FROM CLASSIC FAILURES TO GLOBAL COMPETITORS: BUSINESS ORGANIZATION AND ECONOMIC DEVELOPMENT IN THE CHINESE SEMICONDUCTOR INDUSTRY

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SUMITTED IN PARTIAL FUFILLMENT OF THE REQUIEMENTS

FOR THE DEGREE OF MASTER OF ARTS

ECONOMIC AND SOCIAL DEVELOPMENT OF REGIONS

UNIVERSITY OF MASSACHUSETTS LOWELL

ACKNOWLEDGEMENT

I would like to express my most sincere gratitude to my advisor, Professor William Lazonick, for continuous support and guidance over the past two years. Working with him has taught me not only how to do good research, but also how to be a human being of determination, fairness and kindness. Bill's passion in pursuing knowledge to improve human conditions will continue to motivate me to pursue a successful career in academia. This piece of work, I hope, will become the first step to achieve this goal.

I would also extend my gratitude to Professor Robert Forrant and Professor William Mass for sitting in my committee and helping me go through the process. Professors in the RESD program, being both teachers and friends, together they gave me a unique intellectual experience.

At last but always not least, I give my thanks to my parents, Liancheng Li and Huiqin Zhu, for allowing their son to travel to the other end of the world in chasing a distant dream.

And to Rong, for being my inspiration.

ABSTRACT

The transformation of the Chinese semiconductor industry from a small state-owned sector into a global competitor is a spectacular episode of China's economic success. This thesis documents the developmental history of this industry, from its stagnant state-dominated eras (prior to 2000) to a more successful stage led by innovative business enterprises (after 2000). The Chinese experience of developing the high-tech semiconductor industry raises several questions about business organization and economic development: Why could some companies be more innovative than others? How does the growth of innovative business organizations, in which economic development is generated, occur? Drawing on the theory of innovative enterprise (Lazonick, 2002, 2010), this thesis attributes the cause of innovative successes to strategic, organizational and financial conditions of the business enterprises, which have been supported by institutional changes in the Chinese society.

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I. INTRODUCTION

1.1 The story of the Chinese semiconductor industry

At any given time of history, the world's less developed nations have to face a critical challenge of economic development. That is, given the lead of advanced economies, how can they catch up and join the ranks of wealthy nations? Fortunately, history is full of successful stories of latecomers. The United States in the 19th century, Japan in the 1960s and 70s, and Korea and Taiwan in the 1980s have all successfully transformed themselves into rich countries by their achievements as innovative latecomers in leading industries of the time – the textile industry in the 19th century, the automobile industry in the 20th century, and since the 1980s the microelectronics industry. The development of industry generates economic development by accumulating innovative capabilities, which enable a society to produce goods and services with higher quality and lower costs at the prevailing factor prices (Lazonick, 2002; 2004b; 2010). Recognizing the function of the industry, nevertheless, requires a further understanding of industrial innovation: Why can some industries in some countries in a particular time become innovative, while others cannot?

The transformation of the Chinese semiconductor industry in the 2000s provides a case for understanding industrial catch-up and innovation. Not long ago, at the end of the 1990s, China's domestic semiconductor industry was insignificant internationally by any standard of measurement. The firms in the industry were too small to achieve sufficient levels of economies of scale or scope. The main products of this industry, integrated circuits (IC), commonly known as computer chips, were technologically several generations behind those prevalent in the international market. 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. Throughout the 1990s, the need to create a Chinese semiconductor infrastructure prompted the Chinese government to invest billions of dollars in state-led grand projects in the hope of building competitive Chinese chipmakers. In the two most well-known projects, State Project 908 and State Project 909, the government purchased 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. 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. By 1999, the combined output of all Chinese semiconductor manufacturers accounted for less than 2 percent of world production (Naughton and Segal, 2003; Fuller 2005).

A decade later, however, among the world's largest fifteen semiconductor foundries[1] in terms of revenue, four companies are now Chinese (see Table 1.1). The

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[1] A pure-play foundry, or foundry, is a semiconductor company that operates fabrication facilities to fabricate semiconductors and integrated circuits (ICs) for customers on the basis of contract manufacturing. The semiconductor companies that design chips but do not have in-house manufacturing facilities and rely on foundries and assembly companies to produce its chips are called fabless companies. An Integrated

most successful Chinese company, Semiconductor Manufacturing International Corporation (SMIC), was the third largest from 2004 to 2007, and is now the fourth. Its closest Chinese competitors, Hejian and Grace Semiconductor, also joined the ranks of the top ten in 2008 and 2009, respectively. Driven by the outsourcing strategies of the American 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 PricewaterhouseCoopers, a consultancy, 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, 2009). 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).

Table 1.2 Top Semiconductor Foundries, 2009

Rank 2009	**Company**	**Foundry Type**	**Country of origin**	**Revenue (million USD)**		
				2009	**2008**	**2007**
1	TSMC	Pure-play	Taiwan	8,989	10,556	9,813
2	UMC	Pure-play	Taiwan	2,815	3,070	3,430
3	Chartered [a]	Pure-play	Singapore	1,540	1,743	1,458
4	GlobalFoundries[b]	Pure-play	USA	1,101	n.a.	n.a.
5	SMIC	Pure-play	China	1,075	1,353	1,550
6	Dongbu	Pure-play	South Korea	395	490	510
7	Vanguard	Pure-play	Taiwan	382	511	486

Device Manufacturer (IDM) is a semiconductor company that has the complete set of in-house capabilities to make a chip, including design, fabrication, and sometimes assembly and test.

8	IBM	IDM	USA	335	400	570
9	Samsung	IDM	South Korea	325	370	355
10	Grace	Pure-play	China	310	335	310
11	He Jian	Pure-play	China	305	345	330
12	Tower Semiconductors	Pure-play	Israel	292	252	231
13	HHNEC	Pure-play	China	290	350	335
14	SSMC	Pure-play	Singapore	280	340	359
15	Texas Instruments	IDM	USA	250	315	450

Notes: a) Now acquired by GlobalFoundries;
b) Spinoff from Advanced Micro Device (AMD) in 2009.

Source: IC Insights, "2009 Major IC Foundries", March 2009

A more surprising fact is that none of the state-owned enterprises or their joint ventures but one company HHNEC (Huahong NEC, a Sino-Japan joint venture partnering with Japan's NEC, ranked 13th in Table 1.1), have been able to get into the top list. All of today's leading Chinese semiconductor firms, SMIC, Grace and He Jian, are non-government companies started within the past ten years. If the Chinese semiconductor industry prior to 2000 could be referred to as "state-led development", this industry has entered a stage of business-led development. Why have these young startups, often founded and managed by US-educated Chinese engineers and managers, been able to lead in technological change and drive the growth in the industry, whereas the state-funded grand projects failed? What have enabled them to be so innovative that they have become the engines of technological catch-up and economic development? And how did the investment strategies and organizational structure that generate innovation emerge?

