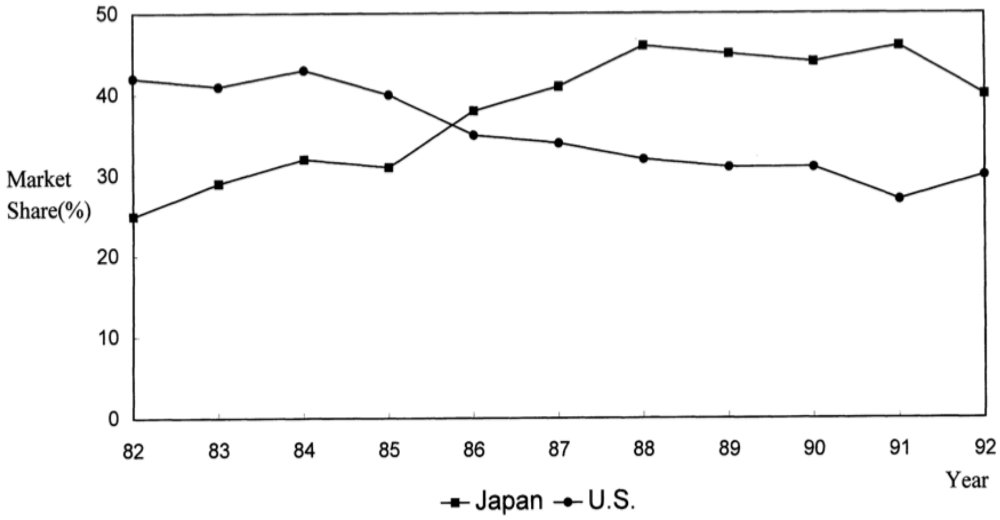
On the other hand, with a high concentration of electronics companies, dominant global market share in electronics, and high quality of its products, China's neighbor Japan has a good reputation for its technologies in the electronics industry. Japanese electronics manufacturers are well known for producing a wide variety of product lines, including televisions, mobile phone handsets and personal computers, which are under the category of consumer electronics. Nowadays, Japan is the largest consumer electronics manufacturer in the world. In contrast to China, which bears the impressions of "low quality" and "low tech", Japanese companies are famous for high quality and innovation, having introduced products such as the Sony Walkman and VHS recorder.

In response to this phenomenon, a question comes up: why does China have a growing electronics industry but with low value-added while Japan on the other hand attains a large market share in the industry with high value-added? In order to compare and analyze the differences in the development strategies between China and Japan, a core sector in the electronics industry—the semiconductor industry—is picked in this study. The semiconductor industry is a representative example of the general electronics industry, and it plays an important role in supporting the electronics industry. These tiny microchips perform the vital functions of arithmetic calculations and information storage and retrieval, which constitute the "brain" of computers and other industrial and consumer products. During the financial crisis, it is the strong sales of semiconductors that has been keeping Japan's growing exports and offsetting the declining sales in the consumer electronics market. For this reason, the semiconductor industry is chosen to represent the general electronics industry in this study.

Japan had the successful experience of developing its semiconductor industry and managed to leapfrog over the U.S. to take over the dominant global market position in 1986, 32 years after Japan's market entry. The growth of the Japanese semiconductor production had been phenomenal. The overall production volume had increased between 1971 and 1992 at an annual average rate of more than 18%. Integrated circuits accounted for a major share with 23% annual growth (Semiconductor Yearbook 1985-1993). Japanese manufacturers took industry leadership between 1986 and 1992, controlling 38% to 46% of the world's semiconductor market (Cho et al 1998). Figure 1.1 shows the changing market share of the US and Japan in the world's semiconductor shipments.

It is interesting to note that, however, in these days, Chinese firms, who are beginning to approach Japanese quality at much lower price, are increasingly outperforming Japanese firms. China already has the world's third-largest domestic semiconductor market, closely following the United States and Japan. According to Table 1.1, U.S. imports from China surpassed imports from Japan in 2002 and continued to rise over the next years. As a latecomer in the semiconductor industry, Chinese semiconductor companies succeeded to grow tremendously in the global sector.

<u>Figure 1.1 Changing Market Share Changes in the World's Semiconductor Shipments: United States and Japan, 1982-1992</u>



Source: Nikkei Tsushin

When looking at Chinese and Japanese development history of the semiconductor industry, there are some similarities such as their pirating of the design from foreign products, their protectionist trade policies and industrial projects. A series of questions further occurred to me: is Chinese path of developing the semiconductor industry different from Japanese path? How did two countries' governments contribute to the industrial development and were these policies effective? What are the similarities and differences in the government policies that Chinese and Japanese governments implemented? What are the factors that led to China and Japan's current status in the global semiconductor market? Are Chinese and Japanese industrial development strategies coherent with the economic theories?

Table 1.1 US electronics and information industry trade with China and Japan, 1997-2005

	US imports[a]			US imports from China as share of total imports (percent)	US imports from Japan as share of total imports (percent)	US exports[b]			US exports to China as share of total exports (percent)	US exports to Japan as share of total exports (percent)
Year	China	Japan	World			China	Japan	World		
1997	16.4	54.6	261.3	6	21	3.9	17.0	219.8	2	8
1998	20.2	52.4	275.7	7	19	4.3	14.7	226.1	2	7
1999	25.1	56.7	308.2	8	18	4.2	15.2	229.8	2	7
2000	32.7	65.6	364.4	9	18	5.5	18.7	265.5	2	7
2001	33.3	49.8	313.7	11	16	6.7	15.6	229.5	3	7
2002	44.5	44.2	311.7	14	14	7.0	12.2	204.5	3	6
2003	58.3	44.2	325.5	18	14	8.2	11.4	202.2	4	6
2004	83.8	50.4	382.8	22	13	10.7	11.8	223.3	5	5
2005	95.6	48.6	462.8	21	10	9.8	10.4	240.2	4	4

Source: USITC Dataweb 2006

Note semiconductors account for a significant share of electronics and information industry trade

As I have found no previous text about the comparison between Chinese and Japanese development history in the semiconductor industry, I hope to answer these questions by referring to China and Japan's development histories and analyzing the economic histories by applying economic concepts and theories. In this paper, I will focus on the economic analysis of the semiconductor industry. I will track and compare the development histories in the semiconductor industry between China and Japan and analyze the economic factors.

My project will be organized in the following fashion. In the rest of the first chapter, I will give a brief introduction to the development history of the overall semiconductor industry, state my literature review and describe the current status of China and Japan's semiconductor industry development. In the second chapter, I will track back to China and Japan's development histories in the semiconductor industry. In the third chapter, I will compare the two countries' industrial development strategies from an economic perspective. The comparison of the development histories will be divided into a couple of sections, all of which I believe contribute largely to the different paths of the development in the two countries, including comparative advantage, economic and political system, government policy, international trade and foreign investment. In the fourth chapter, I will conclude my study and provide answers to the questions I raised in the beginning of this study.

I.2 Literature Review

Longtime observers of the Chinese semiconductor industry, notably Dennis Simon, started to track the development of this sector in the mid-1980s (Simon, 1987; 1992; 1996; Simon and Rehn 1988; Naughton, 1999). Most of the studies during this time emphasized the role of the state had played in industrial planning while a few researchers gave attention to regions and companies. Increasing interest was attracted to the industry when it experienced rapid growth around the 2000 (Chen and Toyama 2006; Chesbrough 2005; Chesbrough and Liang 2008; Dewey-Ballantine 2003; Fuller 2005; Klaus 2003; Lin 2009; PWC 2004; Wu and Loy 2004; Yuan 2001). Since the Chinese state had a record of intervening in industries, the scholarly research emphasized an analysis of industrial restructuring and policies of liberalization at the country level (Chesbrough and Liang 2008; Klaus 2003; Lin 2009; Wu and Loy 2004; Yuan 2000).

Among these scholars, Li (2011) described the transformation of the Chinese semiconductor industry from a small sector into an international competitor as a spectacular episode of China's economic success. Li (2011) documented the developmental history of the Chinese semiconductor history from its stagnant state-dominated eras (prior to 2000) to a more successful stage led by innovative business enterprises (after 2000). Li (2011) found that the success of the industry came from the transformation of investment strategies and organizational structures of businesses and governments. It involved the transfer of strategic control from the state to techno-entrepreneurs and managers, the adoption of new organizational structures to support the needs for investment (Ibid).

On the other hand, there are many literatures written about the factors leading to Japanese success in the semiconductor industry. (Anderson 1980; Abegglen 1973; Bylinsky

1981) Due to Japan's aggressive pricing strategy in the global semiconductor market and Japan's surpass over the U.S. in the 1980s, many researchers in the U.S. pointed to Japan's government's effects on the semiconductor industry (Cupertino 1983; Hay 2012; Okimoto et al 1984). Within these literatures, Cupertino (1983) asserted that the Japanese semiconductor industry was mainly affected by its government targeting. While the report is highly polemical, it shows that the Japanese semiconductor industry has received and continues to receive various forms of assistance from its government. Okimoto et al (1984) analyzed the strengths and weaknesses of Japanese semiconductor with reference to the role of government and policies.

I.3 A Brief Intro to Semiconductor Industry Development

The semiconductor industry is an extremely dynamic sector. For over fifty years, this industry has been generating innovative semiconductor chips of increasing power (higher quality) and decreasing prices (lower cost) at an astonishing pace according to Moore's Law[1]. The application of semiconductor chips in a wide range of areas has contributed enormously to economic development by boosting productivity growth and delivering consumer welfare. But the rapid technological advances in the semiconductor industry are not exogenous shocks; rather, they are the result of heavy R&D spending and organizational learning (Li 2011).

The rapid advance of technology and the distinctive features of semiconductor production have resulted in massive R&D expenditures and high fixed costs for the industry. The costs of building a leading-edge semiconductor manufacturing facility, a wafer fabrication plant (or a fab), continue to increase. A state-of-the-art 300mm (12-inch) fab costs $3 billion to $4 billion to build, while a 200mm (8-inch) fab of earlier generation technology

---

[1] Gordon Moore, one founder of Intel, predicted that in mass production, the number of transistors that can be placed on an integrated circuit would double every two years, resulting in higher performance and lower costs. See Moore, 1965

costs $1.6 billion (Ibid). Developing and deploying process technology is increasingly costly as well. Developing 90-nanometer logic process technology costs approximately $300 million, while the costs of developing 45-nanometer technology rose sharply to $600 million by 2006 (MGI 2007).

Prior to the 1980s, the semiconductor industry was vertically integrated. Semiconductor companies owned and operated their own silicon wafer fabrication facilities and developed their own process technology for manufacturing their chips. These companies are also in charge of the assembly and testing of their chips, the fabrication. Thus these types of semiconductor companies, which design, manufacture and sell integrated circuit products are usually called integrated device manufacturer (IDM).

To help maintain full utilization of the increasingly expensive fabs, IDMs began to offer manufacturing services to design houses in the 1980s, making it possible for chip design to be separated. Since Taiwan Semiconductor Manufacturing Corporation (TSMC) invented the pure-play business model, the semiconductor industry has become a segment of increasingly vertical specialization. According to the pure-play business models, two types of new start-up firms arose: fabless and foundry. Fabless (fabrication-less) semiconductor companies specialize in the design and sale of semiconductor chips while outsourcing the fabrication (fab) of the devices to specialized manufacturers called semiconductor foundry. Foundries are typically located in countries with lower cost labor so that fables companies can benefit from lower capital costs while concentrating their research and development resources on the end market.

Foundries have gained bigger and bigger shares of chip production, as they have been able to exploit a larger economy of scale than most IDMs. Except for a few of the largest integrated players such as Intel and Samsung, semiconductor companies nowadays are giving up their foundry operation, outsourcing chip manufacturing to pure- play foundries in Eastern

Asia, particularly Taiwan, Singapore and China. The Americans, however, did not enter the pure-play foundry segment until the establishment of enter the pure-play foundry segment until the establishment of GlobalFoundries in 2009, a spin-off of microprocessor maker AMD (Ibid).

I.4 Current status of China and Japan's Semiconductor Industry

In this section, I will discuss the current status of China and Japan's Semiconductor Industry so that we can see the current results of the long-term strategies of the two countries.

I.4.1 China's Current Status in the Semiconductor Industry

China's semiconductor production growth since 2000 has been substantial. With a booming electronics industry, the semiconductor industry has developed rapidly in China. The Chinese government has been aiming to further develop its semiconductor industry through information and the sector was identified as a key industry for development in the 11th Five-Year Plan. In 2007, sales revenue of China's semiconductor market reached RMB 562.4 billion, growing by 18.6% from the previous year (China Knowledge).

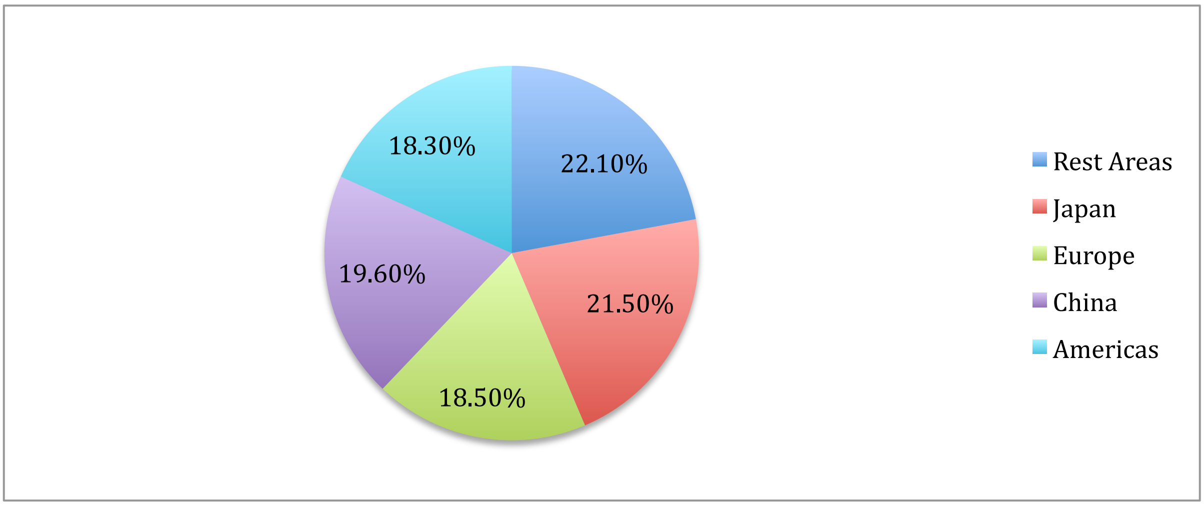
However, China's current production in the semiconductor industry accounts for only a small percentage of the worldwide market. According to Table 1.2, the proportion of China's semiconductor sales value to semiconductor worldwide market sales value is 17.7% in 2003, 19.6% in 2004 and 21.7% in 2005.

Table 1.2 The Proportion of China's Semiconductor Sales Value to Semiconductor Worldwide Market Sales Value 2003-2005

	2003	2004	2005
Percentage	17.7	19.6	21.7

Source: CSIA and CCID, Compiling Committee, Development Status of Semiconductor Industry in China, May 2005

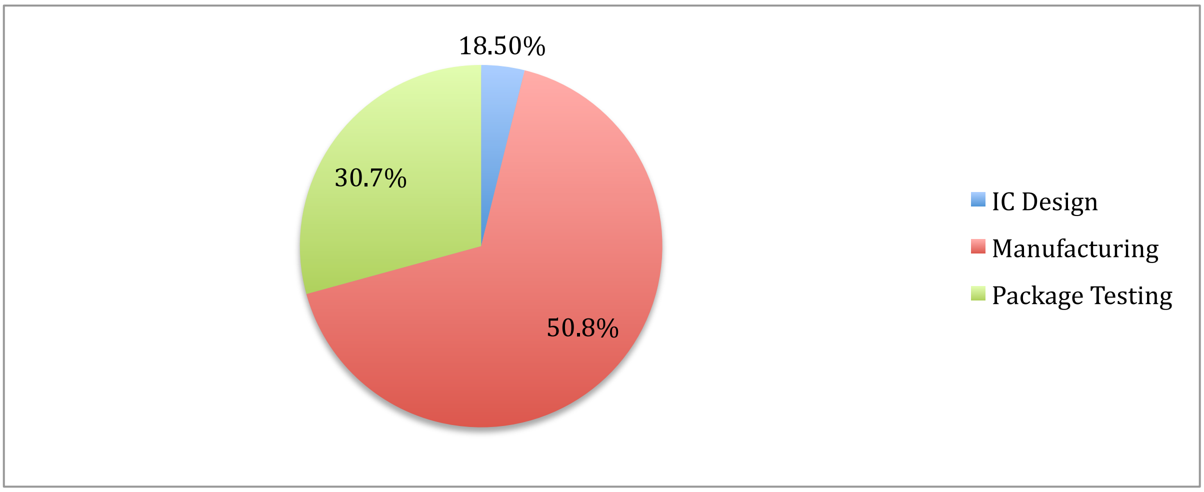
Figure 1.2 Worldwide Semiconductor Market by Region in 2004



Source: Pecht 2007

China's rapid growth in the semiconductor industry is largely accredited to its foundry, an integral part of the semiconductor chip manufacturing industry. Foundries in China have been recording an exponential growth with the introduction of the Semiconductor Manufacturing International Corporation (SMIC 2004) and Grace in 2001. In 2009, among the world's largest fifteen semiconductor foundries in terms of revenue, four companies are now Chinese (Li 2011). Driven by the outsourcing strategies of the US firms, the global semiconductor industry had become increasingly segmented into two subsectors, the fabless industry and the foundry industry. Measured in the share of world production and level of technological sophistication, the Chinese presence in the world foundry sector has become significant. According to statistics from PWC, China manufactured approximately 8.7 percent of chips in the world in 2008, and the share is expected to grow to more than 10 percent within a few years (PWC 2010). The leading Chinese firm, SMIC, is able to manufacture chips only one generation behind the products of leading US and Japanese firms, meaning the technological gap is ten to twelve months instead of the five to seven years gap that existed in the 1990s (SMIC Annual Report, 2009).

<u>Figure 1.3 Percentages of China's Sectors in the Semiconductor Industry in 2005</u>



Source: ChinaIRN.com

However, China's technological advance in the semiconductor industry is still below the global level. Global semiconductor companies usually attribute to China components on value chains that tend to be more labor-intensive. China's development in the semiconductor industry is still concentrated mainly on low-tech, labor intensive and low-value-added sectors. According to Figure 1.2, in 2005, China's ratio among IC design, manufacturing and package testing is 18.5%, 30.7% and 50.8% respectively. The usual ratio is 3:4:3. But China is lagging behind in the IC design sector while majorly focusing on the packaging design sector. This shows China's role in the global semiconductor industry is an intermediate processing role with low profit and added value. The major reasons behind are China's low technological development, lack of high-tech core wafer, key equipment, which is inaccessible due to other countries' limitations. Moreover, China does not have as many IDMs as advanced countries such as Japan, leading to separation of design, manufacturing and implementation.

I.4.2 Japan's Current Status in the Semiconductor Industry

Japan took over several critical areas of the market in the 1980s and today is the leading supplier of several key pieces of equipment, including lithography machines that miniaturize circuitry design and use light waves to transfer them onto silicon wafers.

According to Hays (2012), in the 1980s the Japanese dominated the global computer chip industry, surpassing American companies. Japanese companies produced 51 percent of the world's semiconductors and the three top chipmakers—NEC, Toshiba and Hitachi—were Japanese. Today, Japanese global market share (28 percent) is about half of what it used to be and Japanese companies is being outperformed by American as well as South Korean, Taiwanese and even Chinese companies (Hays 2012). In 2006 Intel and Samsung had a combined share of the market that was as large as Japan's 20 largest chipmakers (Ibid). After sharply falling off in 2008 and 2009, the semiconductor industry picked up in 2010 both in terms of volume and prices, driven by strong demand for cell phones, computers and other electronic devices, with total sales of semiconductors expected to top $310 billion for the year. (Ibid) Moreover, Japan's disastrous earthquake further shakes Japan's leadership in the semiconductor industry in 2011.

Nevertheless, Japan's success in surpassing the United States is hard to be omitted. But Japan's falling in the 2000s also cast a new aspect on my project – to compare China and Japan's difference in development history of the semiconductor industry and learn from both the success and failure experience.