1.2 The State of the Literature

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, but a few researchers gave attention to regions and companies. For example, Simon and Rehn did a case study of the semiconductor sector in Shanghai, where the city government had overcome the fragmented and inefficient decision-making system (*tiao tiao kuai kuai* problems) to collaborate with multinationals to develop joint-venture companies in the city (Simon and Rehn, 1988). Unfortunately, the semiconductor companies in the 2000s have largely grown from outside of the old industrial system, leaving these discussions only partially relevant for the purpose of this thesis. Nevertheless, these scholars documented a high-tech industry in transition from the planned system to a more market-oriented economy, and provided a foundation for understanding the evolution of the state-owned sector.

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; PricewaterhouseCoopers, 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, 2001). Unlike the study of semiconductor industry in Japan, Korea and Taiwan, where rich cases studies of the catch-up firms have been made (Kim, 1997; Matthews and Cho, 2000), there is limited research of firm-level activities in the Chinese semiconductor industry (Chen and Toyama, 2006; Chesbrough, 2005; Fuller, 2005).

At this stage, studies on the companies displayed an awareness of how differences in the organizational structures of Chinese semiconductor firms influenced their industrial performance and catch-up capabilities. Chesbrough (2005) and Chesbrough and Liang (2008) made a clear distinction between the domestic-oriented segment and the global-oriented segment in this industry. The global-oriented segment, basically referring to startups and multinational subsidiaries from 2000, is considered to have achieved success by collaborating with the multinationals and accessing global markets. The problem with this argument is that the ability to collaborate and access the market is the outcome of capabilities developed in the firms rather than a cause of these capabilities.

A case study of HHNEC by Der Chao Chen and Ryoko Toyama (2006) argued that the Chinese semiconductor companies imitated most of the "linkage-leverage-learning" strategies (Matthews and Cho, 2000) in other newly-industrialized countries, such as importing the latest technologies and competing in terms of scale and scope. It has recognized that there was a transition of technology and market strategies of Chinese semiconductor around 2000, particularly a strengthening linkage with the world market and increasing reliance on returned engineers and managers as the mode of learning after 2000. Yet, the paper provided little understanding on how the different learning strategies were formulated, referring simply to market liberalization. The investment strategies and business structures of the companies remained unexamined. In addition, since HHNEC itself followed the strategies of other leading Chinese firms after 2000, the case study could not possibly recognize the origins of the change in learning strategies, which was due to the rise of non-government foundry companies.

Douglas B. Fuller (2005) has developed a framework to explain different outcomes of Chinese and foreign high-tech companies making technology upgrading in China. In this framework, the successes and failures of technology upgrading in a range of information and communication technology (ICT) sectors, including semiconductors, were explained by two institutional factors: state-firm relations and a China-based operational strategy. State-firm relation and operational strategies, Fuller argues, create and shape opportunities for upgrading in China through their impacts on incentives and capabilities (Fuller, 2005, pp. 15-21). A China-based operational strategy is the social basis for companies to continue making investments in upgrading in China instead of anywhere else. Relations with the state determine the company's source of finance, whether it is state-owned banks that provides credit with soft budget constraints, or disciplined foreign financial institutions (i.e., credit with relatively hard budget constraints), or simply being cut-off from finance. Access to the state-granted credit with soft budget constraints undermines the incentives of Chinese state-owned or state-favored companies to upgrade, since the companies are no longer subject to competitive pressures with unconditional and unlimited state support. Foreign companies have the finance and capabilities but insufficient commitment in China for upgrading. The only semiconductor companies that meet the requirements for successful upgrading were foundry startups in the 2000s: They have both the nationalist commitment and financial discipline because they are managed by ethnic Chinese entrepreneurs and have raised capital partly from the disciplined foreign institutions.

By emphasizing operating strategies and sources of finance, Fuller actually points to three elements for successful technology upgrading/catch-up: motivation for upgrading, sufficiency of funding, and competitive pressure. Finance is particularly important because a functioning financial institution provides resources for capability building and a malfunctioning one can undermine the competitive pressure that sustains the motivation to upgrade. While the requirements of motivation, funding and competition set the *ex-ante* conditions for technology upgrading, they have not touched the actual process of upgrading. The pressures from market competition and financial obligation may induce the company to invest in upgrading, but they could also lead to short-term behaviors, such as extracting rents from existing capabilities. Fuller referred to "a mix of nationalist ideology, state monitoring and support and corporate self-interest" to provide the motivation for upgrading (Fuller, 2005, p. 15). But what is needed is a theory of how companies strategize to invest in technology. There is also a lack of understanding of how companies use the capital to build up capabilities. If the process of upgrading is time consuming and cash draining, which actually happen all the time, then what is the adequate pressure from meeting financial obligations during the process? To ensure a bigger success of the company, shouldn't a functioning financial institution keep the cash within the firm during the process? If so, are hard budget constraints or soft budget constraints adequate standards in measuring the role of finance in technology upgrading?

1.3 The Theory of Innovative Enterprise

To answer these questions requires a theory of "indigenous innovation", a process of business enterprise making use of technologies transferred from advanced economies to develop innovative capabilities and generate superior technologies at home (Lazonick, 2004a, p. 273).

A pioneering attempt to explain the growth and innovation of Chinese high-tech enterprises from the perspective of indigenous innovation appeared in Qiwen Lu's study of the computer industry (Lu, 2000). The computer industry in the 1990s had posed a question similar to that of today's semiconductor industry: why were indigenous computer companies able to outcompete multinationals in the competitive Chinese market? Lu's research on the emergence and growth of four computer electronics companies – Stone, Founder, Legend (now Lenovo), and Great Wall – showed how China engaged in indigenous innovation in the computer industry. The innovation process was put in place through reforming the science and technology (S&T) infrastructure and organization of industrial enterprises. The emergence of the self-sufficient enterprises, particularly the non-government companies, set the conditions for innovation: in the newly established or reformed enterprises, as scientist- and engineer-turned managers gained decision-making autonomy that enabled them to allocate the companies' resources to innovative investment strategies. The financial foundation for such a strategy was provided through control over the company's revenues and earnings, a result of establishing financial independence from the state. The control of resource allocation further gave companies the freedom to structure their employment, providing sufficient incentives for members of the organization to engage in the innovation process.

Qiwen Lu's analysis of the strategic, organizational, and financial conditions that put innovation in place was built on a framework of a "theory of innovative enterprise" that William Lazonick and Mary O'Sullivan had developed at the time (Lu, 2000, p. 14-

15). Lazonick and O'Sullivan subsequently elaborated the framework as three "social conditions of innovative enterprise", which are "strategic control", "organizational integration", and "financial commitment" (Lazonick and O'Sullivan, 2000; O'Sullivan, 2000; Lazonick, 2004b, 2010).[2] As this framework seeks to identify the innovation process in which business enterprises "strategize, organize and finance in order to transform productive resources into goods and services that customers want at prices they can afford" (Lazonick, 2004a, p. 276), it provides a framework for understanding indigenous innovation, a process of transforming technologies transferred from abroad, learning to access markets, and developing superior productive capabilities at home.

The "conditions of innovative enterprise" are not simply a set of constraints of upgrading such as competitive pressure, motivation or funding. Instead, they seek to capture the social process of innovation that is the dynamic interaction of social institutions and the innovation process. To learn to transform technology and access markets, the company has to make innovative investment strategies to confront the technological, market and competitive uncertainties that are inherent in the innovation process (O'Sullivan, 2000). The process of formulating and exercising such a strategy for innovation cannot simply depend on the nationalist motivation or self-interests of the company. Instead, as Lazonick (2004a, p. 276) argues, there are social institutions that can transform strategy into innovation: a set of relations that gives decision-makers who have abilities and incentives to invest in innovation the power to allocate the firm's

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[2] For Lazonick's recent exposition of the theory of innovative enterprise, see Lazonick (2010).

resources to support innovative investment strategies. This social condition is “strategic control”.

After making the innovative investment -- for example after buying the state-the-art and expensive production processes from abroad -- the company now has the imperative to secure high-levels of utilization of the investment and transform the high fixed costs into competitive advantages in the market. The company can make various organizational arrangements to achieve such a goal, such as leveraging existing capabilities in the company, linking with outside resources such as through government-business partnerships or supplier-customer relations, and learning through recruiting employees with skills to train the workforce. This is essentially what the “linkage-leverage-learning” paradigm argues (Matthews and Cho, 2000). But what is the social foundation that provides incentives for individuals to participate in and contribute to the learning process? There has to be social conditions that can transform organization into innovation. That is “a set of relations that create incentives for people to apply their skills and efforts to organizational objectives”, or “organizational integration” (Lazonick, 2004a, p.277)

Finally, companies have to finance the high-fixed costs related to the innovative investment strategies. The bill for innovation or upgrading includes not only the initial investment in plant, equipment, or new hiring, but also the recurring costs to sustain the process of learning. Thus, the social condition can transform finance into innovation has to be “a set of relations that ensure the allocation of money to sustain the cumulative innovation process until it generates financial returns”, or “financial commitment” (Lazonick, 2004b, p. 277). From the perspective of “financial commitment”, hard or soft budget constraints may not be a good standard of judgment for the role of finance in innovation. To an outsider, an enterprise in the process of innovation is not visibly different than one that misbehaves under soft-budget constraints: it requires continuous inflow of resources but cannot guarantee to meet the financial obligation. The credit provider has to have insider knowledge and capabilities to adjust the level of budget constraints, under which neither credit is misused nor the potential success is starved of capital. But the credit providers are not in the best position to monitor if the credit is used in productive activities. As the theory argues, the social condition to ensure proper allocation of resource is “strategic control”.

1.4 Strategy, Organization and Finance in the Semiconductor Industry

In any specific industry, business enterprises are constrained by market (demand) and technological conditions of the industry, and are constantly challenged by the competitors from home and abroad. Innovative enterprises seek to transform the market and technological conditions, thus transforming the competitive conditions of the industry through innovation. An understanding of the strategy, organization and finance of the firm that transformed industrial conditions would not make sense, therefore, without understanding of the industry. In other words, an understanding of industrial conditions forms a foundation for the understanding the social conditions of innovative enterprise in a particular setting.

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 costs) at an astonishing pace according to what is called Moore's Law.[3] 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.

Technological progress in the manufacture of semiconductor chips generally involves two steps: major improvements in products and process, and their implementation in mass production. The contemporary semiconductor technology, or so-called Ultra-Large-Scale-Integration (ULSI),[4] manufactures billions of microscope-scale electronic devices, usually transistors interconnected by wires, all on a single chip. Major advances in technologies that involve integrating more and more components onto one chip have enabled chips to become more powerful. More advanced technology permits electronic components to be smaller and packed more closely together. A common measurement of the technological complexity is the average size of the transistors on the chip, or technology node. In terms of this measurement, the commercial technology has advanced from 10 micrometers in 1971 to 32 nanometers in 2010, meaning that the microelectronic components on today's chips are roughly 300 times smaller than those of three decades ago.

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[3] 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.

[4] Before ULSI, there were Large-Scale-Integration (LSI) and Very-Large-Scale-Integration (VLSI) technologies that integrated thousands and tens of thousands transistors on one chip. When ULSI was adopted it meant millions. But there is no newer term to describe further technological advance.

Large-scale integration has huge advantages in boosting the chip's performance, but it also raise challenges in mass production, the process of fabrication. For the billions of microelectronic devices on the chip to work together require precise controls over a wide range of conditions of production. These conditions include controlling temperature, timing, vibration levels, pressure, and dust – almost everything in the clean room. A slight divergence from the optimal conditions can result in sharp increases in defect rates: chips are produced, but they simply do not work. Getting control of these conditions involves intensive trial and error, which cannot be resolved through the process design alone. In fact, after the process technology of a newer generation has been designed, it will take years for the fabrication plant to figure out how to control the defect rate, which can be as high as 95% initially, and bring it down to a commercially viable level. As different generations of process technology change the optimal conditions of production, sites of semiconductor manufacture have to constantly reengage in the learning process, and continue lengthy experimentation with process details in order to keep in pace with rapid technological change. These learning activities generate enormous firm-specific, or even plant-specific, industrial know-how, which become critical to sustained innovation and firm growth.

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. In the mid-1990s, the global semiconductor sector as a whole spent approximately 12% of industrial revenue on R&D, which then rose rapidly to 18% a decade later in 2006, and is expected to rise continuously.[5] The costs of building a leading-edge semiconductor manufacturing facility, a wafer fabrication plant (or a fab as it is often called), 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 costs $1.6 billion. 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, p.5).

Table 1.3 The rising cost of building a leading-edge fab, 1983-2007

Year	1983	1990	1997	2001	2007
Wafer (millimeter in diameter)	100	150	200	300	300
Line-width (microns)	1.200	0.800	0.250	0.130	0.065
Cost (US$ millions)	$200	$400	$1,250	$3,000	$5,000

Source: Adopted from Brown and Linden (2009, Table 2.1)

The semiconductor industry has also become a segment of increasingly vertical specialization. The semiconductor sector emerged in United States as an integrated part of electronic device makers (Tilton, 1971). As the semiconductor technology was better understood over time, integrated device manufacturers (IDMs) demonstrated the

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[5] In contrast, the global automobile industry, an example of industry with mature technology, spent 3% of industrial revenue on R&D in the same year of 2006 (MGI, 2007, p.5).

advantage of spreading high fixed costs over a high volume of customers. This enabled IDMs to continue to invest in new technologies at a faster pace than vertically integrated electronics makers (Chesbrough, 2005). 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. After Taiwan Semiconductor Manufacturing Corporation (TSMC) invented the pure-play business model, 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 GlobalFoundries in 2009, a spin-off of microprocessor maker AMD.

The specific industrial conditions of the semiconductor industry gave rise to a set of challenges in innovation and technology catch-up. The basic challenge is how to finance the high fixed costs of fabrication activities. From a company perspective, they include the costs of up-to-date plant and equipment, which could amount to billions of dollars today (See Table 1.2). But from a national perspective, they also include high-quality, reliable infrastructure for companies to operate, and a supply of educated labor that companies can further train. Historically, national governments had played a key role in financing the semiconductor industry. The sources of finance provided by the government generally fall into three categories: 1) infrastructural investment that makes resources available to companies at low cost. Particularly, the government investment in a system of education that provides sufficient human capital for chip production was the foundation for establishing the semiconductor industry in Japan, South Korea and Taiwan (Lazonick, 2009, pp. 151-191). 2) Revenues, with government as a source of demand. Government defense and aerospace contracts were the major source of revenue for the emerging US semiconductor industry (Tilton, 1971). 3) Subsidies, one form of which is long-term low-cost capital. Latecomer semiconductor firms from Japan, South Korea and Taiwan have all substantially benefited from the provision of public capital.