II An Overall Development history of the Electronics Industry in China and Japan

II.1 Introduction to the History of China's Development in the Sector

With a booming electronics industry, the semiconductor industry has developed rapidly in China. According to the China Semiconductor Industry Association (CSIA), in 2000-2004, the industry grew with a CAGR of 31% from $2.2 billion to $6.7 billion. The Chinese government 's aim to further develop the semiconductor industry through informationization was identified as a key industry for development in the recent industrial plan.

However, not long ago, at the end of the 1990s, China's domestic semiconductor industry was insignificant internationally by any standard of measurement. China imported more than 80 percent of the chips from the foreign market (Li 2011). Foreign-made chips dominated the middle- to high-end of the Chinese market. Throughout the 1990s, the need to create a Chinese semiconductor infrastructure led the Chinese government to invest billions of dollars in state-led projects in the hope of building competitive Chinese chipmakers. Two most well-known state-led industrial project, State Project 908 and State Project 909, allowed the government to purchase expensive equipment from abroad, sent engineers and technicians abroad to get training, and actively leveraged access to the enormous Chinese market to ask for technology transfer from the foreign companies in the hope to upgrade China's technology to produce the IC. Yet, the semiconductor companies created by the state, whether state-owned or joint-ventures, failed to narrow the technological gap between China and the world and the production gap between Chinese consumption and production.

II.1.1 State-Led Development: Prior to 2000

China is actually among the world's first group of nations that invested in developing semiconductor technologies. The country's first semiconductor was made as early as 1956

(Dewey Ballantine 2003). The Chinese Academy of Science, China's premiere state lab, created the country's first integrated circuit (IC) in 1964, only seven years after IC was invented in the Bell Lab in United States (Simon 1987). Yet political turbulence during the Cultural Revolution disrupted the country's IC research and development (R&D). When the country reorganized for technological catch-up, the technological gap between China and the industrialized world had considerably widened.

Rather than the limited capabilities of the research institutions to develop technologies, however, it is the lack of effective mechanisms for the production units to utilize the developed technologies that hindered innovation in the planned economy (Simon 1987; Lu 2000). In the mid-1980s, Denis F. Simon (1987) observed that the actual production technology being employed by the Chinese semiconductor manufacturers was even more backward than that in the state labs. The prevailing technology used in plants in Shanghai, one of the primary chip production locations in China, had an integration density of 1K or 4K and line-width (width of feature on the chip surface) no smaller than 5 to 6 microns - the technology that existed in state labs before 1979. Even such technologies were not effectively utilized: yields were as poor as 20 to 40 percent (i.e., 60 to 80 percent of the produced semiconductors were rejected), output was low and quality was unstable. (Ibid) At the same time, the best Japanese producers had achieved yields of 70 to 80 percent, with much higher reliability of chips (Ibid). Characterized as high-cost, low-quality products, domestically produced semiconductors were unable to compete with imported ones, which were ready to flood in as China slowly opened for trade.

The state of China was considered as the poor performance of a wide range of industries as a technology issue and sought to solve the problem through technology import. According to Hu (2006), China's former minister of electronics industry, there were at least five major pushes from the state in fostering technological upgrades in the semiconductor industry.

II.1.2 The First and Second Push

The first push was as early as in the 1970s that China imported seven semiconductor production lines from Japan. The second push was the reform in early 1980s, which devolved the authority of decision making to provincial level entities. Factories, labs, and universities rushed to import second-hand lines. Similar large-scale importations of production lines also occurred in sectors such as radio, color TV and refrigerators, exhausting China's foreign reserves in mid-1980s (Simon 1992).

By the beginning of the 1990s, China's electronics industry began to take off, with the share of electronics in total export climbing from only 6 percent in 1985 to 18 percent in 1990. (Ibid) Demand for semiconductor chips was driven by the emerging electronics and computer industry. In 1989, IC consumption in China was estimated to be between 350 million and 400 million chips, while domestic production totaled 114 million (Ibid). However the backward IC plants could hardly meet technological demand of the growing microcomputer, telecommunication, and consumer electronics manufacturers. The production of relatively sophisticated products, such as color TV, relied heavily on importing chips from abroad (Li 2011). In late 1980s, the shortage of foreign exchange for importing foreign components further worsened, causing severe under-utilization of the imported production lines.

II.1.3 The Third Push – Creation of MEI and three Joint Ventures

The third push was state's response to state's lack of to build state's backbone enterprises. Industry planners responded by consolidating the sector to built a national champion State-owned Enterprise (SOE) – Huajing. In 1989, the China Electronics Corporation (CEC) was created by the Ministry of Electronics Industry (MEI) as the ministry-level corporate entity to own and manage the country's large state-owned electronics enterprises, aiming to consolidate manufacturing and R&D efforts and foster the emergence of technologically advanced enterprises with large scale productive capabilities. In the semiconductor sector, the first task for CEC was to build Huajing, a backbone State-owned Enterprise (SOE) conglomerate. With limited resources such as foreign exchange reserves available, planners were also searching for new ways of promoting the industry using resources outside of the budgetary system. Since MEI concentrated resources on Huajing, regional governments were allowed to establish joint ventures (JV) to access foreign capital and technology (Fuller 2005). Three major JVs in the semiconductor sector were established by the mid-1990s, with two in Shanghai and one in Beijing Shanghai Bell, Shanghai Philips, and Shougang-NEC. Through the restructuring started in late 1980s, the four enterprises, Huajing, Shanghai Belling, Shanghai Philips and Shougang-NEC emerged as the backbone enterprises in the semiconductor sector in the 1990s.

II.1.4 The Fourth Push Push – Project 908

The third push created a group of national champions; the fourth push was concerned with strengthening their technological capabilities. The microelectronics industry was recognized as a strategic industry to be supported (officially "Pillar Industry") in the Eighth Five Year Plan (FYP 1991-1995). As a part of the planning, MEI initiated Project 908 in 1990 to upgrade the backbone enterprises, with the plan of deploying a mainstream 200mm (6-inch) wafer fabrication line (or fab) (Li 2011), which was the largest wafer size at that time, and establishing a dozen of semiconductor design centers, one test and packing firm, and six fab equipment supply projects. Yet, when the fab deployed at Huajing finally came online in 1997 after a long delay, the ambitions in Project 908 to close the international technology gap had not been realized (Ibid). Technological advance in the semiconductor industry was simply moving too fast; by 1997, a 200mm fab trailed leading-edge international technologies (Ibid).

The failure of Project 908 was due to the delays, a result of bureaucratic inertia, low-level skills, and management incapability (Ibid). Inefficient coordination occurred among ministries and their departments in establishing a feasible project plan. To come to project approval, it took four years to overcome the debates and quarrels on plan details such as selection of locations, types of equipment and products, and sources for technology transfer. According to Li (2011)'s survey, for example, if Huajing wanted to import a lithography machine used for chip fabrication, it had to submit several documents to different parts of MEI for approval. As the timeline slipped and required investment increased, tensions arose between the Ministry of Electronics Industry and the Ministry of Finance, which was unwilling to allocate extra-budget finance in the project and caused additional delays. In addition, Project 908 made a major divergence from the coordinated supply chain in the planned economy, for it established a semiconductor production chain of chip design, manufacturing, and even some components of wafer supply, but had not included chip users in the coordination. Clearly for Huajing, an IDM that supplied chips to electronics manufacturers, having the advanced process technologies without an instantly marketable product became a huge problem. As reported by engineers from Lucent Technologies, Huajing's fab, though complemented with chip design centers using an IP library from Lucent, had no orders to produce most of the time (Fuller 2005).

Operating this expensive production line incurred heavy losses for Huajing, which was not able to utilize the newer technology to generate marketable products, even though Lucent had trained workers and engineers. In 1997, Huajing recorded a loss of RMB 240 million (Li 2011). Bearing the failure of Project 908, Huajing lost further support from the state, and was later acquired by China Resource, a conglomerate that owned CSMC in 2003.

II.1.5 The Four Enterprises' Failure in Catch-up

The four enterprises, Huajing, Shanghai Belling, Shanghai Philips and Shougang- NEC, were all built to serve China's thriving electronics and telecommunication industry. Huajing and Shanghai Philips initially produced ICs for television and audio use. Shanghai Belling's main products were chips used in digital telecommunication switching, and Shougang-NEC supplied ICs for another NEC joint venture that produced program-controlled telephone exchange. But since their establishment, these enterprises could not catch up with the increasing rates of technological change in the electronics sectors. With aid from Lucent Technologies, Project 908 was planning to install advanced telecommunication switching manufacturing capability in Huajing, which completely failed. Shanghai Philips, which changed its name to Advanced Semiconductor Manufacturing Corp. in 1995 after Nortel joined the venture (Nortel and Philips each took a third of the shares), upgraded to a 200mm, 0.8-to 1-micron fab in 1998. But this level was only roughly in-line with the technology targeted in Project 908 (Li 2011).

Shougang-NEC was the only exception. NEC later in 1996 upgraded the facility to 200mm, 0.5-micron process technology, and expanded its product line to dynamic random access memory (DRAM) and application specified integrated circuits (ASICs). The relatively active role of NEC may be due to the fact that Shougang-NEC was a captive facility that produced components for NEC's export ventures (Ibid), while chips the other three firms were consumed in the domestic market.

II.1.6 Project 909 – Fifth Push – China's Last State-Led, Large-Scale Project

The aftermath of Project 908, however, had not stopped the Chinese state from pushing further into the industry. Inspired by President Jiang Zemin's ambition in building world-class semiconductor enterprises after the Korean model, MEI launched the national Project

909 in December 1995, targeting commercial 200mm, 0.35- to 0.5-29micron process technology (Naughton 1999).

MEI's ambition for the project was to achieve three goals. The first goal was to establish China's own semiconductor technology in the form of an IP portfolio. The second was to create an international competitive semiconductor enterprise based on China's huge market. The third was to train a group of skilled engineers and managers in the industry (Fuller 2005).

Thus, rather than deploying a new fab in an existing SOE, MEI planned to establish a new state-owned corporate entity, Huahong Group, to execute the project with the experiment of a new form of industrial organization. Hu Qili, head of MEI and a high-ranking cadre in the Communist Party, became the chairman of the board of the Huahong Group to exercise direct control over the project. Several senior officials from the Shanghai municipality also joined the management.

Project 909 was China's last state-led, large-scale project in the semiconductor industry (Li 2011), described by Hu Qili as the "fifth push", but it is also the largest and the only one that achieved modest success (Ibid). The project involved capital investment in excess of RMB ten billion, larger than the sum of all prior state investment in the semiconductor sector (Hu 2006). Even more unusual is the way in which the budgets were allocated. Through a special arrangement between the State Council and Ministry of Electronics Industry, Minister Hu Qili was given the authority of allocating the project budget, bypassing the Ministry of Finance.

For Hu's special status in both MEI and Huahong, such an arrangement gave Hu strong control over the investment of Project 909 without interventions from other parts of the bureaucracy. The cooperation from the Shanghai Municipality with several officials on board further avoided bureaucratic barriers from the local actors. Hu later personally admitted that such arrangements gave Huahong unusual freedom in pursuing its investment plan, e.g., the corporation was able to continue investing in its plant in the semiconductor downturn of 1997 (Li 2011).

The construction of the 200mm fab, which was the central piece of the project, was undertaken by Huahong-NEC (HHNEC), established in 1997 as a joint venture between Huahong and Japan's NEC. NEC put up $200 million for a 28.6% stake in the JV, while Huahong Group contributed $500 million for the remaining 71.4% of shares (Naughton 1999). HHNEC started to construct the fab in 1997, and entered pilot production very quickly in the beginning of 1999 (Li 2011). The delay in Project 908 was avoided. Hu's leadership definitely helped to navigate through the bureaucratic system and overcame potential barriers in decision-making. But perhaps what is equally, if not more, important in HHNEC's ramp-up stage was the concession of fab management to the Japanese. Under the joint venture agreement, NEC was contracted to manage the fab for the first five years and promised to keep the new venture profitable.

II.1.7 Huahong's Failure in Indigenous Innovation

Huahong invested in several design ventures with different partners, including NEC as well as several Shanghai-based premiere research institutes, such as Fudan University, Shanghai Metallurgical Research Institute, and Shanghai Computer Research Institute. The design houses were supposed to build advanced skills to utilize HHNEC's advanced process capacity, especially given that the Beijing Huahong NEC IC Design Corp. was a part of the technology transfer between Huahong and NEC. But in reality, designing a marketable chip using HHNEC's 0.25- to 0.5-micron process proved to be difficult.

This is not to say, however, that Huahong's two main design houses, Beijing Huahong NEC IC Design and Shanghai Huahong IC Design, had not engaged in some level of indigenous innovation. Both companies had generated some successful products: for

Shanghai Huahong smart cards used in transportation, banking and national ID cards, and for Beijing Huahong SIM card chips used in cell phones. Yet those low-end products did not actually require such a sophisticated process as that deployed as HHNEC, and thus were not cost-effective ways to ramp up the expensive 200mm fab.

Table 2.1 Huahong's Group Structure and Subsidiaries

Huahong Group			
Subsidiaries	**Year of Establishment**	**Segment**	**Partner(s)** *(shares held by foreign partner(s))*
Shanghai Huahong NEC Electronics	1997	A JV semiconductor fabrication plant	NEC *(28.6%)*
Beijing Huahong NEC IC Design	1998	A JV semiconductor design and marketing firm	NEC *(60%)*
Shanghai Huahong IC Design	1999	A semiconductor design firm	Fudan University and Shanghai Metallurgical Research Institute
Shanghai Huahong-Jitong Smart Card System	1999	An smart card IC system design firm	Jitong Intelligence Card Application System (a spinoff from Shanghai Computer Research Institute's research department)
Shanghai Hongri International Electronics	1997	A JV semiconductor chip marketing firm	Tomen *(49%)*, (a Japanese trading firm)
Shanghai Huahong International (USA)	1998	A Santa Clara-based design and marketing firm	None
Newave Semiconductor	1997[a]	A Silicon Valley-based design firm operated in Shanghai	Unknown [b]

Source: Li 2011

II.1.8 Business-Led Development; The Rise of The Chinese Foundries in the 2000s

Around the year of 2000, China experienced its largest wave of entry into the semiconductor industry, in both chip manufacturing and chip design sector. In the chip-manufacturing sector, multinationals relocated their fabrication lines to take advantage of cheap land, skilled labor, reliable infrastructure, tax benefits and a big market. But indigenous firms were even more aggressive, employing more advanced technologies than multinationals. From 2003 to 2008, domestic Chinese semiconductor manufacturers, not foreign firms, accounted for over 80 percent of China's annual productions (McClean et al 2009). During this time, China's world-class semiconductor enterprise, Semiconductor Manufacturing International (SMIC), emerged as a foundry startup. The other notable entrant in the fabrication sector in 2000 was Grace Semiconductor Manufacturing (GSMC). Both foundry startups were located in Shanghai. Both foundries raised over one billion USD investments from foreign venture capital, domestic banks and government entities to construct their state-of-the-art fabs, starting from 200mm, 0.25- to 0.18-micron process. SMIC would become more successful, owing to a mixture of technological expertise, international market access, deep-pocketed investors and an aggressive expansion strategy (Li 2011). Since 2004, SIMC has remained among the top five foundries globally.

In the chip design sector, the number of firms soared in the first three years of the 2000. Throughout the 1990s, the number of Chinese semiconductor design firms rose steadily with annual entries of 10 to 20 firms. After 2004, the number of chip design firms stabilized around 500 (Ibid).

Table 2.2 Entries of major IDMs and foundries in China's chip manufacturing industry (1980-2010)

Company	Year entered production	Location(s)	Sector	Ownership Structure
Huajing	1984	Wuxi	IDM	SOE
Shanghai Belling [a]	1991	Shanghai	IDM	SOE-JV
Shougang-NEC	1994	Beijing	IDM	SOE-JV
ASMC	1995	Shanghai	IDM	SOE-JV
CSMC [b]	1997	Wuxi	Foundry	Mixed
HHNEC	1999	Shanghai	IDM/Foundry	SOE-JV
SMIC	2001	Shanghai, Tianjin, and Beijing	Foundry	Mixed
Motorola [c]	2001	Tianjin	IDM	Foreign
Shanghai BCD	2001	Shanghai	IDM	Mixed
Grace	2003	Shanghai	Foundry	Mixed
Hejian	2003	Suzhou	Foundry	Mixed
TSMC	2004	Shanghai	Foundry	Foreign

Source: Li 2011

The entry of foundries and design firms in early 2000s created a new industrial ecosystem that is very different from that in the 1990s (Chesbrough 2005). In the design sector, unlike the existing design firms that linked to system firms or integrated device manufacturers (IDMs), the majority of the new design entrants tended to be fabless firms with less than 250 employees that relied on outsourcing to foundries for the manufacture of their chips. In the chip fabrication sector, the two giant new entrants, SMIC and Grace had both positioned themselves as foundry service providers. As demonstrated in Table 2.2, the foundry became a dominant form for new entrants after 2000. Some of the older IDM firms, seeing the opportunities provided by a growing number of fabless firms, had started to offer foundry services as well. As a result, the foundry-fabless model became a dominant business model, particularly in semiconductor clusters near Shanghai where new foundries and fabless startups are highly concentrated.

Inside the firms, these new entrants organized their productive activities in distinctive ways in terms of governance structure, employment relations and sources of finance. Teams of scientist- and engineer-turned entrepreneurs, usually educated in the United States and having substantial work experience, returned to establish and operate these startups. They brought with them not only technological and management skills but extensive contacts to access global markets and finance capital. Fabless design firms have tended to raise funds from venture capital firms located in Silicon Valley with emerging domestic counterparts. (Li 2011) The foundries, requiring a huge fixed investment, often have their capital costs shouldered by a combination of foreign venture capital firms, domestic banks and the Chinese government. As shown in the Table 2.2, these new entrants often had a "mixed" ownership structure, meaning shares were distributed among a variety of foreign and domestic entities. The entrepreneurial teams were more likely to excise managerial control with the absence of dominant shareholders such as the state. Even the old state-owned firms that used to be controlled by bureaucrat-turned managers assigned by the state saw changes in management. Thus with access to global markets, talent and capital, the foundry and fabless startups in the 2000s were transforming the industry.

II.2 Introduction to the History of Japan's Development in the Sector

20 years ago, U.S. electronics manufacturers were the dominant global leader in such key industries as semiconductors, automobiles and consumer electronics. US corporations set industry standards, pioneered new technologies and controlled the largest share of world markets. Japanese competitors at that time were hardly competitive enough to mount a serious challenge, and Japan's economy, even as late as 1960, 6 years after their entry, lagged far behind. Japan had largely depended on overseas markets and raw materials as Japanese viewed their country as small, backward, dependent and fragile. Japan had an early shortage of capital to meet business investment demand, relied heavily on bank loans for corporate financing and was dependent on foreign source of technology. No one anticipated Japan's emergence as the economic giant as it is today.

In 1986, 32 years after their entry, Japanese companies took over the dominant position in the semiconductor industry from the United States. The growth of Japanese semiconductor production had been phenomenal. Parlaying heavy capital investments into modern, highly efficient plant facilities, the Japanese have managed to expand their world market share in one industry after another by offering top-quality merchandise at very low prices, with the promise of conscientious after-service.

II.2.1 Japan's History of Development in the Semiconductor Industry

While American strength lies in sophisticated new product designs like microprocessors, which the U.S. companies develop and commercialize before anyone else, the Japanese, however, excel at process and production technology. (Okimoto et al 1984)

For years following the end of the Second World War, the Japanese were notorious for producing goods of poor quality, just like what the impression was for Chinese goods before 2000s. However, thanks to the adoption of quality control techniques formulated by such American pioneers as William Deming and J.M.Duran, the problem was finally overcome

(Ibid), and today the label “Made in Japan” stands for quality workmanship and unsurpassed reliability. Japanese companies are said to have an easier time substituting capital for labor, partly because their system of lifetime employment lowers labor union resistance to job-displacing mechanization (Abegglen 1973), and partly because capital is more abundantly available for investment in new automated equipment (Okimoto et al 1984).