Though the government provided resources for companies to operate, it had not, and could not, substitute the business organizations and their function in allocating resources. Contrary to the conventional belief that the Eastern Asian governments were directly involved in making investment decisions through the funding channels they provided, the Japanese, Korean, and Taiwanese semiconductor firms sustained their strategic control over their fabrication activities (Matthews & Cho, 2000:14). In the case of Korea, large industrial conglomerates (*chaebol*) financed their upgrading process by leveraging external loans, government credit agencies, bond issues, and/or investments from the cash-cow subsidiaries of the conglomerate (Matthews, 2000, p.125-6).

The next challenge is skill formation. It is true that over time, as the chip manufacturing process became standardized and automated, that equipment was more and more available in the open market. But this only led to industrial know-how gaining critical importance. As rapid technological advance makes a state-of-the-art fabrication facility obsolete within a decade, a capable workforce must move along the learning curve even faster in order to ensure the efficient utilization of massive initial investments. The industrial know-how accumulated in the established firms created another entry barrier in addition to the capital requirements. While the national government provides a supply of educated labor force, it depends on the companies to train the workers in mastering the skills of chip production. One way for latecomer firms to rapidly build up a skill base is to acquire seasoned professionals from incumbent firms, and leverage from their experience to train the workforce. In their early history, Korean semiconductor firms aggressively recruited overseas ethnic Koreans with substantial work experience. They accomplished this by providing generous benefits (Kim, 1997; Matthews & Cho, 2000).[6] Returned industrial veterans contributed even more significantly to the development of Taiwanese firms, whom they often attracted and retained with stock bonuses. Teams of returning entrepreneurs have strategically controlled the most successful firms, such as TSMC (Matthew & Cho, 2000; Saxenian, 2005).

The trend toward vertical specialization is both a blessing and a curse for latecomers. As work used to be done in one integrated chipmaker is now done by independent foundries and fabless companies, firms grow larger to reap the economy of scale. Latecomers have the opportunities to enter by specializing in one particular segment, but establishing a complete semiconductor supply chain becomes even more difficult and costly. It became almost impossible to enter the market as integrated chipmakers since the 1990s. However, countries are also bearing the risks of over specializing. Taiwan, as the only successful example, had leveraged its investment in

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[6] For example, when Samsung was entering DRAM manufacturing, a dozens of engineers from leading US firms recruited by the company were paid as high as three times of that paid to the corporate president (Matthews, 2000, p.107).

foundries to build a vibrant fabless sector (Breznitz, 2007). Malaysia is still stuck in the low-end assembly segment, though foreign semiconductor companies started to assembly chips in this country in as early as the 1970s. India, though increasingly important in chip design, failed to build a single fab by 2010.

As a newcomer to the industry, whether China can achieve innovative success depends on how it copes with the challenges inherited in the industrial conditions. To transform the industrial conditions, the emerging Chinese semiconductor enterprises at least need to achieve successes in three aspects:

- Strategic success: decision makers of the enterprise must have the willingness and capabilities to locate market entry points with long-term strategic implications, formulate a viable strategy to leverage existing technology, and make investment in physical and human capital with good timing.
- Organizational success: attract, retain, train, and motivate a skilled workforce, particularly seasoned technical and managerial staff, capable of adapting to constant technological migration.
- Financial success: secure sources of massive long-term capital without undermining strategic control.

1.5 Structure of the thesis

In next two chapters, Chapter 2 and 3, a business history of the Chinese semiconductor industry is presented. Chapter 2 describes the development of the industry in a state-led stage prior to 2000, in which technological migration and new firm creation were mainly pushed by the Chinese government through a series of state projects. The emergence of non-government semiconductor companies, particularly the rise of one foundry company SMIC, in the business-led 2000s is documented in Chapter 3.

Before moving to a theoretical explanation, Chapter 4 provides an overview of changes in industrial policy, international trade and competitive environment that had an impact on the industry. At last, Chapter 5 compares the strategy, organization and finance of semiconductor companies in the two stages, and traces the changes in institutional arrangements governing the enterprises, thus explaining the industrial transformation in the framework of the theory of innovative enterprise.

II. STATE-LED DEVELOPMENT: THE INDUSTRY PRIOR TO 2000

2.1. The Planned Economy and Self-reliance Development

China is 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, p. 261). Yet political turbulence during the Cultural Revolution disrupted the country’s IC research and development (R&D). In late 1970s, when the country reorganized for technological catch-up, the technological gap between China and the industrialized world had considerably widened. The Chinese Academy of Science, with its two semiconductor labs in Beijing and Shanghai, successfully made 4K random access memory (RAM) in 1979, subsequently 16K RAM in 1980, and 64K RAM in 1985. But in the international market, the 256K RAM had already come to mass production in 1984, and the technology for 1 Megabit chip had been developed in 1985. In the late 1980s, when economic “reform and opening” rediscovered the benefits of international trade, decision makers of the Chinese economy began to see technology import as a tempting way for industry growth. Plans for developing IC technology indigenously, such as the 256K RAM, were either abandoned or delayed.

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. At the same time, the best Japanese producers had achieved yields of 70 to 80 percent, with much higher reliability of chips. 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.

2.2 Moving to the Era of Reform

The poor performance of a wide range of industries was first deemed as a “technology” issue, which decision makers of China sought to solve through technology import. According to Hu Qili (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. The first one was as early as in the 1970s that China imported seven semiconductor production lines from Japan. Later in early 1980s, when the reform devolved the authority of decision making to provincial level entities, factories, labs, and universities rushed to import another 24 second-hand lines. Each of the 31 lines cost around three to six million US dollars, with a total cost of roughly 150 million US dollars. Similar large-scale importation 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. 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 (Simon, 1992). More critically, 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. In late 1980s, the shortage of foreign exchange for purchasing foreign components further exacerbated the shortage of components, resulting in severe under-utilization of the imported production lines.

Industry planners responded by consolidating the sector. 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 that resulted in 1989 from merging the Wuxi No. 742 Factory, a successful example in employing imported production lines in early 1980s, and a few state labs. 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 the mid-1990s, with two in Shanghai and one in Beijing. Shanghai used its strong telecommunication factories to form JVs with Belgium's ITT and the Netherland's Philips, establishing Shanghai Bell in 1983 (its chip fabrication arm was later spun-off as Shanghai Belling in 1988) and Shanghai Philips in 1989 (later renamed to ASMC with a change in foreign partners). In Beijing, as the leading steel enterprise Shougang (Capital Steel) was diversifying into several industries, Shougang formed a JV with Japan's NEC, establishing Shougang-NEC in 1993. 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.