Competitiveness of Japan’s semiconductor industry was also affected by Japan’s special political institutions and public policies. Japan hold a substantial—even “unfair”—advantage because its government and private sector are believed to be a monolithic entity that works in collusion against foreign competition. One reason Japan was largely feared by U.S. is that Japan’s “national conglomerate” purportedly conferred an assortment of advantages in the semiconductor industry that the first-comer at that time—America, which has a decentralized market structure could never hope to duplicate: preferential lending, nationally organized research project, flexible application of antitrust, and a “targeted” industrial policy that assigns priority to high-growth industries like semiconductors and provides a clear framework for the management of Japan’s industrial economy.

To track back to the history of the development of Japanese semiconductor industry, Japanese and American interpretation of the development differ markedly.

II.2.2 Transistor

A transistor is a semiconductor device used to amplify and switch electronic signals and power. It is the first semiconductor device that appears in the world’s semiconductor history. Walter H. Brattain and John Bardeen at AT&T Bell Laboratories invented the germanium transistor (Japan Semiconductor History Museum).

In the early days of transistor development, U.S. electronics companies developed new consumer products as potential applications for the transistor, but since most of those companies were already selling similar products using electron tubes, only a few companies, like Texas Instrument, which was not marketing electron tube products, were ready to move aggressively into the transistor market. Japanese believed that it was owing to Japanese efforts, led by Sony's introduction of transistor radios in 1955, that the transistor and products using it became popular (Okimoto et al 1984). It was noted by American industry sources that Japanese companies entered the semiconductor industry early, in the 1950s, and therefore have a longer history than most of the leading U.S. suppliers (Ibid). However, the Japanese were relatively unsuccessful than U.S. in developing any applications other than in-house use. The technology was moving rapidly but Japan lagged behind by at least two years. As a result, the Japanese suffered a major setback in the early 1960s because they were unable to compete effectively with companies like Texas Instruments and National Semiconductor through the early 1970's.

II.2.3 IC Era

According to Okimoto et al (1984), as Japan began mass-producing transistors, which had been developed in the United States in the late 1940s, and promoted significant improvements to the high-frequency characteristics and reliability, U.S. invented ICs in 1959, opening the stage to the IC era. MOS ICs replaced transistors for the use of electronic calculators from the mid-1960s. This created the first substantial demand for MOS ICs. Originally manufacturing one calculator required several tens of ICs. Integration advanced rapidly until only several chips were required in one calculator. Single-chip designs eventually appeared in the early 1970s.

In the 1960s, many companies in Japan started trial-production of ICs for practical applications. During the early days of MOS IC development, there was some concern about instability caused by complex problems at the interface between silicon and silicon dioxide layers. Due to these problems, it was said by Japanese that U.S. companies were reluctant to invest heavily in the MOS IC production. Japanese semiconductor manufacturers, especially

NEC and Hitachi, believed that new manufacturing technologies for mass production would assure product quality and reliability. NEC foresaw a potential mass market for the desktop calculator and in cooperation with Hayakawa (the predecessor of Sharp), developed calculators using MOS ICs. They completed a commercial model in 1966, and the success of this venture helped to establish the practicality of MOS ICs (Ibid).

Thus, as U.S. semiconductor companies focused on the military use of the semiconductor and therefore took a lead in the innovation in the semiconductor technology, Japanese semiconductor industry has not made any significant breakthrough in the 1960s in the form of basic discoveries and inventions. However, it has contributed to the realizing the broader potential of new semiconductor technologies. The R&D efforts of most Japanese semiconductor manufacturers have relied heavily on basic technologies developed in the United States, but Japanese semiconductor technology is not a mere copy of American technology.

However, concerning Japan's boldness in establishing a large-scale production line when the commercial soundness of the MOS IC was still questioned by many people in the U.S. industry hastened progress toward the LSI (Large Scale Integration, a technique regarding ICs) and VLSI (Very Large Scale Integration) eras. Also, U.S. industry sources stated that early MOS devices were well suited to the Japanese market, with its emphasis on consumer products and calculators. Although calculators and watches using MOS circuits were first produced in the United States, the Japanese saw the markets for these high-volume consumer products as fitting their strategies well. Thus they aggressively pursued in these markets.

Combining consumer, calculator and others, the personal electronics market segment account for more than 50 percent of the IC market in Japan, showing the importance of application of ICs in the personal electronics in Japan.

Table 2.3 Domestic Japanese Consumption by Major Market Segment in 1979

Market Segment	Percent of Consumption
Consumer	29%
Computer	35
Communications	6
Test and measurement	2
Calculators	11
Other (including watches, automotive)	17

Source: BA Asia Ltd., 1980

After the Japanese began to produce MOS circuit on a large scale for desktop calculators, the U.S. producers who had previously been the principal suppliers of the Japanese gradually lost interest, for two reasons. First, the American companies found they were losing their domestic customers. Second, they found selling in Japan difficult in the face of what they saw as culturally engrained "Buy Japan" attitude. Indeed, at that time (the early 1970's), the import of complex ICs into Japan for distributor stock was not permitted; imports were only allowed for previously specified end customers.

II.2.4 Japan's Targeted Industry and Trade Liberalization

In 1971 the six semiconductor-computer firms in Japan formed three paired groups: Fujitsu-Hitachi, NEC-Toshiba, and Mitsubishi-Oki (Borrus et al 1982). Through these pairings MITI hoped to force a specialization of development efforts and long-term competitive segmentation of the computer market. Toward that end, each group received subsidies totaling some $200 million dollars between 1972 and 1976. Also in 1971, MITI and Japan's Electronics Industry Association formed an LSI cartel among the ten major semiconductor producers. Its purposes were to standardize LSI basic structures and packages, to streamline and standardize manufacturing processes, and to develop LSI test equipment. This cartel may indeed have been the seedbed for the device specialization among the major Japanese firms.

Meanwhile, as U.S. companies have played the preeminent role in basic research and the development of new semiconductor products since the invention of the transistor, there is every indication that the U.S. industry will continue to pour substantial resources into research and new product design (Ibid). However, these areas of basic research and new product development have generally been regarded as weak points in the Japanese semiconductor industry. Some would say that this “weakness” has not been very costly to Japan, because the Japanese industry has benefitted from a “free-ride” on U.S. R&D: American companies have borne the burden of designing new products and supporting the basic research that makes those products possible, while the Japanese, emphasizing the development of process technology that enables them to replicate or adapt U.S. designs at low cost and high quality, have often been able to capture a large share of the market in a relatively short time (Ibid). The speed with which product generations occur in the semiconductor industry has made it very profitable to the U.S. to be first with new product designs. But as the time required to replicate semiconductor product designs has shrunk, the commercial advantages of being the design leader have diminished.

The Japanese are sharply aware of their deficiencies in basic research and product design, and they are determined to overcome them. In the first place, even if the commercial advantages of being first with a new product are less than they once were, those advantages are still significant. Moreover, Japanese engineers assert that technology transfer between Japan and the United States has been one-sided. There is growing reluctance on the part of some U.S. manufacturers to share their technology with the Japanese through licensing agreements, and the Japanese increasingly recognize that continued access to the fruits of U.S. research and development will depend, at least in part, on their offering enough to the U.S. side to make a fair exchange.

It is within the context of these events that MITI’s liberalization of some of the restrictions on foreign access to the Japanese market in semiconductors and computers, announced in 1975, must be understood. During the previous four years of market protection and industry promotion, Japanese semiconductor-computer firms had developed a significant LSI capability, and by 1976 they dominated their domestic market in all but the most advance IC devices (Ibid). They had also succeeded in raising their share of the domestic installed base of general-purpose digital computers to over 60 percent. They were thus in a dominant position in their domestic market at a time when the issue of a protected domestic base from which to enter international competition in LSI-based mainframes had been significantly mooted by international market developments.

Liberalization of trade in components and computer, with continued structural control over the character and composition of penetration, thus made sense-especially when combined with a program of promotion aimed at VSLI. Moreover, liberalization also made great political sense because the industrialized West was in the midst of a mid-decade cycle of recession and recovery, and Japan was exporting excess domestic capacity in a range of economic sectors. The beginning clamor in the United States and Europe for domestic protection against Japanese imports could best be countered by liberalizing access to the Japanese market. In preparation for liberalization and the push toward advance LSI, the Japanese semiconductor-computer industry regrouped in late 1975. Fujitsu, Hitachi, and Mitsubishi formed a joint venture—Computer Development Industries, Ltd.—to develop VLSI and the next generation of computer prototypes (Gresser 1980). Finally, MITI, NTT, and the five major semiconductor-computer firms organized the VLSI project, and in March 197 they formed the VLSI Technology Research Association (Tilton 1971).

Thus Japan's government-supported project on VLSI research and the more recent program on optoelectronics represent a major effort on the part of the Japanese to boost basic research capabilities and to foster the development of new products and processes.

II.2.5 VLSI Project

The real success of Japanese producers, according to American industry sources, came only after the mid-1970s (Okimoto et al 1984). MITI targeted the computer and telecommunication markets as central to Japan's future. Establishing a national goal to lead in those industries, the government offered substantial incentives to encourage R&D and investment, besides restricting foreign access to Japanese markets.

A major thrust of Japan's effort to contribute to basic semiconductor technology has been the well-publicized program for industry-government cooperation in VLSI research. Actually there have been two VLSI products, one directed at communications applications and the other at computer applications. The communications-oriented project began in 1975 under the management of the Electrical Communication Research Laboratories of Nippon Telegraph and Telephone Public Corporation (NTT), which falls under the administrative guidance of the Ministry of Post and Telecommunication. NEC, Hitachi, and Fujitsu cooperated in this project, and government support was provided in the form of procurement. NTT did not give direct financial support, and the three cooperating companies invested their own R&D money on the supposition that the investment would be recovered through future procurement.

In the first phase of the project, which ended in the 1977 fiscal year, the major objectives were to investigate the practical limit of photolithography and to study basic micron and submicron device technologies. In 1971 the Japanese government introduced a national policy for the promotion of certain industries, which targeted the development of advanced technologies (Mackintosh 1979). According to Cupertino (1983), the Law for Provisional Measures to Promote Specific Electronic and Machinery Industries designated three strategic categories: 1) advanced technologies needing direct R&D support-especially technologies like LSI, where Japanese firms lagged considerably behind U.S. firms, 2) production technologies, like those demanded in LSI production, which were intimately linked to device-system cost, quality and performance, and 3) high-volume production technologies. MITI was given responsibility for financing R&D and rationalizing production. By 1977 over sixty different projects had received total financial support in the multi-hundred million dollar range in such areas as electron-beam exposure and LSI production equipment, high performance discrete devices, basic materials research, low power-high performance ICs, and VLSI's.

The second phase, lasting for another three years, applied the results of the first phase to develop special purpose LSI for communications and to carry on the development of other new technologies for communication.

According to Cupertino (1983), the more publicized computer-oriented project, partly founded by MITI, ran from 1976 to 1970. The objective of this project was to develop VLSI technology as a key to the future development of computer systems. As is well known, MITI has singled out computer development as an area of highest priority for the Japanese economy in the 1980's. The project budget was around 70 billion yen (about $200 million) over the four-year-period. About 60 percent of the total budget was financed by the five member companies; the rest came from MITI in the form of interest-free loans to the member companies, to be repaid from royalty income and profits derived from the products that resulted from technologies developed by the project.

As a result of the project, more than 1,000 patents were issued, and about 460 technical papers were published (Borrus et al 1982), many of them as part of international conferences in the United States, Europe, and Japan. In the late 1970s, significant growth in the Japanese market for semiconductor products in computers, telecommunications, and industrial purposes under way.

II.2.6 The 65K and 256K DRAM Competition

The determination of the Japanese to compete with the United States in the development of new product prototypes has been most apparent in the development of state-of-the-art VLSI memory chip technology – specifically, the 64K and 256K DRAM (Dynamic Random-Access Memory). The competition for market share in the 64K DRAM, successor to the 16K DRAM, is a test for producers of memory chips. Sales of the 64K DRAM are expected to reach a peak of $1.8 billion by 1985 (Ibid). By 1989 the annual market for the 245K chips is expected to hit $3,7 billion. The Japanese have spent very heavily to develop and produce these chips, and this is the area in which the most dramatic Japanese successes have been achieved. Although IBM reportedly produced the 64K DRAM in high volume well in advance of the competition, the first 64K DRAM to reach the merchant market was Japanese, introduced by Fujitsu in 1978 (Okimoto 1984).

By the end of 1981, the Japanese had captured 70 percent of the 64K DRAM market, and some industry commentators declared that Japan had "won" the battle for the memory market. As the U.S. computer industry used more DRAMs, resulting to rapidly increasing demand for DRAMs, many U.S. computer manufacturers adopted made-in-Japan DRAMs, which had been acclaimed for their quality. Japanese DRAMs reached the leading edge in terms of design and process technologies, now gaining high evaluations for quality, delivery, and price. The Japanese share of market in 64K-DRAMs overtook US in 1981, and overall DRAM share reached to 80% in 1987 mainly with 256K DRAMs.

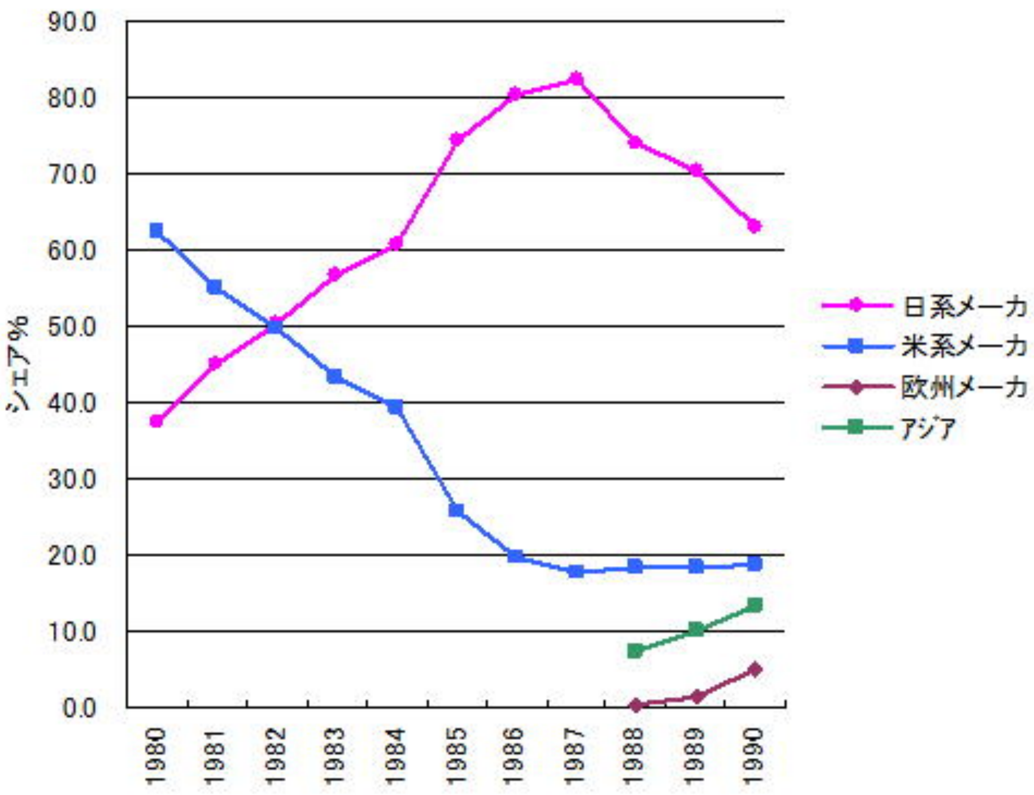
According to Figure 2.2, within the global market of DRAM in the 1980s, Japan surpassed the United States in 1982 and continued to rise in the following 5 years, peaking at 80% of the DRAM market share in 1987.

One reason why the Japanese were able to enter the 64K DRAM market so early and with such strength was their adoption of a conservative design (Okimoto et al 1984). The

Japanese used as a base for their 64K DRAM the cell design originally used in Mostek's 16K DRAM, improving on it, and in effect, scaling up the techniques that had proved successful at the 16K level. Japanese engineers claim that the more conservative design of their chips makes them more reliable, less apt to be defective.

Figure 2.2 Global Share (Japan, U.S., Europe, Asia) of DRAM Sales in 1980-1990

Note: pink-Japan, blue-U.S., brown-Europe, Green-Asia (except Japan)

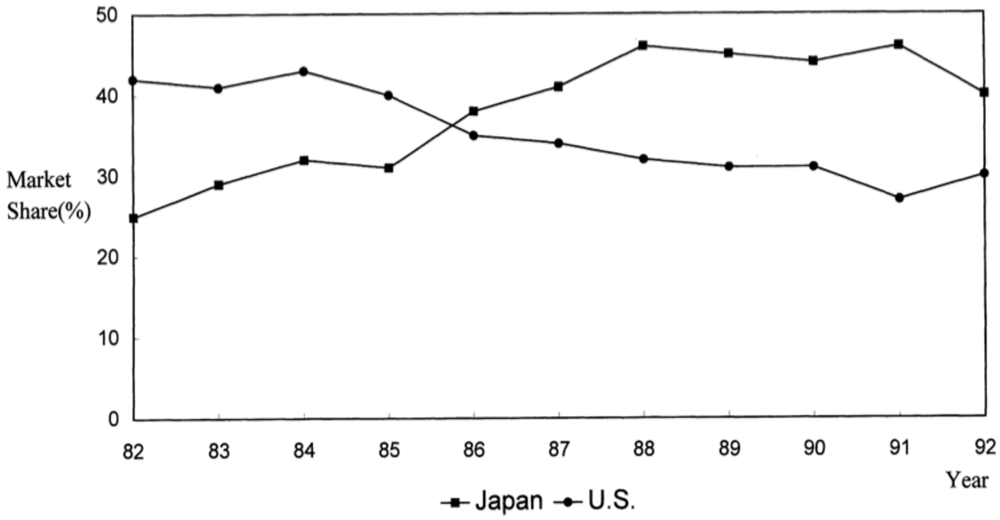


Source: Semiconductor History Museum of Japan

In 1984, new types of consumer electronics, such as audio-visual equipment, became broadly popular in the 1980s. Production by Japanese manufacturers who were highly competitive in this field rapidly expanded to support the demand for Japanese semiconductor products. Meanwhile, the growing demand for DRAMs triggered by the boom in 16-bit PCs allowed Japanese semiconductor manufacturers to increase their share of the global market.

In 1986, Japan becomes the biggest supplier in the global semiconductor market, surpassing the U.S. Japanese manufacturers expanded their share due to increased memory production (such as DRAMs) and stable domestic demand for consumer electronics. The top three manufacturers in 1986 were NEC, Toshiba, and Hitachi, and six out of the top ten were Japanese manufacturers.

<u>Figure 2.3 Changing Market Share Changes in the World's Semiconductor Shipments: United States and Japan in 1982-1992</u>



Source: Nikkei Tsushin

II.2.7 Japan in the 1990s

However, in the 1990s, The Japanese semiconductor industry struggled with the regulations defined by the U.S.-Japan Semiconductor Trade Agreement such as Fair Market Value (FMV) and allowing more foreign semiconductor products into the market (Semiconductor History Museum of Japan). This situation continued until the agreement expired in 1996. Moreover, The Japanese share dropped when South Korean and Taiwanese manufacturers joined the global semiconductor market and U.S. manufacturers regained competitiveness. South Korea reorganized its semiconductor industry and actively encouraged development and investment after the financial crisis of the late 1990s, rapidly raising its status in the field of DRAMs.

II.2.8 Japan in the 2000s

In the early 2000s, Japan started a series of government-industry projects in Japan with main focus to fabrication technologies. However, the business environment for vertically integrated Japanese device manufacturers worsened as the semiconductor industry came to be based on a flatter and horizontally divided structure.

Table 2.4 China and Japan's Timeline of Development (China on the left and Japan on the right)

1956	China made the first semiconductor but later R&D was disrupted by Cultural Revolution
1970s	China reorganized for technological catch-up (wide technological gap)
1980s	"Reform and opening" Technology import 3-inch lines
1990	Project 908 initiated (failed)
1990s	Several JVs established but could not catch up the increasing upgrading rates 6-inch lines
1996	Project 909 initiated (the only one that achieved modest success) 8-inch
2000s	Technological catch-up as foundry emerges 12-inch lines and 0.13-micron process technology
2000	SMIC and Grace established
2002	SMIC begins to construct China's first 12-inch fabs in Beijing; SMIC becomes the first Chinese foundry to have 0.13-micron process technology
2008	SMIC becomes the first Chinese foundry to have 45-nanometer process technology

1960s	Beginning of IC production in Japan. After importing silicon-transistor technologies from the U.S., Japan became the overall largest transistor-manufacturing country
1970s	Japan focus on application technology in personal electronics (DRAM market; microprocessors development; SRAM evolution)
1976-1979	VLSI Project and innovation in process technology
1980s	Japan overtook the U.S. in the race to increase memory capabilities, in the shift to CMOS
1990s	Caught on the back foot in the business by the rise of South Korean companies
Late 1990s	Rise of separation between fabless and foundry created opportunity for U.S. who owns leadership in design technology; transition to 8-inch wafer and then to 12-in wafer (ASTI process technology project).
2000s	Start of Govt-industry projects with main focus to fabrication technology. Fabless model overwhelmed Japan's integrated model business. Flash memory industry is in full fledge – shift to NAND flash capacity.
2001	ASUKA and MIRAI project to develop 45-nanometer process technology.

Source: compiled by the author

III Analysis and Comparison of China and Japan's Development History in the Semiconductor Industry

Chinese and Japanese different development paths in the semiconductor industry could be traced to a couple of factors.

Firstly, an important factor that distinguishes Japan and China's different technological sophistications is Japan's alliance with the United States, which promoted economic cooperation and access to the technological information, while China's development in the semiconductor industry was immensely disrupted by the political turbulence during the Cultural Revolution. Japan started the development of its semiconductor industry early in the 1960s and had depended on U.S. R&D by taking a "free-ride". U.S. companies have shouldered the responsibility of designing new products and conducting the basic research that makes those products possible, while the Japanese, emphasizing the development of the process technology that enables them to replicate or adapt U.S. designs at low cost and high quality, have often been able to capture a large share of the market in a relatively short time. In Japan, engineers were permitted relatively free access to U.S. technologies—compared with China's limited access to U.S. technologies—through frequent conference attendances and company visits during the 1950s and 1960s (Flamm 1996). By concentrating on acquiring U.S. licenses and patents, Japanese firms soon were able to start low-cost mass production by the late 1950s. By 1959, Japan had overtaken the United States in output volume to become the world's largest transistor producer.

On China's side, China did not reorganize for technological catch-up until in late 1970s. China is counted as a latecomer, who fell behind in the technological sophistication. According to Li (2011), when Japan began mass production of 256K DRAM in 1984, China just finished making 4K DRAM in 1979, 16K DRAM in 1980 and 64K DRAM in 1985. The wide technological gap was hard to be made up by indigenous R&D (research and development) in China. Nor did China have the U.S. as ally who was willing to transfer technology to China. In fact, China's technological advance has been hindered by U.S. export control.

Secondly, the differences in the efficiency in the technological catch-up between China and Japan were partly due to the differences in the economic and political systems. Japanese and Chinese economic systems differ largely because Japan has always been a market-oriented economy while China experienced an economic transformation from a command economy to a market-oriented economy. Japan's semiconductor industry emphasized commercial application and was boosted by demand-pull when Japan's early comer—the U.S.—concentrated on the military market, while China suffered from lack of a market-oriented mechanism to create the market for semiconductors. In contrast to U.S. companies, which conducted R&D according to the dominant needs in the military market and from the National Science Foundation's stress on fundamental knowledge, the Japanese system emphasized commercial application and economic advancement. When the U.S. companies developed their strength in sophisticated new product design like microprocessors and led ahead in software, an area that accounted for a growing portion of value-added and was often decisive for the functioning of end-product systems like microcomputers, the Japanese, however, focused on excelling at process and production technology. Boosted by the increasing end-use demand for consumer electronics and computer industries, the Japanese semiconductor industry had grown substantially by the late 1960s. And finally, through Japan's heavy investment in its memory chip development, Japan surpassed the United States in 1986 in the semiconductor volume, largely credited to its large DRAM chip demand.

On the Chinese side, in contrast to Japan, whose application technology fit in its market of personal electronics, China did not have a market-oriented mechanism that promoted the application of the semiconductor the country developed. At the end of the 1990s, China's domestic semiconductor industry was insignificant internationally by any standard of measurement. Foreign-made chips dominated the middle- to high-end of the Chinese market, as the country imported more than 80 percent of the chips it consumed.

Nevertheless, China's economic system grew more market-oriented and liberalized, the types of strategy, organization and finance of non-government semiconductor companies in the 2000's conformed more closely to the types of investment strategies and business structures that could generate innovation. Founded and managed by expatriate techno-entrepreneurs, these enterprises (SMIC and Grace) started to have very capable decision makers who were available in China. Meanwhile liberalized government policy that experimented transferring decision-making power to the entrepreneurs, combined with the rise of fabless-foundry model, provides a good opportunity to China to leverage its comparative advantage and profit from its labor-intensive condition.

Thus it leads to the third reason that contributes to the different development path of Chinese and Japanese semiconductor industry, comparative advantage. To compare the two countries' histories of development, Japan leveraged its advantage in substituting capital for labor or its comparative advantage in capital while China targeted its comparative advantage in labor and leveraged the new emerged fabless-foundry model by concentrating on fabrication.

Fourthly, both states played crucial roles in manipulating the development of the semiconductor industry by large-scale industrial projects. Both China and Japan's governments built up "unfair" advantages by promoting their export competitiveness and triggering technological catch-up by massive investment in R&D. Japan's government targeted prospective industries while providing aid to a certain industries and limiting foreign competition whereas Chinese government also closed its market and imposed import barriers prior to the 2000's. Interestingly, both governments employed strategies to cultivate large national champions. But the private firms dominated Japan while the state-owned enterprises (SOEs) dominated China. Nevertheless after the 2000's China chose a 'walking-out' strategy and encouraged foreign investment in order to leverage China's lab-abundant comparative advantage.

In the rest of this chapter, I will elaborate on my comparison between Chinese and Japanese development histories in the semiconductor industry, divided into four sections – comparative advantage, economic and political systems, government policy and trade policy.

III.1 Comparative Advantage

International trade has played a significant role leading to China's economic growth since its economic liberalization in 1978. International trade gradually sets up a sizeable portion of China's overall economy. Initially, exports were majorly concentrated in industries such as textiles and manufacturing. In the 1990's, however, high-tech electronics exports became the most dynamic sector of export growth. Between 1980 and 2000, electronics exports have grown by an average annual rate of 43 percent, almost three times as fast as total exports (Assche 2006). According to Assche (2006), in 2000, electronics exports were 28 percent of total exports. As a result, China has turned into one of the main traders of electronics products, with a 4.5 percent share of global electronics exports in 2000. In 2000, China had an electronics trade surplus of US$51.4 billion (Ibid), largely due to the export of electronics final products to the developed country such as the United States, Canada, Japan and Western Europe.

China's success in the high-tech electronics exports has led to a rising concern in the developed country with an illusion that China not only specializes in labor-intensive industries but also in high-tech industries such as electronic equipments. The cause of this misunderstanding is that the electronics industry should be a capital-intensive industry with demanding requirements for advanced technology, which China should not have been capable of. This concern is further fuelled by the recent Chinese electronics champions, who have successfully penetrated overseas markets and turned into global competitors. For example, in the consumer electronics industry, Haier has surged to become the world's fourth-largest manufacturer of large household appliances. In the computer industry, Lenovo has made its name by purchasing IBM's PC unit and becoming the first Chinese company to sponsor the Olympic Games. In the telecommunications equipment sector, Huawei and ZTE have emerged as a comparable competitor to Cisco and Nortel. But comparative advantage theory reassures that China's success in the trade in the electronics industry is just a standard case.

To explain the reasons of China's success in the electronics industry, we must first identify the differences between competitive advantage and comparative advantage. A competitive advantage is an advantage that a firm has over its competitors, allowing the firm to generate greater sales revenue, or retain more customers than its competitors. A competitive advantage contains two types of advantages, cost advantage and comparative advantage. A usual confusion usually occurs between two. A competitive advantage is an advantage that enterprises can utilize to retain low costs to undercut. However, a comparative advantage refers to the ability of a country or a firm to produce a particular good at a lower opportunity cost – one country does not necessarily have a greater efficiency (absolute advantage) over another; but rather each has a different relative efficiency.

When people think about China's success in the international trade, the reason they usually bear in mind is China's advantage in the low labor cost. But the low labor cost is only an example of a competitive advantage in China, a factor that should not be sufficient enough to explain China's tremendous trade surplus in a high-tech industry – only to prove China's comparative advantage in the electronics industry can justify China's success.

As I mentioned, a comparative advantage refers to the ability of a country or a firm to produce a particular good at a lower opportunity cost. According to the Ricardian trade theory, due to each country's differences in technological equipments, amounts of resources and costs of outsourcing, each country specializes in different sectors because if scarce factors of production are used to produce two goods, producing more of one good always requires producing less of the other good. Thus the idea of opportunity cost emerges. The opportunity cost of producing more of one good is the required reduction in the production of the other good. Similarly, the opportunity cost of producing some amount of one good is the amount of the other good that could have been produced with the same resources. Consequently, if one country is capable of producing one good with less opportunity cost, it has comparative advantage in producing this good.

Later Eli Heckscher and Bertil Olin developed a general equilibrium model of international trade – Heckscher-Olin model. Heckscher-Olin model builds on David Ricardo' theory of comparative advantage by predicting patterns of commerce and production based on the factor endowment of a trading region. According to Heckscher-Olin theorem, a country will export goods that use its abundant factors intensively, and import goods that use its scarce factors intensively. In the two-factor case, it states: "A capital-abundant country will export the capital-intensive good, while the labor-abundant country will export the labor-intensive good." The reason is that when two countries are in autarky, the price of capital-intensive good in the capital-abundant country will be low because of the oversupply. Same result applies to the labor-intensive good in the labor-abundant country.

Back to the story, China has long been known as a country that is labor-abundant, rather than capital-abundant, compared with developed countries such as the U.S. and Japan. Thus if according to the comparative advantage theory, the usual understanding is that China would have a lower price in the labor-intensive textile industry and thus have a trade surplus in the textile industry while having a trade deficit in high-tech electronics industry because the electronics industry is usually considered to be capital-intensive. So the question is why is China having a trade surplus in the high-tech electronics industry? Should China remain specialized in the electronics industry?

To solve this question, RCA index should be utilized to illustrate each country's specialization. RCA is known as Revealed Comparative Advantage, which is a measurement put out by The United Nations Conference on Trade and Development (UNCTAD). RCA identifies the ratio of exports of each Chinese (or any country's) product to each region by comparing it with the average global exports ratio. Therefore RCA is defined by $\frac{X_j^k / X_w^k}{X_j / X_w}$ where X denotes exports, k denotes the commodity group classification of exports, j denotes the particular country in question, and w refers to the world. Therefore, China's electronics products' RCA for global trade = (Amount of Chinese electronics product exported globally/Total amount of global electronics exports)/Amount of Chinese product exported globally/Total of global exports). Therefore, when RCA is more than one, the product can be seen to have comparative advantage.

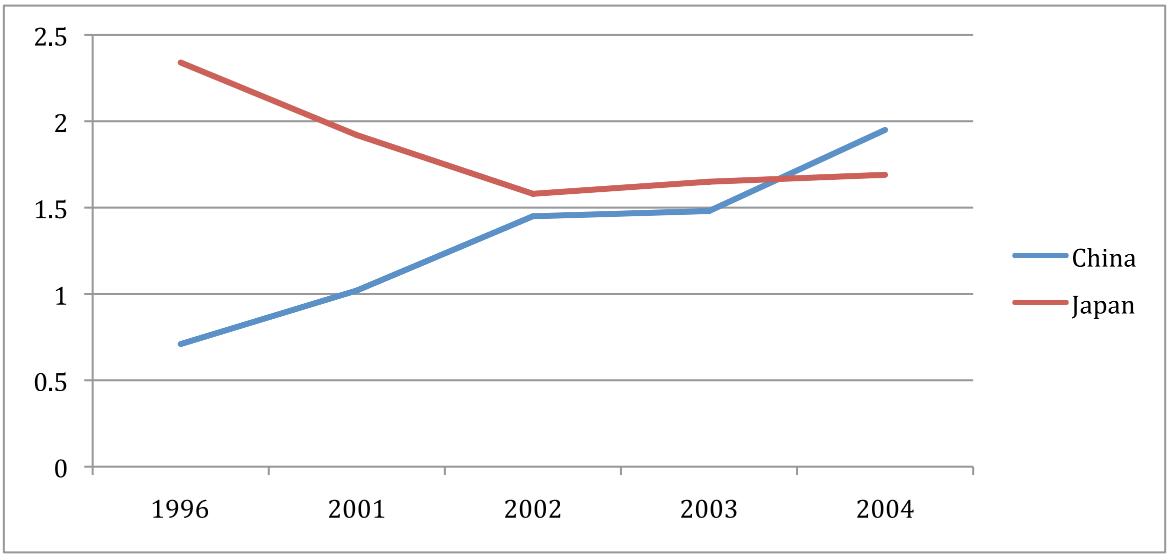
Table 3.1 RCA of China and Japan in the Electronics Industry

Country	1996	2001	2002	2003	2004
China	0.71	1.02	1.45	1.48	1.95
Japan	2.34	1.92	1.58	1.65	1.69

Source: COMTRADE

According to the data on the UN COMTRADE, China's RCA in the electronics industry is constantly increasing while Japan's RCA has been decreasing or maintaining a minor increase. From Figure 3.1, it shows China's RCA in the electronics industry has been growing very fast. China's RCA in the electronics industry surpasses 1 in 2001 and is reaching 2 in 2004, clearly showing China's comparative advantage in the electronics industry, while Japan is decreasing from 2.3 in 1996 to 1.7 in 2004. In 2004, China's RCA in the electronics industry has already surpassed Japan's. But is Japan really loosing?

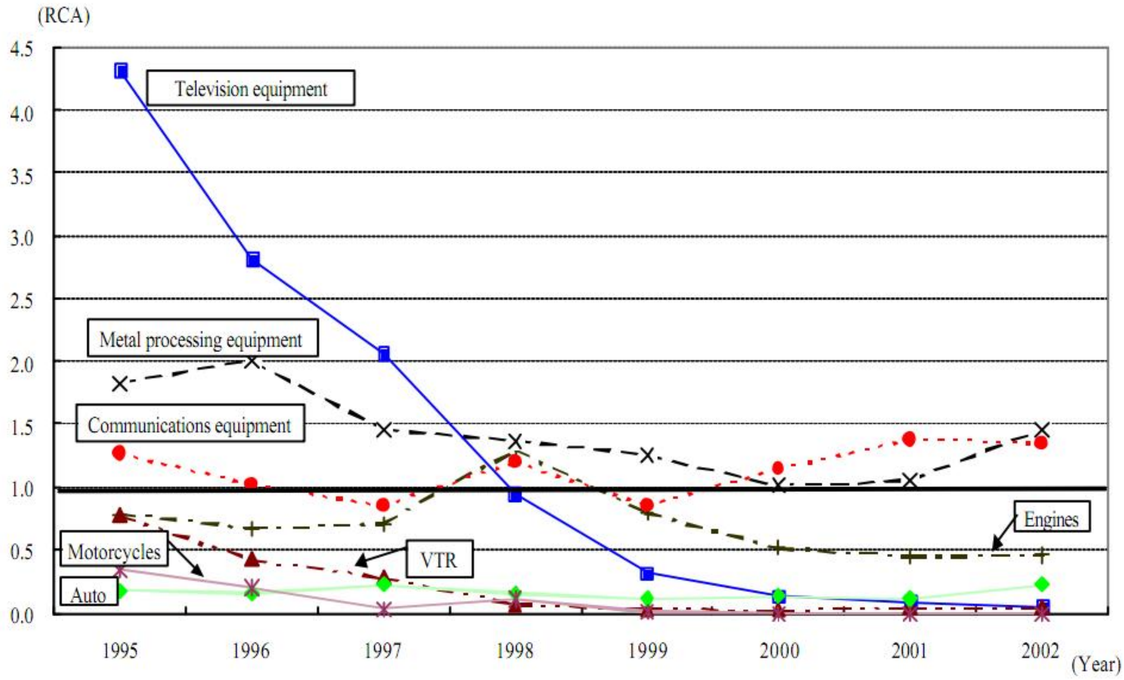
Figure 3.1 RCA of China and Japan in the Electronics Industry



Source: COMTRADE

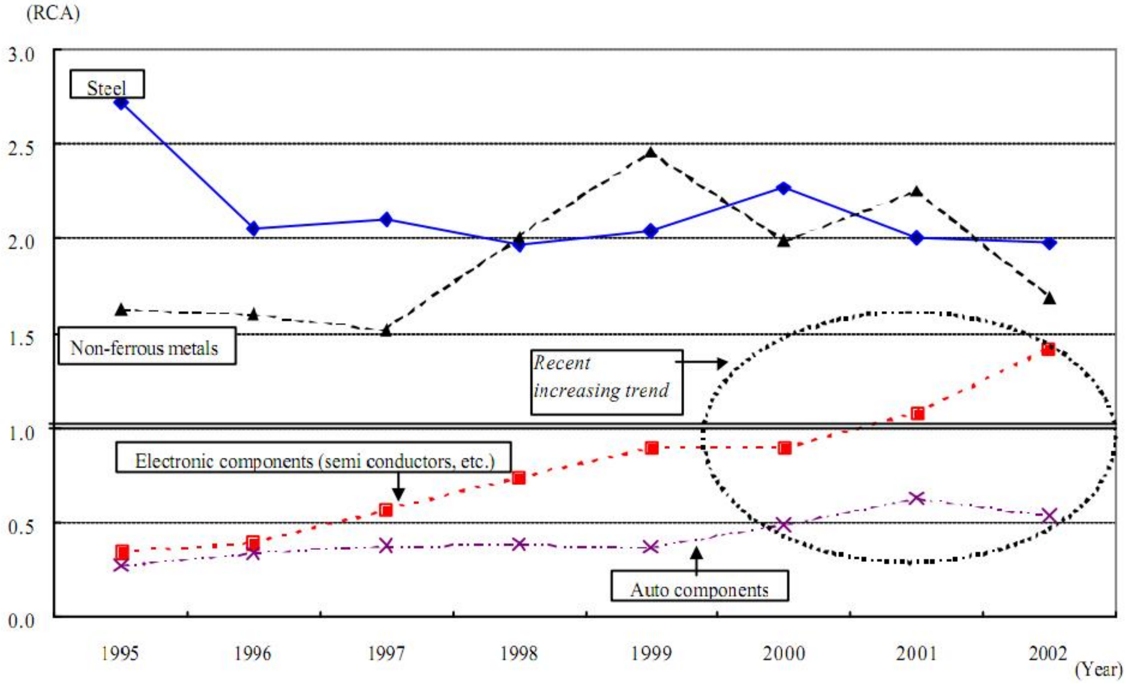
Note: The RCA index is defined by: $\frac{X_j^k / X_w^k}{X_j / X_w}$ *where X denotes exports, k denotes the commodity group classification of exports, j denotes the particular country in question, and w refers to the world.*

Figure 3.2 the Ratio of Japan' s RCA to China's RCA in Final Products and Partially Completed Products



Source: Summary Report on Trade of Japan (Japan Tariff Association)

Figure 3.3 the Ratio of Japan' RCA to China in Materials and Electronic Components



Source: Summary Report on Trade of Japan (Japan Tariff Association)

The RCA index is defined by: $\frac{X_j^k / X_w^k}{X_j / X_w}$ *where X denotes exports, k denotes the commodity group classification of exports, j denotes the particular country in question, and w refers to the world. In this graph, the index on the Y-axis is Japan's RCA compared to China's.*

A closer look at China's electronics import and production data shows that the rising sophistication of China's exports in fact does not reflect its electronics companies' technologic development. In order to explain this statement, we compare Japanese RCA to Chinese RCA in the two sectors – partially completed/completed sectors and parts sectors. Figure 3.2 demonstrates the ratio of Japan's RCA to China's RCA in final products and partially completed products and Figure 3.3 shows the ratio of Japan's RCA to China's RCA in materials and electronic components. According to Figure 3.2, when Japan's RCA index is compared against China during 1995–2002, there is a downward trend for most items in the sector of products and partially completed products except for metal processing equipment and communications equipment. Television equipment shows the largest downward trend in the ratio of Japan's RCA to China's RCA. The decreasing ratio of Japan's RCA to China's

RCA in final products and partially completed products re-demonstrates China's rising dominance in the production of final electronic products.