2.3. Pillar Industry and Project 908

As 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), 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. A foreign partner, Lucent Technologies from the United States, was later selected in 1994 and agreed to transfer the process technologies, train engineers and provide an IP design library for designing new products. Huajing was selected to deploy the fab and receive technology transfer. The MEI 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 process into the submicron (0.8-1.2 micron) line-width era. 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.

The failure of Project 908 was due to the delays, a result of bureaucratic inertia, low-level skills, and management incapability. It provided a window to look at the organizational failure in an industrial system under transition. 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. Described by Berliner (1976) as mission-oriented activities, the success of such projects involved targeted technology or products by the planners, financial commitment from the state, direct government involvement and coordination among industrial enterprises of both producers and users. Project 908 almost failed in each aspect of these standards, according to Hu (2006). 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. 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. It is not clear whether the planners had intentionally made such an arrangement, for at this stage of reform, market access had been deemed as the enterprises' own responsibilities. But 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).

To access the market, one of the major efforts made by Huajing was trying to generate some products through reverse engineering from existing products in the market

(Fuller, 2005, pp. 253-4). Reserve engineering is a feasible strategy for learning in most manufacturing segments, but has little use in the chip industry. Firstly, it is almost impossible to reverse engineer modern chips with extremely high integration density, where tiny components are fabricated on multiple layers of a wafer. Secondly, the component layouts revealed from reverse engineering tell nothing about how the chip works and how it is designed. It is even impossible to identify whether a particular layout has certain functions or just spaces reserved by design engineers for future use. An evidence of lack of learning in Huajing is that the design engineers were making the same chips several years later (Fuller, 2005, pp.254). Reverse engineering was useless for learning in design, and was little help for improving chip manufacturing as well. To reduce defects and increase yields in wafer fabrication, process engineers and design engineers needed to communicate and coordinate to make adjustments in either process or design. Since the layout generated from reverse engineering is hardly a real design, such improvements could not be made. Finally, those chips that can be reverse engineered tended to be low-end discreet products with thin margins and small sales volume. Designed capacity of the 200mm line was 12,000 wafers per month, yet real output in Huajing was around 800 wafers per month. Producing those products could hardly help Huajing to recover its high fixed-cost investments.

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. The 200mm line was eventually rented to Central Semiconductor Manufacturing Corporation (CSMC), a start-up in 1998. 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.

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. And it hardly contributed to the Chinese industry, since Philips purchased about 85 percent of the output. Shanghai Belling had not invested anything in its 100mm fab over the 1990s, probably because its main customer, Shanghai Bell had not developed new products during this time. 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, while chips of the other three firms were consumed in the domestic market. The result was an ever-widening gap between China's IC consumption and production. From 1990 to 1995, China's domestic production of chips expanded from 97 million to 560 million pieces, with sales increasing from $67 million to $405 million. At the same time, chip imports rose from 186 million to 5,118 million pieces, with value increasing from $144 million to $1,949 million (Table 2.1). In 1995, the capacity of the entire Mainland was equivalent to roughly one-third of the capacity of Taiwan's TSMC, with technologies three generations behind state of the art (Hu, 2006, p. 6).

Table 2.4 China's IC Market in 1990 and 1995

	1990	1995
VOLUME (million pieces)		
Domestic production	97	560
Imports	186	5,118
Exports	8	554
SALES ($ million USD)		
Domestic production	67	405
Imports	144	1,949
Exports	9	266

Source: Adopted from Simon 1996, p. 9; Anderson Consulting

2.4 Project 909: A Big Experiment

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-

micron process technology. MEI’s ambition for the project was to achieve three goals. The first goal is to establish China’s own semiconductor technology in the form of an IP portfolio. The second is to create an international competitive semiconductor enterprise based on China’s huge market. The third is to train a group of skilled engineers and managers in the industry (Fuller, 2005, pp.260). 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. Shanghai was selected as the location for the new corporation, for the city had emerged as a major semiconductor production base after a decade of investment by the municipal government and multinationals, accounting 20 percent of total chip production of China in 1995. Co-founded by MEI (through CEC) and Shanghai Municipality in April 1996, Huahong had a registered capital of $604 million with shares distributed between CEC and Shanghai in a 60:40 split. 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, described by Hu Qili as the “fifth push”, but it is also the largest and the only one that achieved modest success. 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, p.6). 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.

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. But both Huahong and NEC each held two seats on the board of directors (Naughton, 1999, p.13). Such concessions had been made partly due to failure in approaching US firms such as IBM, which declined the requests to transfer technology and guarantee the purchase of 35 percent of the plant output. It was also partly due to the concerns on US control of export advanced semiconductor devices to China (Business China, 1997).

HHNEC started to construct the fab in 1997, and entered pilot production very quickly in the beginning of 1999. 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. Managers and engineers from NEC occupied most of the senior positions and implemented the process and technology of production from NEC. The output, initially mainly 64 Megabit DRAM chips, were handled by NEC and sold under NEC's brand, all for export. Engineers, technicians and operators from the Chinese side were sent to Japan for training, costing a total of 45, 000 man-hours. Even the layout of the whole fab was copied directly from NEC's Hiroshima plant. Perhaps without Hu's direct involvement, such a radical approach would not have been able to be implemented, given China's nationalistic attitudes towards Japanese. But the outcome of the whole approach was surprisingly good, at least initially. HHNEC earned a profit of RMB350 million in the first full year of production in 2000, which was a record in the history of China's state projects. The chip yields had improved from 50 percent to more than 90 percent within three months of production, at a time when domestic fabs were generally suffering from low yields.

But Hu Qili and Huahong also had other reasons in conceding the management to the Japanese. The most crucial one was to use it as means for learning. Huahong hoped to have the skills of managing the fab as well as semiconductor industrial know-how passed into the Chinese hands under the Japanese management. This goal, however, was hardly achieved, according to surveys and reports in early 2000s. A survey from the Ministry of Science and Technology (MOST) noted that there was a lack of trained Chinese managers in HHNEC, and Chinese were generally excluded from the core operations (DYBG 2002, No. 11, p.7). Other reports held even more pessimistic views on actual learning at HHNEC. Through interviews with industry insiders, D.B. Fuller (2005, p.261-2) concluded that the Japanese strategically limited training of the engineering staff, as engineers were trained to develop skills in specific tasks without acquiring knowledge of the whole process of fabrication. In the reported cases, Chinese engineers at HHNEC could not, without consulting NEC engineers in Japan, confirm to customers whether the fab had the capacity to produce chip orders.

Though DRAM production had helped HHNEC to improve its skills in chip manufacturing, the goal of Project 909 was to acquire the ability to produce application specific integrated circuits, or ASICs, an important input for advanced electronics products. It was said that NEC and Huahong had a tacit agreement to devote 20 percent of HHNEC's capacity to produce logic chips after 2000, if sufficient demand emerged (Hu, 2006). Yet later NEC resisted the implementation of this plan in fear of passing advanced technologies into Chinese hands. Nevertheless, Huahong experimented with multiple strategies to bypass NEC and pursue the project goal. One was a portfolio strategy of investing in human resources. While having NEC train its staff, Huahong, at the same time, spent some RMB10 million to send engineers to be trained at IMEC, the European semiconductor research center in Leuven, Belgium. According to Huhong's company website (http://www.huahong.com.cn), these engineers returned in 2002 with the skills to deploy 0.18-micron process technologies. Yet other sources stated that in 2003 Huhong's 0.25-micron process was yet to be in ready-for-manufacturing status (Fuller, 2005, p. 262), raising the questions on how these engineers were trained, how they were deployed in Huahong, and how much they actually contributed to technology progress.

Huahong had also pursued a similar portfolio strategy in investing in its design capabilities, establishing several chip design and marketing subsidiaries with a variety of organizational forms. Table 2.2 summarizes all the major subsidiaries of Huahong.

Between 1995 and1997, while Huahong was negotiating with foreign partners for its fabrication plant, Huahong had also approached Tomen, a major Japanese trading company to establish a joint venture Hongri. In the Hongri deal, Huahong exchanged access to the Chinese market for potential distribution channels of its chips, aimed at supplying chips to the Japanese electronics system firms with assemblies in China. Thus the goal of this trading venture was mainly to solve the problem of market access in Project 908. But since initially NEC shipped all the DRAM outputs to Japan, Hongri did not necessarily need to function as HHNEC's distributer. Over the years, Hongri eventually became a pure trading company engaged solely in chip imports and exports.

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. Some of those products dramatically brought down the price of imported chips. For example, the price of SIM dropped from eight dollars per piece to less than one dollar after the domestic substitute came into mass production. And thanks to the supportive procurement policies from the state, particularly from the Shanghai Municipal government and the state-owned wireless network carriers, foreign chips in those applications had almost been wiped out in China. 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.

Huahong was even involved in funding Silicon Valley-based design startups. Newave Semiconductor, which received one third of its capital from Huahong's investment arm, was China's first fabless design house financed from venture capital. The company kept its headquarter in Silicon Valley but operated mainly in Shanghai. A group of returned Chinese engineers and scientists operated the startup, and the company's main offering was telecommunication chips. IDT acquired Newave in 2001 for $80 million, and thus Huahong was handsomely rewarded for its investments. Huahong International subsequently invested in several successful startups, represented by Spreadtrum Communications, one of the leading fabless firms now in China. But as Huahong situated itself as a venture-capital provider, it is questionable on how these fabless firms actually utilized HHNEC's fab. Nevertheless, such acts from a major SOE executing a major state project were likely to encourage entrepreneurial activities for fabless startups.

Table 2.5 Corporate Structure of Huahong Group

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]

Notes: a) 1997 is the year Newave established its Shanghai operation.

b) Huahong invested $1.5 million in the venture

Source: Economist Intelligence Units, *China Business* 1999, p. 8

In 2002, a severe downturn in the DRAM market hit HHNEC badly, causing a loss of RMB 700 million in a single year (Hu, 2006, p. 199). Under great political pressure, Huahong decided to terminate the management contract with NEC early. Having lost NEC as its major customer, HHNEC had to rely heavily on producing chips related to government procurement programs, such as national ID cards and smart cards for public transportation. HHNEC restructured in 2002. New Chinese management with overseas experience was employed. A new foreign partner, America's Jazz Semiconductor was brought in to as a new technology partner, replacing the Japanese, who had become a passive shareholder. Facing new competition in the 2000s, HHNEC had also taken the lead in consolidating state-owned fabs in Shanghai, by acquiring a controlling share of Shanghai Belling, which already acquired ASMC (Shanghai Philips). By 2003, HHNEC transformed itself as a foundry service provider serving both fabless design houses inside and outside of Huahong Group.

2.5 The foreign companies

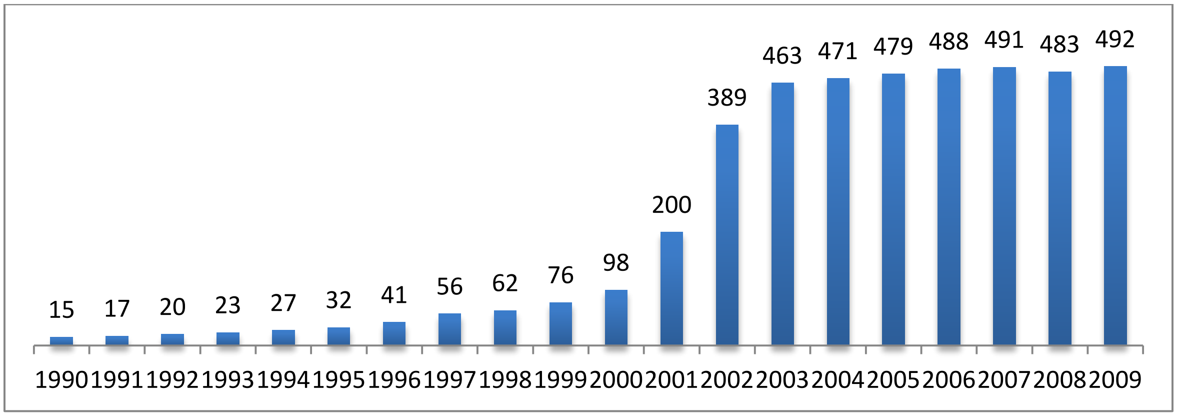
Throughout the 1990s, the domestic semiconductor market of China remained a protected one. Tariffs on semiconductors varied from 6 to 30 percent, and foreign direct investments were highly regulated (Dewey Ballantine, 2003). Very few multinationals were able to establish wholly foreign-owned enterprises (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. The only exceptions were perhaps Intel and Motorola. In early 1990s, Intel began to build wholly-owned chip test and packaging plants in coastal areas, mainly for assembling its Pentium microprocessors. But Intel did not enter chip fabrication activities in China until 2010. Motorola, which maintained a substantial share of the cell phone and telecommunication switching market in China during the 1990s, relocated large-scale test and assembly activities to China's coastal cities. In 1997, Motorola began to build a 200mm mega-fab in Tianjin, utilizing a 0.35- to 0.25-micron process with the designed capacity of 20,000 wafers per month. The fab could have been China's most advanced fab, but in reality it never entered volume production under Motorola's control. The reasons were multifold. During the semiconductor downturn around 1998, Motorola postponed the investment plan, and had not resumed deploying equipment until the market recovered in 2000, resulting in a long delay in bringing the fab online. After the fab entered pilot production in 2001, it faced extremely bad timing as the international semiconductor prices went into a steep fall. Outcompeted by indigenous firms such as Huawei and ZTE, Motorola was unable to sustain its leadership in China's telecommunication market in early 2000s, and thus it lost interest in make further investments in China. On the corporate level, Motorola began to adopt an "asset-lite" strategy at about the same period, spinning off its semiconductor division, as Freescale. In 2003, prior to the spinoff, Motorola sold the Chinese plant, which had cost the company $1.9 billion to build, to SMIC for $260 million. Freescale did not subsequently elect to undertake costly fabrication activities in China.