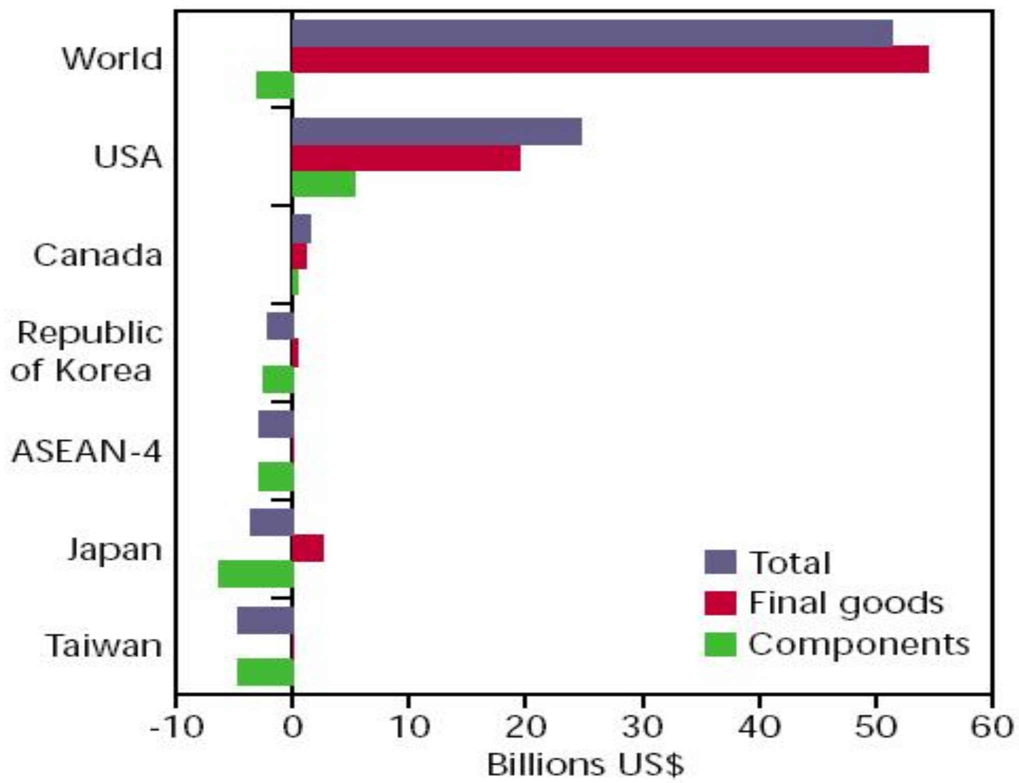
However, this is only a part of the whole picture. When we take a look at the sector of materials and parts, however, Japan's RCA compared to China for electronic components - such as semiconductor - is still gradually increasing. From Figure 3.3, steel and metals are not on an upward trend because China is a large country abundant with natural resources. But for electronic components, which play key functions in electronic equipments, China's comparative advantage is decreasing, compared with Japan's.

In other words, in regards to the specialization structure with China—including Japanese affiliates located in China—the comparative advantage of high value parts manufactured by companies located in Japan against China is still increasing. This tendency indicates the international specialization relationships between Japan and China, demonstrated by Japan's shift in the trade structure from products/partially completed products to highly functional materials/part—Japan tend to specialize in producing material/part which requires high-tech and outsources assembly line to China. This shift, in turn, is in line with the development of international specialization in China.

China's role in the international trade remains labor-intensive. Chinese companies have not become specialized in producing key components yet and are still depending on procurements from foreign companies; their strength is mostly in the form of production specialized in processing and assembly. In fact, many Japanese and other Asian companies located in China are focused on processing and assembly in order to take advantage of the low labor costs, leading to the structural dependence of China on imports from Japan for key components. China imports highly complex electronics components from abroad and uses low-skilled workers to assemble them in export goods. In such way the production activities of electronics firms in China generally remain relatively unsophisticated. Therefore, China's story of large exports in the high-tech electronics industry does not mean that it is diverting from the Heckscher-Olin theorem, rather it is just a standard trade theory case.

In fact, in recent decades, non-Chinese electronics companies have been relocating their assembly plants from other East Asian countries to China, thus making China a global assembly platform for electronics products such as computers, telecommunications equipment and consumer electronics. These firms continue to rely on Japanese companies for the primary source for their electronic components such as semiconductors, but are assembled in China. Once the assembly is completed, they export the final goods to Western countries. These trends are clearly reflected in China's electronics trade balance in Figure 3.4.

Figure 3.4 China's Electronics Trade Balance



Source: United Nations-NBER Trade Data, 2006
As the graph shows, China has a huge trade surplus towards Japan and United

In the electronics component sector, China has held trade deficit to every country in ASEAN-4 region and to the United States. Indeed, as can be seen in Figure 3.4, China's trade deficit in electronics components is almost entirely driven by the import of complex "active components" such as semiconductors and integrated circuits. The trade deficit in the less complex "passive components" such as capacitors, resistors and printed circuit boards is much smaller. This trade dynamic figure reassures China's role in the electronics industry in the context of international trade.

III.1.1 Comparative Advantage in the Semiconductor Industry

In the semiconductor industry, China initially was merely selling the country's comparative advantage in cheap labor and land, which is at the very last stage of a supply chain. In this stage, technologically advanced countries transfer primary fabrication and assembly chain to technologically disadvantaged countries but keep high-tech fabrication, R&D and marketing domestically. In this stage, China relies on the cheap labor to gain small processing fee, which is what happened in China before the 2000s. After the 2000s, China gradually imported advanced technology and capital stock and moved toward the stage of a fabrication foundry, stepping towards capital-intensive stage.

With the creation of wafer industry by TSMC in 1987, many IDM (integrated device manufacturer) semiconductor manufacturer transformed into fables and foundry model, turning a vertically integrated model into different stages. With the emergence of the fabless-foundry model, countries are able to make better use of each country's comparative advantages. Manufacturing is usually outsourced to a third party – in the current global industry, China, Korea and Taiwan in the most cases – in order to leverage cheap manufacturing cost. Thus China is able to leverage the country's labor-abundant comparative advantage and concentrate on wafer foundry, packaging and testing while knowledge-abundant countries such as United States and Japan focus on semiconductor design and fabrication.

On the other hand, Japan, as a "resource-poor nation" dependent on the export of manufactures to pay even today for the importation of almost 90 percent of its energy needs, over half of its food, and the greater part of its chief resources, the Japanese choose industries for domestic development that can serve to expand oversea sales. Unlike China that has abundant land and labor resources, Japan does not have the same economic condition.

Thus the conscious theme of policy in Japan has been to create comparative advantage in high value-added industries as an alternative to remaining dependent on the labor-intensive resources and capital. The state aggressively promoted the shift out of agriculture into industry and out of low-wage into high-wage industrial sectors. Government policy served to channel resources into those industries for which there were growing domestic demand and potential economies of scale to facilitate export. Thus the state targeted a certain industries that would help Japan grow out of labor-intensive resources. In fact, the state played a crucial role in manipulating the access of foreign competitors to domestic Japanese market in order to promote their export competitiveness. Thus in pursuit of MITI (Ministry of International Trade and Industry)'s goal of creating comparative advantage in the knowledge-intensive and technology-intensive industries, the Japanese had to turn a relatively backward semiconductor industry into a world-class competitor. This is the reason why during the 1970s, the Japanese industry moved from a consumer product orientation and a position of relative technological inferiority in components toward a state-of-the-art capability in components, telecommunications, and computers.

III.2 The Economic and Political System Difference

Japanese and Chinese histories of semiconductor development are inevitably related to the different economic and political system in both countries.

III.2.1 China's Centralized Economy in the History and Japan's Free-Market

Firstly of all, the Japanese and Chinese economic systems differ largely because Japan has been a market-oriented economy with government as a promoter while China experienced economy transformation from command economy to market-oriented economy with government controlling the decision-making power. Japan's semiconductor industry emphasized commercial application and is boosted by the demand-pull when Japan's early comer—the U.S.—concentrated in the military market, while China suffered from lack of a market-oriented mechanism to create the market for semiconductors. Even now, China is still under the strict control of the state, and government has the rights to intervene in the market to a certain degree.

In China's economic history, starting from 1949, the CCP in China adopted a planned economy and created institutional arrangements to lower the barriers to the development of heavy industries, i.e., low interest rates, depressed product and factor prices, and a central resource allocation system. While this system quickly established a relatively complete industrial structure and likewise led to economic growth resulting from massive investment, the costs associated with economic inefficiency were extremely high. For instance, there were no links between the expansion of an enterprise and its economic efficiency, or between workers' income and their productivity. The power was centralized in the hand of the state while the lower-provinces and enterprises have no economic power to invest. Thus in the semiconductor industry, despite the fact that the Chinese Academy of Science, China's premiere state lab, created the country's first integrated circuit (IC) in 1964, only seven years after IC was invented in the Bell Lab in United States (Simon 1987), it was unable to be put into commercial production because there was not a market-oriented resource allocation system.

As illustrated by Adam Smith, one of the founding fathers of economics, in a market-oriented economy, there is an invisible hand of the market operated in a competitive market through the pursuit of self-interest to allocate resources in society's best interest. This means, in a market-oriented economy, supply and demand construct the price mechanism, which signals the scarcities and surpluses of the resources. Individuals are left up to themselves to decide what to produce, who to work for, and how to get the things they need. This type of economy, though it may be chaotic at times, allows people to change along with the shifting market conditions to maximize their profits. However in a planned economy like China in the 1960s, resources were not relocated according to the price mechanism but rather according to the government's command. Without price as a signal of the market, the market could not reach its efficiency because the amount of production based on the principle of profit-maximization but rather based on the CPC's planning. Without price as a signal of the market, the CPC had no means to "predict" the market demand or allocate the resources ideally. Instead of taking advantage of China's labor-abundant comparative advantage, China chose to develop the heavy industries that required massive capital and technology. Therefore it was this lack of incentives severely suppressed productivity and resulted in low economic efficiency.

On the other hand, the Japanese market ranks high among the world's market-oriented economy. Thus the major economic system differences between China and Japan mark the distinctness between their industrial development histories in the semiconductor industry. Compared with China's large state-led investment and development in the semiconductor industry before the 2000's, Japan's development of the manufacturing capacity was largely left to the private sector.

III.2.2 Interference by Chinese Political Turmoil

Second of all, the Chinese technological lag-off is inevitably related to China's political turmoil during 1960s. Later Two of Mao's campaigns brought chaos and severe economic distress to the Chinese – "Great Leap Forward" from 1958 to 1961, which aimed to use China's vast population to transform the country from an agrarian economy to a country of rapid industrialization, and the "Cultural revolution" from 1966 to 1976, which removed capitalists from Chinese society. The disruption caused by the "Great Leap Forward" and the "Cultural Revolution" led to the wide technology gap between China and the advanced countries. In late 1970s, when China started to reorganize for technological catch-up, Japan, as a military ally to the US, already imported many production technologies from the US, such as silicon-transistor technology and became the largest transistor-manufacturing country, progressing toward application technology and VLSI project.

III.2.3 China's State-Owned Enterprises (SOEs) and Japan's Private Firms

Under the Chinese system prior to 2000, the state was responsible for the development of all sectors and decided all aspects of enterprises' operations, for example, product range and scope, investment, prices, wages, suppliers and purchasers. The major forms of the ownership of the enterprises were state-owned enterprises (SOEs). Enterprises were required to concentrate not on profit making, but rather on fulfillment of the production plan, Industries were dominated by state-owned enterprises (SOEs) in cities and communes in the countryside, with no private ownership permitted (Five Year Plan 1986-2004). Thus rather than the limited capabilities of the research institutions to develop technologies, however, it is the lack of effective mechanisms for the production units to utilize the developed technologies that hindered innovation in the planned economy (Simon 1987; Lu 2000) Until late 1990s, the state-owned and joint-venture semiconductor companies, which dominated in China prior to 2000, were firmly controlled by agents of the state, particularly the ministries.

Although these companies were large enterprises with huge investments by the Chinese standards at the time, managers of these enterprises were effectively given little autonomy in decision-making. This centralized decision-making structure in the bureaucratic hierarchy caused two consequences. Firstly, managers were not able to make decisions to maximize the profits of the firms. Thus secondly firms lost their competitiveness because the decisions were made by political leader who might sacrifice some firms' benefits for the cause of the state. In such cases, managers no longer had incentives to improve the firms and thus result in low management skills and corrupted managers.

In Japan, on the other hand, large private firms (keiretsu) dominated the market. Each of the top six Japanese semiconductor companies was tied to a Keiretsu - a conglomerate industrial grouping of companies arranged around either a single large bank or large industrial firm (or several firms). The Keiretsu's form ranged from groups with close intercompany ties to looser, basically financial arrangements. The Keiretsu structure itself provided important advantages for the Japanese electronics firms that could draw on its resources. First of all, the Keiretsu members provided an important internal market for the firm's products (Borrus et al 1982). Second, each Keiretsu usually included a large trading company, which was frequently used by Japanese firms to perform overseas sales, distribution, and financing. The trading company thus provided increased access to international semiconductor market. (Chase) It should also be noted that Japanese firms were privately owned. Thus companies had autonomy in decision-making and government's role was to use market-oriented policy tools to provide incentives.

Moreover, in Japan's economy, compared with Chinese government's role as an administrator, Japanese government played a role of an industrial promoter. Japan had established a Ministry of International Trade and Industry (MITI) in order to serve the role as an architect of industrial policy, an arbiter on industrial problems and disputes, and a regulator. MITI was responsible for shaping the structure of Japan's industries, supervising the healthy growth of those industries and their production and distribution activities, managing Japan's foreign trade and commerce, and controlling patents, industrial technology, and technology acquisition (MITI Establishment Law). Over the years, MITI has successfully "targeted" industries of increasing sophistication. MITI's specific policies to promote the market will be discussed in the government policy section.

III.2.4 Japan's Bureaucracy-Business Relationship and China's Bureaucratic Inertia

Another distinctive asset about the economic system in Japan is its close bureaucracy-business relationship. The close relationship ensures a massive flow of exchange, consultation, and consensus on broad technological objectives. This close government-business relationship was modeled after Germany, ensuring that government's economic policy was providing the correct incentives for the enterprises. Tensions and problems were inevitable and require constant communication and compromise. Such a system, however, functionsed far better than government-relations in China. While in China, without such a consultation channel, government's relatively centralized power in decision making led the industry to a path that was not beneficial to the business environment. In China prior 2000, the SOEs' managers were not required to make decision to maximize profits positions. These managers were inferior to the state's decisions. And the enterprises could hardly negotiate economic policies with the state. Such a system led to the bureaucratic inertia and management incapability in China.

Project 908 was a proof of result of the bureaucratic inertia, low-level skills, and management incapability in China. In the Project 908, described by Li (2011), the MEI (the Ministry of Electronics Industry) allocated a budget of 2 billion RMB for the project, aiming to leapfrog domestic technologies from the outdated 100mm (4-inch), 4.0-1.3 micron-width processes into the submicron (0.8-1.2 micron) line-width era (Li 2011). Yet, when the fab deployed at Huajing finally came online in 1997 after a long delay, the ambitions in Project 908 to close the international technology gap had not been realized. Technological advance in the semiconductor industry was simply moving too fast; by 1997, a 200mm fab trailed leading-edge international technologies (Ibid).

During Project 908, even though China's reform towards a market-oriented economic system had gone underway for a decade, the logic of Project 908 was still similar to projects of large-scale, state-led technological development under central planning. During Project 908 inefficient coordination occurred among ministries and their departments in establishing a feasible project plan. To come to project approval, it took four years to overcome the debates and quarrels on plan details such as selection of locations, types of equipment and products, and sources for technology transfer.

III.2.5 Different U.S. Attitudes towards China and Japan

U.S. different attitudes towards Japan and China also led to the different speeds in the technological catch-up. As the U.S.' strategic ally, Japan started the development of its semiconductor industry early in the 1960s and had depended on U.S. R&D by taking a "free-ride". The U.S. designed new products and conducted the basic research, while the Japanese adapted U.S. designs at low cost and high quality. The Japanese have often been able to capture a large share of the market in a relatively short time. In Japan, engineers were permitted relatively free access to U.S. technologies through frequent conference attendances and company visits during the 1950s and 1960s (Flamm 1996). By concentrating on acquiring U.S. licenses and patents, Japanese firms soon were able to start low-cost mass production by the late 1950s.

On China's side, one of the major external barriers that hindered China from developing an advanced semiconductor industry prior to the 2000s was U.S. exports controls on semiconductor manufacturing equipment and materials (SEM). According to GAO

(2002), under the Wassenaar Arrangement, SEMs were classified as dual-use technologies, i.e., technologies that could be potentially used in both civil and military domains. Such is a legacy of the Cold War, but the U.S. government was quite stringent in adhering to these controls. It was said that the U.S. government generally ensured that the technology transferred to China was at least two generations older than the state-of-the-art in the US (GAO 2002).

III.2.6 Chinese Economic System after Reform

It should be noted that, beginning in 1978, the CCP, under the leadership of Deng Xiaoping, established a national objective of modernizing agriculture, industry, defense, and science and technology. The objective of the second phase of reform (1984-1991) was to improve resource allocation mechanisms. According to Chen (1995), the main focuses of the reforms were (a) the material management system, (b) the foreign-trade management system, and (c) the banking system. The third phase of reform (1992-present) has focused on the macro-policy environment, including the reform of pricing, exchange rate and interest-rate policies (Li 2011). After the reform, in the 2000's, the open market structure conformed more closely to the types of business structures that can generate innovation. In contrast to the large state-owned enterprises before the 2000's, founded and managed by expatriate techno-entrepreneurs, enterprises after the 2000's possibly had the most capable decision-makers who were available in China.

In the 1987 enterprise reform, large enterprises were granted a number of rights to operate with substantial autonomy outside the plan activities. They were allowed to hold foreign trade rights, to decide the scope of sales, technology imports and upgrading, to diversify production, to establish financial subsidiaries, and to raise funding. However, the Chinese leaders had strong political considerations, which stressed the state's primary controlling ownership in the high-tech industries for the purpose of consolidating the socialist system, ensuring national security, supplying public goods, and adjusting economic structure and leading economic growth.

III.3 Government Policy and Industrial Projects

Japan's strategy towards the semiconductor industry has been characterized by active government involvement in the industrial and technological upgrading. The Japanese state played a crucial role both in manipulating the access of foreign competitors to the domestic market and in restructuring the key domestic industries to promote their export competitiveness. Intended to learn from Japanese strategy of building export competitiveness, China launched the 'grasping the large and releasing the small' strategy, in order to build state enterprises into vertically integrated and international competitive giant companies in pillar industries.

In this section, we compare the similarity and difference between Chinese and Japanese government policies and industrial projects.

III.3.1 China's Market and Autonomy Reform

In the mid-1950s, China adopted a Stalinist-style centrally planned system that aimed to substitute the administrative plan for competitive markets, and to abolish social inequality by nationalizing production. Under this system, the state was responsible for all sectors and decided all aspects of enterprises' operations. But this situation changed dramatically with the implementation of the development reorientation and opening up strategy in 1979. The government began to get enterprises previously involved in the production of military goods to convert to the production of civil goods. During the 1986-1992-reform period, China started promoting four targeted circuits: integrated circuits, computers, telecommunications equipment and software. Industrial policies were designed to extend enterprises' autonomy over management and administration, invest in R&D and education, and encourage technology importation (FYP 1986-2004). However, enterprise and market-oriented reforms were carried out at a time when the bureaucratic economic apparatus remained dominant. Macroeconomic imbalances frequently emerged.