III. BUSINESS-LED DEVELOPMENT: THE RISE OF THE CHINESE FOUNDRIES IN THE 2000S

3.1 Transformation of the industry

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, pp. 2-54). 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. Over the 2000s, SMIC had continued to expand its capacity by building fabs in Tianjin, Beijing, Wuhan and Chengdu, pushing into more advanced 300mm, sub-0.1-micorn process. 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. As Figure 3.1 shows, throughout the 1990s, the number of Chinese semiconductor design firms rose steadily from 15 in 1990 to 98 in 2000 with annual entries of 10 to 20 firms. But there are 102 new entries in the single year of 2001, another 189 in 2002, and additional 74 in 2003. After 2004, the number of chip design firms stabilized around 500.



<u>Figure 3.1 Numbers of Semiconductor Design Firms in China (1990 - 2010)</u>
Source: Reprinted from PWC, 2010, Figure 15

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 2.4, 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.

Table 3.1 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

Notes: a. Belling is a spinoff from Shanghai Bell, a JV
b. CSMC is founded by taking over Huajing's production lines
c. Motorola’s Tianjin fabs had been sold to SMIC in 2003
Source: Compiled by the author

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. 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 Table 3.1, 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. The prime example is HHNEC, which recruited almost all of its senior executives from returnees. The way of developing skills changed as well. China was still lacking skilled engineers in both chip design and fabrication. But rather than sending engineers to be trained abroad, the entrepreneurs actively used their extensive global networks to attract engineers from overseas, luring them with the promises of making a fortune, often in the form of a substantial amount of stock options.

With access to global markets, talent and capital, the foundry and fabless startups in the 2000s were transforming the industry. There are three measures of the rise of the Chinese semiconductor industry in the 2000s: an increasing share of global production, closing the technology gap with the world’s frontier, and an improving mix of products.

China’s share of world semiconductor production rose from less than 1 percent in 2000 to almost 9 percent in 2009 (PWC, 2009). Behind the expanding capacity, there are now four Chinese foundries which are among the top fifteen globally, with two among the top ten, and one among the top five (See Table 1.1).

Led by SMIC, leading Chinese firms have closed the technology gap with the world's frontier. Figure 3.2 illustrates the leap of technology with the coming of SMIC in the 2000s. In this figure, technology implemented by the U.S. firm is considered equal to the global technology frontier. Until mid-1990s, fabrication technologies employed by Chinese firms were at least three generations behind the global leading firms in the United States and Japan. Project 908 and 909 imported and deployed advanced production lines, but the technology did not fall into hands of the Chinese, at least not immediately. In the case of Project 908, the 150mm, 0.8-micron technology would not be considered to have been absorbed by 1998 when the fab was rented to CSMC. In Project 909, Huahong did not exercise strategic control over a fab with 200mm, 0.35-micron technology until 2002 when Chinese regained management control from the Japanese. As demonstrated in Figure 3.2, China's technology catch-up in 1990s seems to have been slower than was previously thought. Nevertheless, SMIC has followed the world frontier closely with a process only one generation behind since 2003.

In terms of product mix, the move towards the ASIC, the most sophisticated IC category, was even more impressive (Table 3.2). Until 1999, domestic IDMs mainly supplied discreet and later analog chips used in commodity electronics products. The skills to produce memory chips, a commodity as well but one that requires sophisticated manufacturing techniques to bring down defects, were not available to the Chinese until the operation of HHNEC in 1999. But in the 2000s, foundries such as SMIC and Grace engaged in manufacturing sophisticated logic chips for foreign fabless design house, and later received more and more orders from domestic designers.

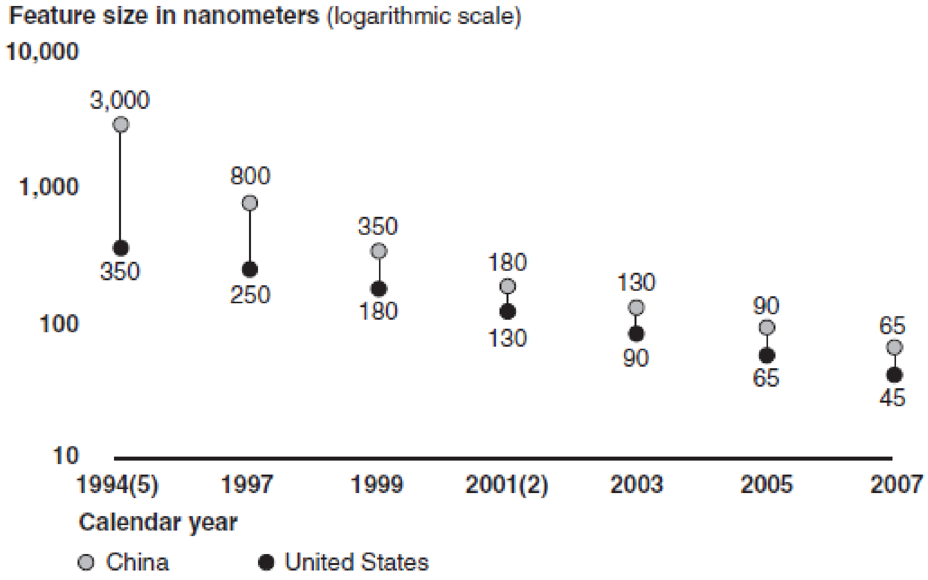


Figure 3.2 U.S. and Chinese Semiconductor Manufacturing Capabilities (1994 - 2007)

Source: GAO, "Export controls: Challenges with Commerce's Validated End-User Program May Limit Its Ability to Ensure That Semiconductor Equipment Exported to China Is Used as Intended", 2008

Table 3.2 Changing semiconductor technologies and product mix in China

Year		1984-1996	1997-1999	1999-2002	2002-2008
Best Products		Discreet	Analog	Memory	Logic
Technological Frontier	Micron-width (micron)	4 .0 - 1.3	0.5 - 0.25	0.18	0.13 - 0.065
	Wafer size (mm)	100	150	200	300
Representative Firms		Huajing, Shanghai Belling, SG-NEC, Shanghai-Philips	CSMC, Shanghai Belling, SG-NEC, ASMC	HHNEC	SMIC, Grace, HHNEC

Source: Compiled by the author

3.2 The rise of SMIC

3.2.1 The Founding of SMIC

After Richard Ru Gin Chang sold his four-year-old foundry startup WSMC to TSMC in January 2000, he was urged by a group of investors and customers to start a new foundry, this time in China. Backed by several big name international investors, Chang traveled around China to shop for a location. In Shanghai, Chang received the warmest welcome from the municipal officials, who not only offered generous tax breaks, cheap lands, and world-class water and electricity supply, but also promised to take stakes in the new venture. Seven months later in August 2000, Semiconductor International Manufacturing Corporation (SMIC) commenced plant construction in Shanghai’s Zhangjiang science park, close to HHNEC and Grace Semiconductor, the other two of China’s largest foundries.

Born in Mainland China, raised in Taiwan, work experience in United States, and then founder of China’s No.1 semiconductor company, Richard Chang pursued a successful career of the type that a generation of techno-entrepreneurs who have returned to China since the 1990s have dreamed about. Like a typical technology immigrant, Chang went to the United State to pursue a graduate degree in engineering, after which he joined an American high tech company, Texas Instruments (TI), where he accumulated first-hand industrial experience as well as technology and management expertise. At TI, Chang helped to build six semiconductor foundries in Asia and Europe as part of the company’s global expansion. With his specialty in launching new semiconductor businesses, Chang took an early retirement from TI in 1997, and received backing from US investors to found his first foundry startup, WSMC in Taiwan (Iritani, 2002).