Before the 2000's, it was the lack of firms' freedom to make decisions according to the market information rather than the inefficiencies of the economic policies of the government that resulted in the technological lag-behind in China. The state-owned and JV semiconductor firms which dominated in China were firmly controlled by the state. Thus companies lacked the autonomy in decision, resulting in little efficiency in decision making. The government did not decentralize but instead concentrated power in the hands of Qili Hu, who was a season party cadre, to oversee the Project 908 and 909, two large state-led projects intended to upgrade the semiconductor technology in China. Hu made the largest ever investment in semiconductors, while giving its Japanese partner authority over management decisions, in exchange for an extended period of learning from the Japanese for the Chinese staff. However, the disqualification of Chinese managers from exercising strategic control was merely proving further evidences of the deficient capabilities of Chinese managers in 1990's.

The state's power was increasingly decentralized and transferred strategic control gradually to the firms, during the process of China's economic reform. Throughout the 1980's and 1990s, the government made various experiments of corporate governance regimes in state-owned firms in the hope of establishing a more efficient enterprise system. In the 1980's, the major effort was transferring responsibilities of decision-making to managers through a Contract Management Responsibility System (Chen 1995). To overcome the prevailing short-term behavior encouraged by CMRS, in the 1990's the state established a shareholding structure for large-sized SOEs and privatized the small- and middle-sized SOEs in the name of "Modern Enterprise Management System" (Ibid).

As a result of the reform, the transformation of strategy, organization and social conditions occurred and were translated into economic development, rise-up of the new enterprises and technological catch-up. Institutional changes, along with economic transformation to a market-oriented economy, brought in the power of the market and started to stimulate the dynamic function of the market system.

Yet, given the strategic importance of the semiconductor industry and its capital-intensive nature, the Chinese state continued to intervene in the corporate governance of the state-owned semiconductor firms up until the end of the decade. The presence of Minister Hu Qili at Huahong, a Chinese government's backbone SOE, is the obvious evidence. But still, the Chinese government was aware of the dire ability of the state in the centralized economy to command each sector and so was ready to privatize the sector by transferring the power from the state to the engineers and entrepreneurs, transforming to a more market-led economy.

III.3.2 Japan and China's Similar Big Business Strategy

Against a transforming economic background, China strived to learn from successful countries' strategies to promote the export competitiveness in the electronics industry. It is interesting to find that China mimicked Japan's strategy of domestic market protection and national champions promotion.

To track back to Japanese history of development, Japan, as a "resource-poor nation", chose electronics industry for domestic development because it is a targeted industry that Japan could serve to expand oversea sales. Unlike China that has abundant land and labor resources, Japan initiated government policies that are intended to create comparative advantage in high value-added industries as an alternative to remaining dependent on the labor-intensive resources and capital. Thus it is due to this reason that led the Japanese state to use government policies and trade policies to promote electronics industries, which would grow Japan out of labor-intensive resources.

Targeting this objective, Japan's Ministry of International Trade Industry used a variety of incentives and controls, including influence over financing, tax policies, import-export measures and "administrative guidance" to induce Japanese firms to compete vigorous and dynamically but at the same time to move in directions that are consistent with overall national goals, targeting at a certain industries of increasing sophistication, taking advantage of the demand pull from the consumer electronics and leveraging the close relationship between government and business in Japan.

When Japan was at the beginning period of semiconductor industry development, the Japanese market had relative weakness in computers and telecommunications. Japan also lacked the military demand that had pushed U.S. semiconductor industry's growth, meaning that the domestic semiconductor industry's development was not pulled toward innovation except in consumer products. This situation posed a central dilemma for Japanese policymakers. Under conditions of free trade and open market access, they faced the risk that U.S. firms might dominate domestic Japanese markets in semiconductors, computers and telecommunications. If they protected their markets and denied U.S. firms open access, they risked severe technological backwardness in those sectors. The solution the policy makers chose was characteristic of postwar Japanese development strategy. They used trade policy to limit foreign penetration of the domestic market while deploying a range of financial and promotional policies to assist the industry's growth. In the role of controlling access, the Japanese government has been characterized as an "official doorman" between domestic Japan and the international arena, determining what, and under what conditions, capital, technology and manufactured products enter and leave Japan (Pempel 1977). Selective control over international foreign investment discouraged foreign efforts to control Japanese firms and to manufacture in Japan. Imports were limited through tariff and nontariff barriers to ensure that domestic firms would capture most the explosive growth in domestic demand.

Technology imports were controlled by MITI in order to force foreign firms, whenever possible, to sell technology. Thus "a closed market provided Japanese firms a stable base of demand on which to build competitive productions and distribution network". (Borrus et al 1981) Only after 1975, when Japanese firms had grown in their technological competence and domestic market dominance, did the government begin to move toward a partial dismantling the restrictions on foreign penetration. A more detailed discussion about Japan's trade policy will be mentioned in the next section.

Simultaneously, Japanese firms purchased huge amounts of foreign technology, mostly from the United States, and used their strength in consumer products to subsidize a limited price competition with U.S. firms in international semiconductor markets.

Japanese state played a crucial role both in manipulating the access of foreign competitors to the domestic Japanese market and in restructuring the key domestic industries to promote their export competitiveness. In contrast to Chinese government's centralized power in the state, Japanese state provided sufficient freedom the its private sectors but instead promoted the market. What's more, in addition to protecting the domestic industry, the Japanese government encouraged domestic competition by supporting the expanding firms. The state organized a stable availability of cheap capital; provided tax breaks to assure cash flow liquidity, gave R&D support and helped to promote exports. Thus Japanese encouragement of domestic competition eliminated the industrial losers and kept winners. As a result, in most sectors, a few large vertically integrated firms emerged and carved up the domestic market as a matter of company strategy and state policy. Markets were rationalized, and in MITI's words, "intra-industrial specialization" (MITI Policies) was encouraged as a means of building efficient scale economies in market segments. Also, in Japan, semiconductors were produced not by specialized semiconductor companies but by the semiconductor divisions of large electronic systems companies. These companies – mainly manufacturers of communications equipment, computers and consumer electronics – had all been producing semiconductor devices since soon after the invention of the transistor. Due to this pattern, the semiconductor producers not only had access to low-cost capital but also could take indirect advantage of tax incentives and other special benefits. Capacity expansion was often planned with the state's help. Thus vertical integration, "rationalization", "oligopolization" and "cartelization" were an integral part of the sectoral development policy (Cupertino 1983). At one extreme lied the image of "Japan, Inc.," in which at every level of relations, businessmen and governmental promoters collaborate to further the development and international competitiveness of Japanese business. At the other extreme, was "Japan, the Land of Fierce Competition," in which cutthroat competition was assumed to characterize domestic Japanese markets (Borrus et al 1982).

On China's side, China launched the 'grasping the large and releasing the small' strategy, intended to build state enterprises into vertically integrated and international competitive giant companies in pillar industries, including the electronics sector. In 1984, the central government reiterated that the mergers and acquisitions (M&A) between enterprises would be voluntary and horizontal and would preferably take the form of cooperation and alliances between large and medium-sized SOEs in the form of joint-stock companies (JSCs).

In response to this central 'blueprint' and the enterprise autonomy reform, the government announced a development strategy of 'applying theories of economies of scale and building China's IBM, Hitachi, and Siemens' in order to catch up with leading countries. It was emphasized that enterprises should develop greater self-initiatives and 'competitive consciousness' that could alter their attitude towards the new reform strategy from 'I am asked to integrate' to 'I want to integrate' with other enterprises to improve performance (Li T. 1986). Although enterprises were given decision making rights, they were treated as subdivision of local hierarchical bureaucracies and in practice were required to respond to the command of governing authorities.

Moreover, China's development strategies in the electronics sector were in fact inspired by the Japanese models to support a team of national ICT group companies with a wide range of statist industrial policies. Just like how MITI constructed import barriers, provided subsidies for R&D and leveraged demand pull – Chinese government initiated policies such as domestic market protection through tariff and non-tariff barriers; demand pull and supply chain building through government procurement and local content requirements; financial subsidies and incentives such as the purchase of production inputs on preferential terms, tax relief, preferential loans from the state-owned banks. Tight control was imposed to main the primary state ownership in the industry. And the Ministry of Information Industry (MII) was set up in 1998, serving a similar role of MITI in Japan.

Thus the logic behind China's adoption of a big business strategy in the semiconductor industry at first sounds very reasonable. As historians and economists have observed, the substantial level of economic growth in the eighteenth and eighteenth centuries was largely due to technological progress, to which large industrial enterprises made a more significant contribution than small-scale firms, and large firms were therefore the major driving force behind economic development (Nolan 2001). Large firms are often the first mover in new technologies or processes and the first to commercialize them into products and services. Their financial position, derived from exploiting economies of scale, enables them to invest heavily in R&D and compensate for the inherent market failure issues associated with high technology and knowledge-intensive industries. Their ability to accumulate valuable human resources ensures that they have a sustainable technological capacity to maintain innovative activities (Chandler 1990).

However, the performance of these Chinese large group companies was not as good as expected. In 1997 the government announced that the total industrial sales, production output, exports and value added of 12 targeted large firms accounted for roughly 10 percent of all indicators of the total (Ning 2007). However, in 2004, fifteen targeted large firms accounted only for 8 percent of total industrial output, 8 percent of the industrial sales, 1 percent of total industrial profit, 6 percent of total exports, 9 percent of total value added and 12 percent of the total industrial assets. (Information Technology Yearbook 2004; Ibid)

The problems in China of failing to replicate the same strategy are as follows. First of all, China's firm size strategy primarily targeted SOEs against the background of its gradual market reform from the centrally planned economy, whereas the Japanese strategies focused on private firms in economies that were market-oriented. Private firms in China expanded in search of larger competitiveness but SOEs in China expanded their scales due to the command of government. Second of all, the Japanese government encouraged domestic competition by supporting the expanding firms. The state organized a stable availability of cheap capital, provided tax breaks to assure cash flow liquidity, gave R&D support and helped to promote exports. Japanese encouragement of domestic competition eliminated the industrial losers and kept winners. Thus in Japan it was due to companies' willingness to increase competitiveness that they merged with other enterprises. However, in China, enterprises were "forced" to take "voluntary" mergers with other enterprises. Some local authorities whose definitions of large firms were unclear would merge large firms in their region that had nothing in common – and these large firms would still be small-scale by national standards. Such "forced" marriage only creates problems of corporate governance in managing different firms.

III.3.3 China's Divergence from Japan's Big Business Strategy

Adding to what has been discussed, in late 1980s, China proposed to pursue the small and medium-sized business (SME) promotion strategy: "while promoting collectively the large enterprises, we also need to develop a number of small, new, specialist small and medium size companies in order to complement the development of the large firms" (Li T. 1986) However, this proposal was not implemented until 1990s after the problems of large firms have been found in the Asian financial crisis while the Taiwan SME model succeeded in weathering the crisis. Moreover, due to China's entry to WTO, China minimized trade tariffs and other interventional policies for protecting domestic markets and restricting foreign investment. Thus in 2002, the central government promulgated the SME promotion law by offering support in a number of areas including finance, business start-ups, technology innovation and upgrading and market expansion.

Promoting the SMEs can increase degrees of competition and provide firms with incentives to improve their technological capabilities and managerial abilities. In addition, the SMEs can reduce the market power of local monopolies and allow a more efficient allocation of resources. Moreover, small firms are regarded as having played an important role in long-term economic structural change where jobs move from one sector to another or new sector after trade (Aghion and Blanchard 1993). Their flexible nature allows them to respond quickly to market changes and become more diversified so to withstand the volatilities of financial stocks (Wade 1998, 2004). During financial crisis in 1990s, it was just the lack of SMEs that discouraged Japan from adjusting the structure. Moreover, Japan's failure to adjust to the newly emerged fables-foundry caused it to miss the opportunity of taking advantage of the separation of supply chain and leveraging other countries' labor-abundant comparative advantages. On China's side, China joined WTO and became integrated into the world's economy. Thus China started from material-based and labor-intensive industries and based its production on SMEs in order to fully exploit and reflect these two comparative advantages.

III.3.4 Japan's joint-efforts research capability and China's failure with joint R&D

A very important project that pushed the great development of the Japanese semiconductor industry was the VLSI project, a joint industry-government R&D effort. The project was instituted to develop advanced semiconductor technologies, particular very large-scale integrated circuits (VLSI). In the mid-1970s, MITI targeted the computer and telecommunication markets as central to Japan's future, aimed at increasing Japan's contribution to innovation in basic technologies, an area of technology that Japan significantly lags behind in compared with the U.S. In mid and late 1975, MITI organized the leading semiconductor firms into two government-supervised industrial groups (NEC-Toshiba and Fujitsu-Hitachi-Mitsubishi) and fixed as the primary long-range goal the development of Japan's VLSI capability. It subsequently established an "executive plan" for the semiconductor sector and budgeted amounts needed to implement the Plan. According to MITI Machine and Information Industry Bureau, the Plan included 1) specific targets for semiconductor research and development supported by government funding 2) specific targets for semiconductor production, supported by government loans, and 3) specific targets for "rationalization" of the Japanese semiconductor industry (MITI Machine and Information Industry Bureau 1979)

The VLSI project was a "research cartel": participating firms divided R&D tasks to avoid duplicate efforts and pooled their results. The Project was jointly undertaken and staffed by MITI and Nippon Telephone & Telegraph (NTT), and Japan's five leading semiconductor firms – NEC, Hitachi, Toshiba, Fujitsu, and Mitsubishi. A central laboratory with about 100 personnel conducted fundamental research into semiconductor technology. Its findings were turned over to two "applications" groups that developed marketable products from the basic research. The VLSI Project promoted extensive cross-fertilization of ideas between and among Japanese firms and government scientists and at the same time, gave each participating firm access to advanced technological know-how at a very low cost. As a result, over 1000 new VLSI patents were developed, reflecting Japan's goal of enabling Japanese firms to pull abreast of U.S. firms technologically.

On china's side, Chinese government concentrated on reducing semiconductor producers' costs because of lack of scale and fund in the semiconductor companies rather than promoting R&D in basic technologies. Moreover, due to the inefficiency of government decisions within the Chinese government, although the state and enterprises planed to establish a collective research center, they had limited knowledge of the huge cost and management models of such a research lab. Thus eventually China failed to establish a state's semiconductor research center (Yang 2005).

Furthermore, due to the lack of bureaucratic coherence, what happened in Chinese semiconductor industry was that the subsidies provided for research in China was distributed in too many sectors, instead of focusing on one specific technology and distributing the fund to targeted companies. Some of the research firms that received subsidies were not even capable of conducting commercial research of the semiconductor that cost over 1 million dollars. Neither did China have the combined force of a group of companies in the research and development like what Japan did in 1970s in developing its VSLI project. The Chinese government's subsidy for R&D was 80 million dollars in 2001-2004 and was distributed among many firms. But in Japan, each group out of three paired groups formed by the six semiconductor-computer firms received $200 million dollars between 1972 and 1976 (Borrus et al 1982). The government-subsidies intended for research and development between two countries differed largely.

III.4 Trade Policy and Foreign Investment

While Japanese success in the semiconductor industry was credited to its government's protectionist policy in protecting the domestic market and encouraging the domestic market, Chinese success in becoming one of the top semiconductor markets should be attributed to China's 'walking out' strategy, which was inseparable from the state effort in market reform and trade liberalization.

III.4.1 Japan's Protected Domestic Market and Import Displacement

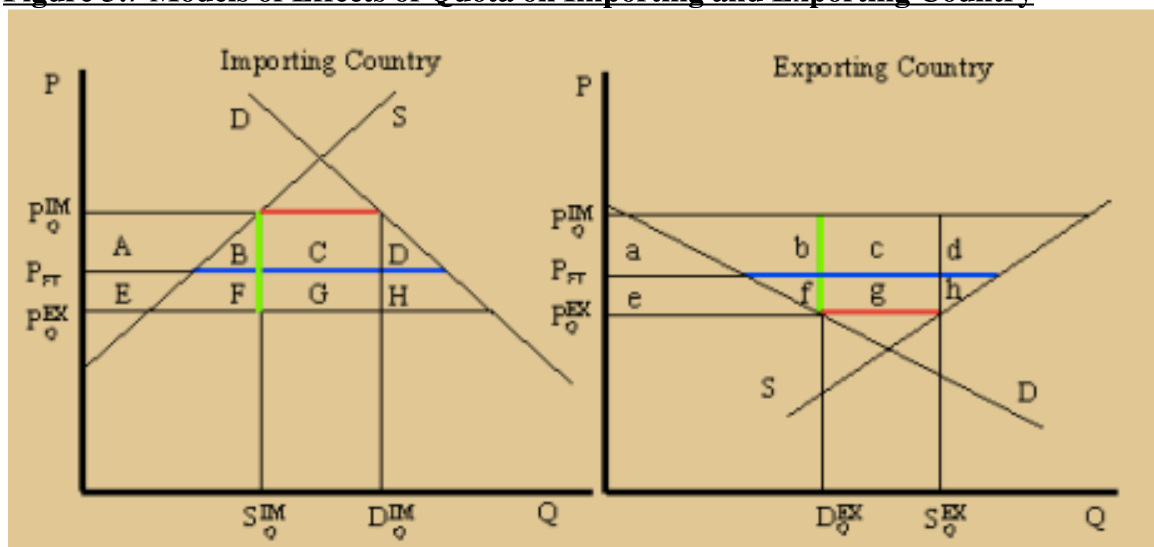
Until 1974, the Japanese semiconductor market was officially closed. Japan maintained quotas that were never sanctioned under the General Agreement on Tariffs and Trade (GATT) on imports of semiconductors. Over a period of years, U.S. firms made repeated efforts to penetrate the Japanese semiconductor market. With limited exceptions, these efforts were not successful. MITI permitted some imports of U.S. semiconductors which its own firms could not make and which its own end-products firms needed to remain competitive, for example, ICs for pocket calculators and digital watches. Japanese firms also imported U.S. semiconductor technology to enable Japan's own semiconductor sector to grow.

Moreover, the government consistently rejected all applications for wholly owned subsidiaries and for joint ventures in which foreign firms would hold majority ownership. It also restricted foreign purchases of equity in Japanese semiconductor firms. Simultaneously, the government limited foreign import penetration of the home market through high tariffs and restrictive quotas and approval-registration requirements on advanced IC devices in particular. The price to US firms for limited access to the Japanese market was—similarly to Chinese case before 2000—their licensing of advanced technology and know-how. This too was regulated closely by the Japanese government, whose approval was required on all patent and technical-assistance licensing agreements.

Japan's general policy was simple and effective. It required foreign firms to license all Japanese firms requesting access to a particular technology. In line with the characteristics emphasis on export strategy, MITI often linked the import of particular technologies to the acquiring firm's ability to develop export products using that technology. The total result of these policies was a controlled diffusion of advanced technology throughout the Japanese semiconductor industry. Moreover, prior to 1975, formal quotas and prior-approval requirements restricted imports of semiconductors into Japan was so strictly regulated as to be essentially forbidden. The effect of such a quota on the exporting country is demonstrated as follows.

Suppose for simplicity that there are only two trading countries, one importing, Japan and one exporting, the U.S., as indicated in Figure 3.7. According to "Import Quota", which explains the international trade theory, the supply and demand curves for the two countries are shown in the adjoining diagram. PFT is the free trade equilibrium price. At that price, the excess demand by the importing country equals excess supply by the exporter.

<u>Figure 3.7 Models of Effects of Quota on Importing and Exporting Country</u>



Source: "Import Quota." UNIPV. N.p., n.d. Web. 25 Apr. 2012.
<http://economia.unipv.it/pagp/pagine_personali/msassi/readinglist/doc2.pdf>.

In the case between Japan and US, the horizontal distance between the supply and demand curves at the free trade price is Japan's import from US during free trade. International trade theory tells us that - as "*Import Quota*" so indicates - that when an importing quota is set equal to the length of the red line (the horizontal distance between the supply and demand curve at the P^{IM} of the importing country), the price of the importing country goes up to P^{IM}_{Q} in the importing country and the price of the exporting country receives goes down to P^{EX}_{Q}. Thus when a new equilibrium is reached the price in the importing country will rise to the level at which import demand (D^{IM}-S^{IM}) is equal to the quota level. The price in the exporting country will fall until export supply (S^{EX}-D^{EX}) is equal to the quota level. Thus the outcome of price effect on both the importing country and the exporting country is enormous: when Japan sets a quota on the semiconductor industry, it not only raises the importing prices of the semiconductors imported from foreign countries (mainly from U.S.) but also reduces the exporting prices U.S. firms will receive. A great percentage of U.S. firms' price competitiveness and profitability are lost due to the quota. As a result, the import and export amount shrink from the length of blue line (which indicates the amount of import and export during free-trade) to that of red line (which indicates the amount of import and export under quote control).

Historically, in response to Japan's protectionist policy, American chip producers urged that Washington initiated market access negotiations with the Japanese government. Early industry pressure forced the Japanese to enter into negotiations with the United States in 1982. This early set of talks produced an agreement in which the Japanese government committed itself to using its authority to prevent dumping, providing U.S. with greater access to Japanese patents, refraining from copying U.S. propriety circuits, and encouraging Japanese to increase purchases of U.S. semiconductor products through administrative guidance. Throughout 1983, the semiconductor industry released numerous reports and studies with detailed accounts of the unfair trade practices pursued by Japanese chipmakers and the Japanese government.

But interestingly, even years after “liberalization”, U.S. semiconductor firms did not hold a larger share of the retail merchant market than they held when imports were controlled by the quotas. An important factor in the inability of U.S. firms to penetrate the Japanese market was the simple fact that the same firms that produced most of Japan’s integrated circuit also accounted for a majority of Japan’s semiconductor consumption. Moreover, Japan had the skill to displace imports – due to Japan’s ‘buy Japan’ strategy - from the U.S. so that even after the “liberalization” U.S. still could not penetrate the Japanese market. U.S. companies were able to achieve some penetration of the Japanese market with a particular product so long as sufficient quantities of a competing Japanese product were not available, but as soon as Japanese firms could supply the product in sufficient volume, U.S. firms’ sales dropped sharply, sometimes almost to zero.

However Due to Japanese protected domestic market strategy, many companies chose merger and acquisition in order to create individual enterprise’s competitiveness by becoming a large-size company. The consequence of Japanese semiconductor’s frequent merger was that these producers’ scales were so large that it took longer time for Japanese large-scale semiconductor firms to restructure.

Furthermore, due to the closeness of the market, the lack of foreign investment caused their inertia to spot the global trend shift and make changes accordingly. For many years, Japanese firms were responsible for both design and product and are increasing investment in R&D in the production technology in order to increase the product competitiveness. Since the rise of the pure-play business models, fabless (fabrication-less) semiconductor company has been specialized in the design and sale of hardware devices and semiconductor chips while outsourcing the fabrication or “fab” of the devices to a specialized manufacturer called a semiconductor foundry. The U.S. semiconductor firms adjusted to the model very quickly and started to outsource chip manufacturing to foundry such as TSMC in Taiwan and SMIC in China. The results of such collaboration between horizontally divided organizations overwhelmed Japanese integrated device manufacturers. Thus the business environment for vertically integrated Japanese device manufacturers worsened as the semiconductor industry came to be based on a flatter and horizontally divided structure.

China, on the other hand, established many foundries in the form of a mixed ownership, invested by foreign companies, thanks to China's 'attracting in and walking out' strategy. After liberalization in the 2000's, the Chinese semiconductor firms came to collaborate with U.S. companies to provide fabrication-outsourcing services. Leveraging China's comparative advantage and conforming to the liberalized open trade in the global market, China's export to the U.S. continued to grow at an average around 30 percent.

III.4.2 China's 'Attracting in and Walking Out' Strategy

In the beginning of the Chinese development history of the semiconductor industry, the Chinese market had been a closed one with tariffs and regulated foreign direct investment. However, along with Chinese economic transformation, after 2000's, China gradually reduced its tariffs and opened its economy for trade and foreign investment.

According to Li (2010), throughout 1990s, the domestic semiconductor market of China remained a protected one. Tariffs on semiconductors varied from 6 to 30 percent, and foreign direct investments were highly regulated (Dewey Ballantine, 2003). Very few multinationals were able to establish wholly foreign-owned enterprises (WFOEs) during this time. Major multinational chip producers, including Alcatel, Lucent, Philips, and NEC, entered China in the form of joint ventures, subject to conditions such as transferring technologies and guaranteed purchases of outputs. China restricted market access in order to regulate the large entry of foreign competitors unless foreign companies agree to transfer technologies or purchase outputs produced domestically in China.

However, Jiang Zeming (the former MEI minister) recognized that this highly controlled trade and investment regime prevented the electronics industry from gaining from technology spillover effects and forming the start-up basis for production. He argued that capital- and technology-intensive industries such as the electronics industry could not be established on the basis of developing countries' own capabilities. Countries such as Brazil and India, which focused on across-the-board import substitution, experienced many difficulties in increasing their foreign reserves. Their capabilities were too weak to develop new products and they had to import costly technologies and equipment for production. Conversely, the East Asian 'tigers' had switched to an export-oriented strategy and achieved great access. During his term of office at the MEI, he launched a set of more liberal trade and investment policies, namely the 'attracting in and 'walking out' strategies, based on Deng's 'open door' policy at the national level.

Jiang believed that the selective introduction of FDI to develop this sector was particularly helpful to alter China's industrial production structure towards export-oriented labor-intensive industries. Jiang proposed to step into the international electronics market through carrying out assembling and OEM activities for foreign firms (Jiang 1993; Li 1993). In the 1980s, the government began to introduce 'special economic zones' in order to provide market export-oriented institutions and preferential policies outside the plan system to attract and support FDI activities. After Deng had pushed forward a renewed reform agenda in 1992, special provisions and more liberal policies were made much more widely available for FDI including tax and tariff concession and relaxation on business era. In 2001, when China was preparing for admission into the World Trade Organization (WTO), China became a signatory of the Information Technology Agreement (ITA), which required reducing tariffs on all ITA products, including semiconductors, to zero. To comply with WTO rules, China had to make large-scale legal amendments in line with those in other WTO countries. In June 2000, the State Council issued a semiconductor industry policy document that would be the most influential for the next decade: "Policies on encouraging the development of software and integrated circuit industry" (Circular 18). According to China's Tenth Five Year Plan (FYP 2001-2005), Circular 18 restated the state's ambition to develop a world-class semiconductor industry, but promoted a very different means to achieve this goal. The major policies in Circular 18 can be summarized as the following:

1) Tax break. Eligible IC manufacturers (investment exceeding 8 billion RMB and line-width smaller than 0.25-micron) can receive a five-year tax holiday from corporate income tax starting from the first profit year. The tax rate would then be halved for an additional five years. (FYP 2001-2005)

2) Value-Added Tax (VAT) and import duty exemptions on imported raw materials, equipment and machinery. VAT rebates for domestically produced ICs. Designers and producers can qualify for up to a 14 percent VAT rebate for domestically produced chips. In another words, a 17 percent tax is imposed on imported semiconductors while only 3 percent is charged for those produced domestically. (Asian Wall Street Journal 2004)

3) Infrastructure investment. Direct budgetary funds shall be allocated to provide financial support for construction of infrastructure (usually by local governments) (FYP 2001-2005)

4) Foreign currency retention. "To evade the exchange rate risk, [IC manufacturers] are allowed to deposit the after-tax profits in the special accounts in the form of The VAT rebate policy later became controversial among foreign investors and their government. In March 2004, the US government complained to the WTO that China was violating trade rules by using tax to discriminate against oversea producers. As a result China withdrew the VAT

rebate in April 2005 foreign currency if the profits are to be used for reinvestment in China." (Ibid)

6) Capital provision. The state provides assistance in the form of favored status and financial support to the establishment of venture capital firms. (Ibid)

7) National treatment of foreigners. The policies are applied to both foreign and domestically owned firms that qualify (article 52).

8)Training programs. Universities are encouraged to provide courses and degrees on electronic engineering through increased budget allocations on the basis of increased enrollments (FYP 2001-2005)

These policies were major departures from the industrial support of the 1990s, which emphasized government involvement in industry coordination, leveraging the huge Chinese market for technology transfer, and using the domestic market to create national champions that could compete globally. Instead, Circular 18 promoted industrial development through deregulation, subsidies, tax incentives, FDI liberalization, investment in infrastructure, and science, education and training programs. The old tools used to promote infant industries, such as market access restriction, tariff protection and technology transfer requirements, had to be largely abandoned. Circular 18 reflected an attempt by China's industrial promoters to experiment with new policy tools, given China's new need to play be a new set of rules in global competition. It seemed that China changed to play the game of market-based incentive policies.

The changes in developmental strategies starting from Circular 18 had an enormous impact on the semiconductor industry. First of all, instead of focusing on the state-led projects, new policies now promoted the growth of all players, regardless of indigenous or foreign, state-owned or non-government. It was under such an industrial conditions change that the foundries, which required a huge fixed investment, often having their capital costs shouldered by a combination of foreign venture capital firms, domestic banks and the Chinese government, rose in the Chinese market and pumped up the semiconductor industry.

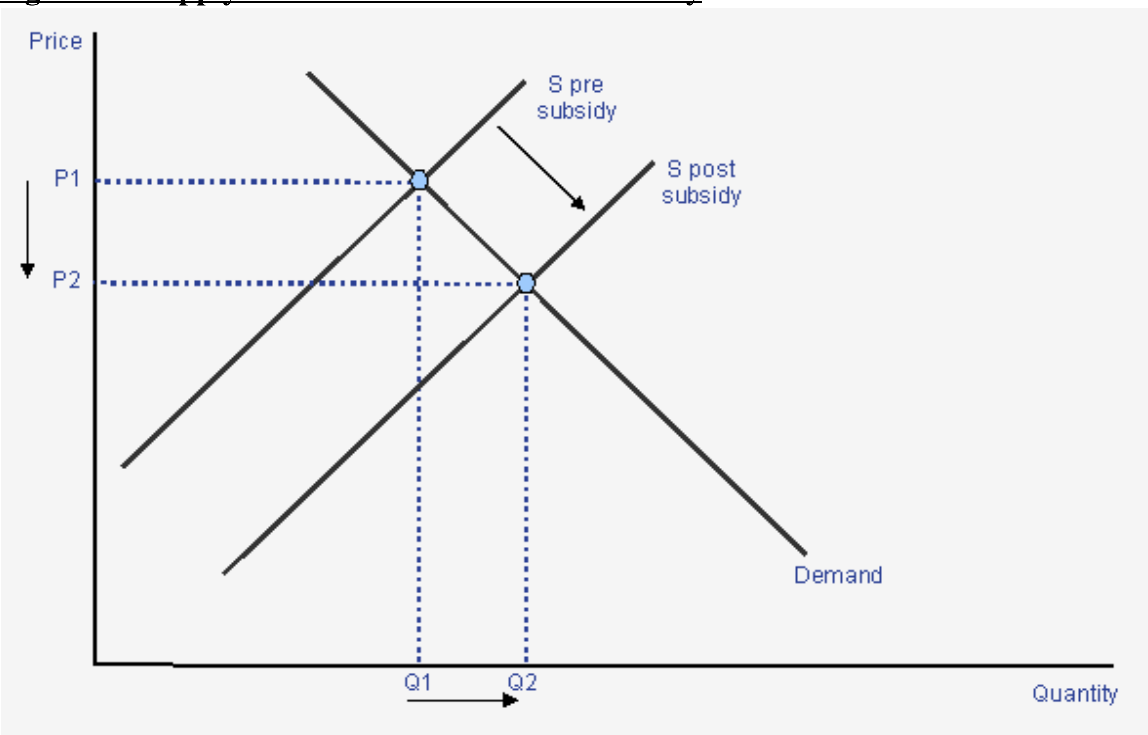
Secondly, circular 18 provided encouragement of foreign investment to a large degree. The old players in the semiconductor sector that entered prior to 2000 were mostly owned in the form of SOE-JV (state-owned enterprise and joint venture). New entrants often had a "mixed" ownership structure, meaning shares were distributed among a variety of foreign and domestic entities. The entrepreneurial teams were more likely to excise managerial control with the absence of dominant shareholders such as the state. Even the old state-owned firms that used to be controlled by bureaucrat-turned managers assigned by the state saw changes in management.

Thirdly, Circular 18 specifically pointed to semiconductor industry as exempted from 17 percent VAT on the imported machinery and raw materials are eternally eliminated – further added up to the incentives provided by the tax break – allowed firms to grasp this opportunity to import the latest technology from the advanced countries with exemption from the import tariff. Moreover, according to the third government policy, where a major VAT cut to 3 percent is imposed on domestically produced semiconductor while 17 percent VAT on imported semiconductors, firms were strongly encouraged to develop the production of semiconductors indigenously rather than importing the semiconductors from abroad and taking charge of merely assembling.

Here the Chinese government made use of the idea of subsidy in order to encourage the development of the semiconductor industry by providing incentives to the business managers of these companies. A subsidy is an assistance paid to a business or economic sector. Most subsidies are made by the government to producers or distributed as subventions in an industry to prevent the decline of that industry or an increase in the prices of its products or simply to encourage it to hire more labor. Examples are subsidies to encourage the sale of exports; subsidies on some foods to keep down the cost of living, and subsidies to encourage the expansion of some industry production.

Figure 3.5 shows a simplistic graphical explanation of the effect of a subsidy on the industry. When semiconductor companies are qualified for a specific tax cut (thus lowering the production cost), they will increase the domestic supply, shifting the supply curve of the firm towards the right. The same theory applies to the semiconductor industry: if the whole industry is qualified for a tax cut as long as the companies in the industry produce semiconductors domestically, the supply curve of the entire industry shifts to the right – more semiconductor companies rise while the demand curve remains – driving the domestic price of the semiconductor down. The result is that if in a closed market, the price of the semiconductor will go down.

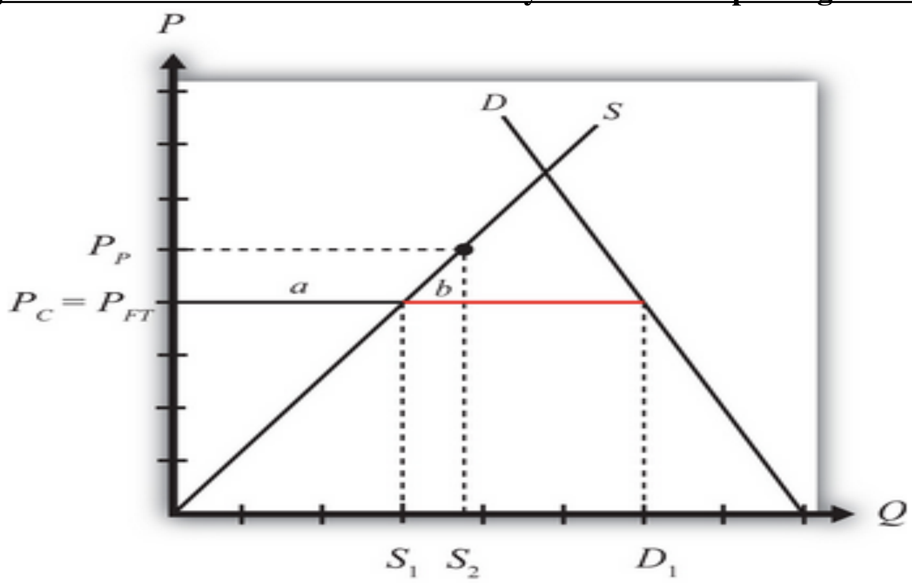
<u>Figure 3.5 Supply and Demand Model with Subsidy</u>



Source: drawn by the author

To consider the impact of a domestic subsidy policy in the semiconductor industry in the international market, we depict this equilibrium diagram in Figure 3.6. Figure 3.6 supposes for simplicity that only the importing country's (in this case, China's) supply and demand are shown. We assume that the Chinese semiconductor market relies largely on imports from foreign countries and domestic production will not affect the supply curve. According to the international trade theory, explained in "*Production Subsidy Effects in a Small Importing Country*", the original price is given by P_{FT}, a price determined by the global semiconductor market. The domestic supply is S_1, and domestic demand is D_1, which determines imports in free trade as D_1-S_1 (the length of the red line). When a production subsidy is imposed, the domestic producer price rises by the subsidy value to P_p. If we assume in this case that China did not have any other trade barriers and China's semiconductor production in the beginning of 2000 was still weak thus not able to influence the global semiconductor market's price. Thus the effect of China's subsidy on the semiconductor would be categorized as a domestic production subsidy in a small importing country. As a result of the subsidy, the domestic consumer price remains at P_{FT}; but the prices domestic producers would receive would go up to P_p. The effect of the subsidy in this case would raise domestic supply from S_1 to S_2, while domestic demand would remain at D_1. Imports from other countries, would fall from (D_1-S_1) to (D_1-S_2).

Figure 3.6 A Domestic Production Subsidy in a Small Importing Country

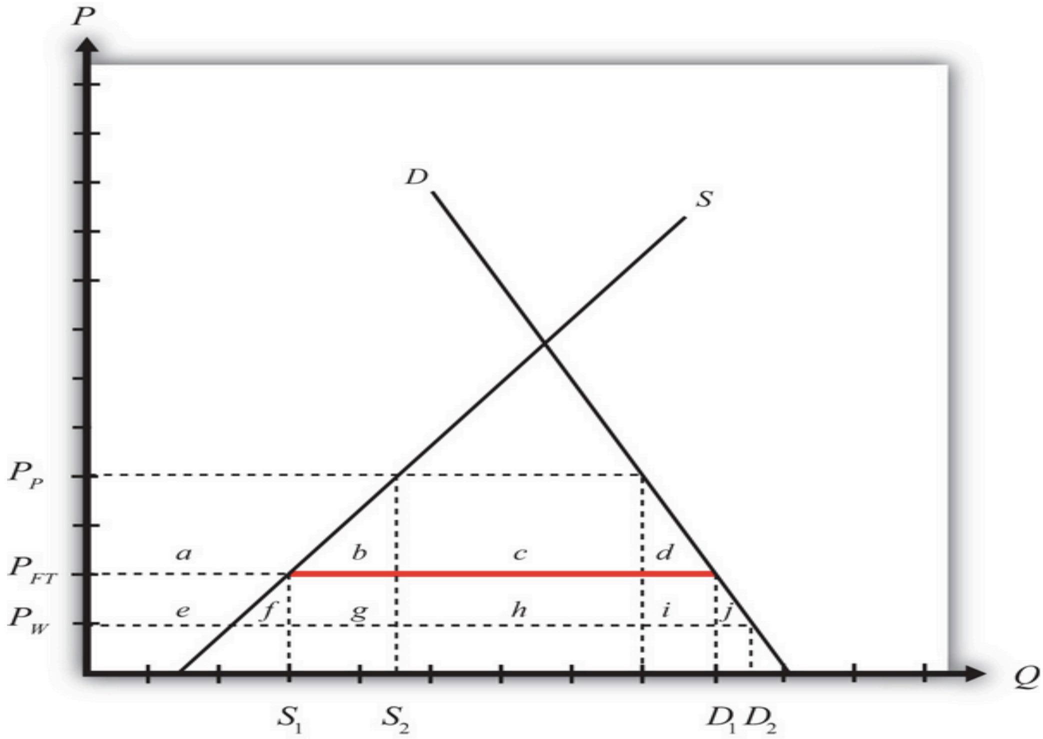


Source: "*Production Subsidy Effects in a Small Importing Country.*" *PEOI. N.p., n.d. Web. 25 Apr. 2012. <http://www.peoi.org/Courses/Coursesen/intrade/ch/ch9d.html>.*

Note: assuming China's semiconductor production in the beginning of 2000's in is small

If that is the case, the domestic consumers are unaffected by the subsidy since the domestic consumer price remains the same. The subsidy will cause the price producers receive to go up to P_P, which in turn stimulates an increase in output from S_1 to S_2. Foreign prices will remain unchanged, and although their exports to this country will fall, these changes in trade volumes will be too small to be noticed in the rest of the world.

<u>Figure 3.7 A Domestic Production Subsidy in a Large Importing Country</u>



Source: "*Monopoly and Monopsony Power and Trade.*" *PEOI. N.p., n.d. Web. 25 Apr. 2012.* <*http://www.peoi.org/Courses/Coursesen/intrade/temp/ch10g.html*>.
Note: assuming China's semiconductor production in the beginning of 2000's is largely influenced by the subsidy and the increase of production is large enough to affect the global market price.

On the other hand, if China's subsidy would largely influence Chinese semiconductor companies' production amount—that is—sufficient enough to influence the price in the global semiconductor market, it would become another case, which is shown in Figure 3.7. According to "*Monopoly and Monopsony Power and Trade*", when a specific production subsidy is imposed, the producer's price rises, at first by the value of the subsidy. The consumer's price is initially unaffected. This increase in the producer's price induces the producer to increase its supply to the market. The supply rises along the supply curve and imports begin to fall. However, because the country is a large importer, the decrease in imports represents a decrease in the world demand for the product. As a result, the world price of the good falls, which in turn means that the price paid by consumers in the import market also falls. When a new equilibrium is reached, the producer's price will have risen to Pp, the consumer's price will have fallen Pw, and the difference between the producer and consumer prices will be equal to the value of the specific subsidy. Note that the production subsidy causes an increase in supply from S_1 to S_2 and an increase in demand from D_1 to D_2. Because both supply and demand rise, the effect of the subsidy on imports is, in general, ambiguous.

Table 3.3 US electronics and information industry trade with China and Japan, 1997-2005

Year	US imports[a]			US imports from China as share of total imports (percent)	US imports from Japan as share of total imports (percent)	US exports[b]			US exports to China as share of total exports (percent)	US exports to Japan as share of total exports (percent)
	China	Japan	World			China	Japan	World		
1997	16.4	54.6	261.3	6	21	3.9	17.0	219.8	2	8
1998	20.2	52.4	275.7	7	19	4.3	14.7	226.1	2	7
1999	25.1	56.7	308.2	8	18	4.2	15.2	229.8	2	7
2000	32.7	65.6	364.4	9	18	5.5	18.7	265.5	2	7
2001	33.3	49.8	313.7	11	16	6.7	15.6	229.5	3	7
2002	44.5	44.2	311.7	14	14	7.0	12.2	204.5	3	6
2003	58.3	44.2	325.5	18	14	8.2	11.4	202.2	4	6
2004	83.8	50.4	382.8	22	13	10.7	11.8	223.3	5	5
2005	95.6	48.6	462.8	21	10	9.8	10.4	240.2	4	4

Note semiconductors account for a significant share of electronics and information industry trade
Source: USITC Dataweb, 2006

In reality, what happens between China and US in the semiconductor market was that both US exports to China and imports from China increased, according to Table 3.3. Moreover, it should be noted that from 2001 to 2005, U.S. imports from China was five times

US exports to China. China's semiconductor export rose dramatically from 2001 to 2005 while US export rose too. Thus China's subsidy should be categorized as the second case, demonstrated in Figure 3.7 where a domestic production subsidy will largely influence the international semiconductor market supply. Therefore, China's case not only raised Chinese exports but also expanded China's imports from other country.

However, US government alleged that China provided preferential tax treatment for domestic semiconductor producers and that the preferences violated China's national treatment obligation (Institute for International Economics). Through bilateral negotiations, China agreed to eliminate VAT refunds for any new semiconductor products or manufacturers and to phase out semiconductor rebates in 2005. America argued this was unfair to American semiconductor producers, but in this case, the increase of the supply in china would drive down the semiconductor prices in the international market and would in fact more import demand for the semiconductors from US. The loss of subsidy on the domestic semiconductor producer might drive up the prices of the semiconductor in the global market again, reducing the import demand from the US. The decrease of US exports to China and Japan in 2005 could be a consequences caused by the increase of semiconductors' prices.

Nevertheless, the implementation of a more liberal 'attracting in' policy led China to a sharp rise in FDI, which has become the industry's main investment source and reduced pressure on the tight state budget since the mid 1990s (Harrold and Lall 1993; Lardy 2001). With the rising of fabless-foundry model, by 2000, China had emerged as an attractive location for new fab investment in terms of cost advantages. During 2003-2005, China remained the world's third largest ICT producer (*semiconductors account for a significant share of electronics and information industry trade)*, which, with an increase in industrial output from US $14.7 billion to US $20.1 billion (Information Technology Yearbook 1986-

2006). China has been closing the gap between its world output share and that of Japan, the world's second largest ICT producer, from 2.1 percent to 0.6 percent and the gap with that of the United States, the largest, from 12.4 percent to 5.5 percent (Ibid).

III.4.3 Chinese and Japanese Trade Policy Compared

In summary, comparing Chinese and Japanese trade policy, both countries were alleged "unfair" protectionist by the U.S. and the western world and thus headed toward liberalization. What is different is that the Chinese economy transformed from a close economy to an open one with policies to encourage foreign investment and open trade in order to absorb technology and knowledge from the western world while Japan adopted the strategy of protectionist trade policy in order to gain technology transfer and competitiveness.

In the beginning of Chinese development history of the semiconductor industry, Chinese market was a closed one with tariffs and regulated foreign direct investment. However, along with Chinese economic transformation, after the 2000's, China gradually reduced its tariffs and opened its economy for trade and foreign investment. But Japan, on the other hand, did not liberalize until Japan had obtained significant results in the basic technology development in the industry. Before liberalization, Japanese government consistently rejected all applications for wholly owned subsidiaries and for joint ventures in which foreign firms would hold majority ownership. Formal quotas and prior-approval requirements restricted imports of semiconductors into Japan. The requirement was so strict that the imports were nearly forbidden in Japan.

An essential difference between China and Japan lies at that Chinese strategy focused on providing incentives to domestic semiconductor producer by providing subsidies and preferential tax incentives, which should be defined as domestic production subsidy rather than a trade-oriented subsidy while Japan imposed strict trade restriction tools. Moreover, the result of the Chinese subsidies was not necessarily reducing imports because the increase of

Chinese semiconductor production would in fact lower the price in the global market and consequently raise the import demand from the U.S. On the other hand, Japan's strategy focused on the international trade policy to create a closed Japanese market protected from foreign competitions, thus providing more incentives for domestic firms to conduct R&D. Preventing foreign competitions while encouraging internal competitions, MITI intended to establish "buy Japan" attitude" in addition to create technological catch-up.

IV Conclusion and Future Directions

In conclusion, China and Japan's paths of development in the semiconductor industry are unalike, due to two countries' historical, economic and natural differences. Historically speaking, the political turmoil in China in 1960s largely disturbed China's technological development. When China found itself lagging behind on the technological ground in the 1970's, China's semiconductor technology was already ten years behind Japan's. In terms of the economic systems, a major divergence between China and Japan is that China went through an economic transformation from a command economy to a market-oriented economy; Japan, on the other hand, has always been a market-oriented economy. Finally, in terms of natural resources, China is a labor-abundant country while Japan is a "resource-poor" country.

As a result of these environmental differences, Japan's development strategy targeted a knowledge- and capital- intensive industry (semiconductor industry, in this case) by providing preferential assistances while deliberately keeping that market protected from foreign competitions to ensure that the industry had a high volume and a profitable base. When the Japanese achieved the economy of scale and cost competitiveness and gained enough production experiences, Japan expanded the market share by aggressive pricing and ultimately dominated the foreign market. On the other hand, China's development strategy went from a protectionist strategy in a command economy—learning from the Japanese model—which focused on cultivating large state-owned enterprises to be national champions and protecting the market from foreign competition, to an export-oriented strategy in a relatively more market-oriented economy which encouraged foreign investment and leveraged China's comparative advantage by cooperating with foreign firms.

To answer the question I raised in the beginning of this study—why China is bearing an impression of assembly center and Japan having a proving ground of technological advance—the concept of comparative advantage from Heckscher-Olin theorem explains Chinese and Japanese firms' respective positions in the global semiconductor market. As a labor-abundant country, China serves the roles of packaging and assembling final products, which require labor. Unfortunately, labor-intensive sectors usually contain low added value, and thus this is the reason why China has an impression of being an assembly center.

Japan, on the other hand, is a "poor-resource" country and thus strives to develop capital- and knowledge-intensive industries via protectionist strategies. In order to achieve this objective, Japan's MITI encouraged domestic competition, provided assistance and ensured freedom in the private sector while manipulating the foreign competition. Firms were encouraged to build efficient scale economies in market segments. Meanwhile, Japan benefited from being the U.S.' strategic ally and took a free ride on U.S. technologies. Subsequently, a few large vertically integrated firms emerged and carved up the domestic market. Japan is thus specialized in application technology and production technology with higher value-added.

But is Japan's development path necessarily better than China's path? Looking at Japan and China's current status in the semiconductor market, we see that the rising Chinese companies increasingly outperform Japanese semiconductor companies and moreover the U.S. is regaining its cost competitiveness by outsourcing production to the labor-intensive countries. I believe that the origin of this phenomenon is Japan's protectionist strategy and China's 'walking out' strategy.

In the beginning of Chinese development history of the semiconductor industry, the Chinese market was a closed one with tariffs and regulated foreign direct investment. However, along with the Chinese economic transformation, after the 2000's, China gradually reduced its tariffs and opened its economy for trade and foreign investment. But Japan, on the other hand, in order to develop a capital- and knowledge-intensive industry, adopted the protectionist policy towards trade by imposing import tariffs and restricting foreign investment. Meanwhile, Japan promoted domestic competitions by cultivating large-size national champions. As a result, many companies chose merger and acquisition in order to create individual enterprise's competitiveness by becoming a large-scale company. The consequence of Japanese semiconductor's frequent mergers was that these producers' scales were so large that it took longer time for the Japanese large-scale semiconductor firms to restructure and adjust to the changes, especially during financial crises. Furthermore, due to the closeness of the Japanese market, the lack of foreign investment caused Japanese firms to be slow to spot the global trend shift. It was hard for Japanese firms to make changes accordingly. One proof is Japanese firms' failure to adjust to the newly emerged fables-foundry model. Japanese firms have adopted the form of IDM for many years, responsible for both design and manufacturing. Since Taiwan Semiconductor Manufacturing Corporation (TSMC) invented the pure-play business model, the semiconductor industry has become a segment of increasingly vertical specialization. Fabless (fabrication-less) semiconductor companies specialize in the design and sale of semiconductor chips while outsourcing the fabrication or "fab" of the devices to a specialized manufacturer called a semiconductor foundry. Foundries are typically located in countries with lower cost labor so that fabless companies can benefit from lower costs while concentrating their research and development resources on the end market. But Japanese firms were so large-scale that it was difficult for them to adapt their business models to the newly emerged fabless-foundry model. In response to this change, U.S. semiconductor firms, however, adjusted to the model very quickly and regained competitiveness by outsourcing chip manufacturing to the foundries in labor-intensive countries such as TSMC and SMIC in China. Thus, the business environment for vertically integrated Japanese device manufacturers worsened as the semiconductor industry came to be based on a flatter and horizontally divided structure.

China, on the other hand, established many foundries, which are invested by foreign companies. The rise of the foundries in China is due to China's "walking out" strategy. After the liberalization in the 2000's, Chinese semiconductor firms came to collaborate with U.S. firms to provide fabrication-outsourcing services. Leveraging China's comparative advantage and conforming to the liberalized open trade in the global market, China's export to US continued to grow at an average around 30 percent. From 2003 to 2008, domestic Chinese semiconductor manufacturers, not foreign firms, accounted for over 80 percent of China's annual productions (McClean, et al 2009). During this time, China's world-class semiconductor enterprise, Semiconductor Manufacturing International (SMIC) and Grace Semiconductor Manufacturing (GSMC) emerged as a foundry startup. Both foundries raised over one billion USD investments from foreign venture capital, domestic banks and government entities to construct their state-of-the-art fabs, starting from 200mm, 0.25- to 0.18-micron process. SMIC became successful, owing to a mixture of technological expertise, international market access, deep-pocketed investors and an aggressive expansion strategy (Li 2011). Since 2004, SIMC has remained among the top five foundries globally. And it was during the 2000's that China experienced its largest wave of entry into the semiconductor industry and had its largest historical growth.

IV.1 Future Directions

Overall, this study compares Japanese and Chinese development paths in the semiconductor and finds an explanation of how Japan and China's semiconductor industries came to their current status in the global market. However, many other directions remain to be discussed. For example, are protectionist policies - as what Japan implemented - only short strategies? Is liberalization a better path for a country's economy? How should China upgrade its technologies and how should China conduct R&D in order to move towards a global position with high value-added?

References

The 10th Five-Year Plan (2001-2005) . (2011). *China Daily*.

Aghion, P. and Blanchard, O.J. (1993). On the Speed of Transition in Central Europe. Working Paper 93, Massachusetts Institute of Technology (MIT), Department of Economics

Abegglen, J. (1973). *Management and Worker*. Tokyo: Sophia University and Kodansha International.

Anderson, R. W. (1980). *The Japanese Success Formula: Quality Equals the Competitive Edge*.

Assche, A. (2006). China's Electronics Exports: Just A Standard Trade Theory Case. *Policy Options*.

Borrus, M., Millstein, J., & Zysman, J. (1982). *International competition in advanced industrial sectors: Trade and development in the semiconductor industry*. U.S. G.P.O.

Bylinsky, G. (1981). Japan's Ominous Chip Victory. *Fortune*, 52.

Chen, D. (1995). *Chinese Firms between Hierarchy and Market: The Contract Management Responsibility System in China*. London and New York: Macmilan/St Martin's Press.

Chen, D. C., & Toyama, R. (2006). Catch up of semiconductor latecomers in China. *International Journal of Emerging Markets, 1*(3), 247-261.

Chesbrough, H., & Liang, F. (2008). *Return to R&D Investment and Spillover in the Chinese Semiconductor Industry: A Tale of Two Segments*. *Industry* . Studies Association Working Papers.

Chesbrough, H. W. (2005). *The Globalization of R&D in the Chinese Semiconductor Industry*. Sloan Foundation Research Report.

ChinaIRN. (n.d.).

Chinaknowledge. (n.d.). *Manufacturing in China*.

China Semiconductor Industry Association (CSIA). (2012).

China's export of electronic information products up 26.2 percent. (n.d.). *Peopledaily*.

Cho, D., Kim, D., & Rhee, D. (1998). *Latecomer Strategies: Evidence from the Semiconductor Industry in Japan and Korea*. Organization Science.

Compiling Committee. (n.d.). Development Status of Semiconductor Industry in China. *CSIA and CCID*.

Cupertino, C. (1983). *The Effect of Government Targeting on World Semiconductor Competition: A Case History of Japanese Industrial Strategy and Its Costs for Americans*. Semiconductor Industry Association.

Dewey-Ballantine. (2003). *China's Emerging Semiconductor Industry: The Impact of China's Preferential Value-added Tax on Current Investment Trends*. Washington DC: Dewey Ballantine LLP.

Economic Operation Report of China Electronic Information Industry. (2007, June). Retrieved from Research and Markets database.

Flamm, K. (1996). *Mismanaged Trade?: Strategic Policy and the Semiconductor Industry*. Brookings Institution.

Fuller, D. B. (2005). *Creating Ladders out of Chains: China's Technological Development in a World of Global Production* (Unpublished doctoral dissertation). MIT, Cambridge.

Gresser, J. (1980). *High technology and Japanese industrial policy*. U.S. G.P.O.

Harrold, P., & Lall, R. (1993). *China: Reform and Development in 1992-93*. Washington, D.c.: World Bank.

Hays, J. (2012, April). *Japanese Electronics Industry: History, Semiconductors, Decline and Competition from Apple, China and South Korea*. Retrieved from Facts and Details database.

Hu, Q. (2006). *Memoirs on National 909 Project on Very Large Scale Integrated Circuits* . Beijing: Publishing House of Electronics Industry.

Japan Tariff Association. (n.d.). Summary Report on Trade of Japan. *Summary Report on Trade of Japan*.

Jiang, Z. (1993). *Discussion on the New Features of the Development of the World Electronics Industry and the Development Strategy of Our Country's Information Industry*. Academic Journal of Shanghai Transportation University.

Klaus, M. (2003). Red chips: implications of the semiconductor industry's relocation to China. *Asian Affairs: An American Review*.

Lardy, N. (2001). *The Role of Foreign Trade and Investment in China's Economic Transformation*. Oxford: Oxford University Press.

Li, T. (1986). *The Minister's Report on the Electronics Industry*. Beijing: Ministry of the Electronics Industry.

Li, T. (1993). *A Study of the Development of the Electronics Industry and Reform 1986*. Beijing: Beijing Electronics Publishing House.

Li, Y. (2011). *From Classical Failures to Global Competitors*.

Lu, Q. (2000). *China's Leap into the Information Age: Innovation and Organization in the Computer Industry*. New York: Oxford University Press.

Mack, L. (n.d.). Chinese History: Eighth Five-Year Plan (1991-1995). In *Five Year Plan 1991-1995*.

Mackintosh Consultants Company. (1979). *Microelectronics into the 80's*. San Jose: Mackintosh Publications, Ltd.

McClean, B., Matas, B., & Yancey, T. (2009). *The McClean report: A complete analysis and forecast of the integrated circuits industry*. Scottsdale, AZ: IC Insights, Inc.

McKinsey Global Institute (MGI). (2007). *Creating Value in the Semiconductor Industry*. McKinsey Global Institute .

MITI Establishment Law (1950). Tokyo, Japan.

Naughton, B. (1999). *The Global Electronics Revolution and China's Technology Policy*.

Nolan, P. (2001). *China and the global economy: national champions, industrial policy, and the big business revolution*. Palgrave Macmillan.

Okimoto, D., Sugano, T., Weinstein, F., & Flaherty, M. (1984). *Competitive Edge: The Semiconductor Industry in the U.S. and Japan*. Stanford University.

Pecht, M. (2007). *China's Electronics Industry - The Definitive Guide for Companies and Policy Makers*. William Andrew Publishing.

PEOI. (n.d.). *Monopoly and Monopsony Power and Trade*.

PEOI. (n.d.). *Production Subsidy Effects in a Small Importing Country*.

PWC. (2004). *China's Impact on the Semiconductor Industry*. New York, NY: PricewaterhouseCoopers.

PWC. (2010). China's Impact on the Semiconductor Industry 2010 Update. *PWC Global Reach*.

Semiconductor Yearbook. (1985-1993). Tokyo, Japan: Press Journal.

Simon, D. (1987). *Innovation in China's Semiconductor Components Industry: The Case of Shanghai*.

Simon, D. (1992). Sparking the Electronics Industry. *The China Business Review*.

Simon, D. (1996). From Cold to Hot - China Struggles to Protect and Develop a World Class Electronics Industry Class Electronics IndustryThe China Business Review. *The China Business Review, 23*(6), 8-16.

Simon, D., & Rehn, D. (1988). *Technological Innovation in China: The Case of the Shanghai Semiconductor Inudstry*. Cambridge, MA: Ballinger Publishing Company.

SMIC. (2004). *Announcements and Notices – Issuance and Repurchase of Shares under Share Option Plans of the Company*.

SMIC. (2009). In *SMIC Annual Report*.

SSIS. (n.d.). *Integrated Circuits* [Semiconductor History Museum of Japan].

Tilton, J. (1971). *International Diffusion of Technology: The Case of Semiconductors*. Washington, DC: Brookings Institution.

UN COMTRADE [Data file]. (n.d.).

UNIPV. (n.d.). *Import Quota.*

United Nations-NBER Trade Data [Data file]. (2006).

US Fights China's Tax on Imported Chips. (2004). *Asian Wall Street Journal.*

U.S. GAO. (2002). *Challenges with Commerce's Validated End-User Program May Limit Its Ability to Ensure That Semiconductor Equipment Exported to China Is Used as Intended.*

USITC. (2006). *Interactive Tariff and Trade DataWeb.*

Wade, R. (1998). The Asian Debt and Development Crisis of 1997? Causes and Consequences, World Development, 26:1535-1553

Wade, R. (2004). Governing the Market: Economic Theory and the Role of Government in East Asian Industrialization. Princeton, NJ: Princeton University Press.

Wu, F., & Loy, C. B. (2004). Rapid Rise of China's Semiconductor Industry: What are the Implications for Singapore. *Thunderbird International Business Review, 46*(2), 109-131.

Yuan, Z. (2000). Semiconductor industry: industry development under government initiatives. *China's Industrial Policy in Transition*, 407-437.