Many of the veteran managers and engineers at WSMC followed Chang to the Mainland. Some of them were foreign-born experts. For example, Marco Mora, Chang's Chief Operating Officer was an Italian national, who had previously held managerial positions in STMicroelectronics, Texas Instruments, Micron, WSMC and TSMC (SMIC, 2004). However, to assemble a team of chip engineers and production experts that would meet the demands of SMIC's aggressive expansion plan and ambitious technological goals, Chang turned to a larger pool of talent – ethnic Chinese working in established semiconductor multinationals. Roger Lee, for example, one of SMIC's vice presidents, was recruited from Micron Technology, one of the world's largest memory chip makers. At Micron's American operation Lee was a senior engineer in product development and held 115 patents under his name. However, Lee felt that he was hitting a glass ceiling in advancing his career because it was "hard for one person to make a difference" in such an established firm, and therefore decided to join Chang's SMIC venture (Iritani, 2002). In another example, the vice president of manufacturing at SMIC, T. Y. Chiu, had run several fabs for TSMC and had also worked for a long time at US IDMs (Fuller, 2005, p. 290).

For those coming or returning to China to work at SMIC, such a choice came along with a substantial cost, most notably a significant pay cut. At SMIC, employees are paid at prevailing Chinese rates, which for senior managers are 25 to 30 percent of US salaries. What made the offer of SMIC attractive was, in the words of a LA Times journalist, "a chance to be on the ground floor of a pioneering venture, with ***stock options*** (emphasized by the author)”. Indeed, through offering SMIC stock shares and stock options, SMIC lured hundreds of managers and engineers from rivalry foundries, TSMC, UMC and Chartered. From TSMC alone, SMIC hired more than 140 production experts, offering certain key employees as much as 80,000 shares of stock and options, worth $1.4 million dollar at the company’s NYSE IPO price of $17.5 per share (Clendenin, 2004).

The expertise gathered through global hiring allowed SMIC to achieve “an implausibly quick ramp-up of its production facilities and fabrication processes”, as described by the rivalry foundry TSMC. Commencing construction in August 2000, SMIC’s 200mm fabs in Shanghai entered mass production in less than one and a half year or as early as January 2002. In contrast, it took SMIC’s closest Chinese competitor Grace Semiconductor, which started at approximately the same time in Shanghai, an additional one year to start ramping up. While Grace’s plan of 21-24 months for qualifying its 0.18-micron node was aggressive, it took SMIC less than one year from announcing the 0.18-micron process to enter mass production (Clendenin, 2004).

In November 2009, SMIC lost a long-running patent lawsuit in the United States, in which TSMC charged the company for stealing trade secrets through hiring ex-employees of TSMC. It resulted in compensation to TSMC of $200 million and approximately 8 percent of SMIC shares plus a warrant to subscribe to an additional two percent of SMIC shares. This lawsuit, on the one hand, showed that SMIC had been considered as a serious rival by the top-tier competitor; on the other hand, it confirmed the central role of human resources, particularly experienced engineers, in the knowledge-intensive semiconductor manufacturing business. The faster ramp-up of SMIC brought the company a huge first-mover advantage in competition with its closest competitor, Grace Semiconductor in China, laying down a solid foundation for its rapid expansion in the 2000s.

3.2.2 The race with Grace Semiconductor

At the same time as SMIC, there was another billion dollar semiconductor new venture founded in the Zhangjiang science park of Shanghai, namely Grace Semiconductor. Of the two brightest rising stars in China’s chip making industry, Grace was thought to be more promising when they were first founded. Compared to the $1.48 billion venture of SMIC, Grace raised a relatively larger sum of $1.63 billion from investors across the Taiwanese Strait. Furthermore, an advantage of Grace that could hardly be ignored was the company’s deep business and political connections. Of the two co-founders of Grace, one is Winston Wang, the son of a powerful Taiwanese industrialist Wang Yongqin; and the other is Jiang Mianheng, son of the president of China, Jiang Zemin.

In addition to being founded at the same year and the same location of SMIC, Grace and SMIC bore even more similarities in their business models. As contract chip manufacturers, both companies were betting on the potential growth of the Chinese chip design houses, whose products were desperately needed by China’s growing industrial base. While SMIC had attracted talent from the overseas engineer community, Grace brought in Taiwanese engineers and managers through its Taiwanese connections, with the use of stock options to a lesser extent than SMIC (Fuller, 2005, p. 278). As recognition of the expertise of both teams, both companies raised funds from domestic and foreign investors. SMIC's big name investors include Walden International, Vertex Venture Holdings (both from Silicon Valley), H&Q Asia Pacific (Taiwan) and Goldman Sachs, in addition to the Shanghai municipal government. Grace had funds from state-owned companies in China, industrial groups in Taiwan, and Japanese chip makers.

In the chip manufacturing business with its requirements of huge fixed costs, achieving economy of scale is essential to obtain competitive advantages. Scale not only attracts big customers with orders requiring large production volumes, but also provides more opportunities for learning-by-doing that enables a foundry to move up the yield curve. Both SMIC and Grace made heavy investments in establishing a capacity of processing over 100,000 wafers per month, which would enable them to compete with the top five pure-plays in the world. They even implemented similar operational strategies to utilize these facilities. They both started with state-of-the-art 200mm fabs equipped with mainstream 0.18-micron process technologies, which did not exist in China then. To quickly ramp up the expensive fabs, both companies opted to produce commodity-type DRAM chips before moving into more advanced logic IC products. Producing commodity-type chips in start-up phrase had the advantages of testing and ramping-up production lines and training workers, but for the Chinese firms, it was also a shortcut to obtain intellectual property protection. By leveraging their operations as a second source for DRAM makers, SIMC secured process technology and relevant intellectual property (IP) from clients such as Toshiba, TI, Infineon and Elpida, while Grace received technology transfers from SST, Oki, Sanyo and Toshiba.

Eventually, the first-mover position became a critical advantage for SMIC in this race. Though SMIC was found stealing "detailed process flows… including process target and equipment type" (TSMC court charge, cited in Clendenin, 2004) from TSMC, SMIC was one year ahead of Grace in the ramp-up. By the time Grace came into mass production in 2003, SMIC already had two fabs in Shanghai fully operational, had begun its national expansion, and had prepared to launch an initial public offering on the New York Stock Exchange. Though Grace has held the position of No.2 in China since 2003, SMIC has grown to be three to five times larger than Grace in terms of revenue.

To be fair, SMIC was able to gather a corps of more seasoned executives and engineers than Grace. Though Winston Wang of Grace came from a powerful industrial group in Taiwan, his only experience in the semiconductor business before Grace was with a DRAM chipmaker Nanya, which had a record of mediocre performance. Nasa Tsai, the main executive at Grace, previously served in Taiwan's Mosel Vitelic and CSMC. The two firms are a small IDM and a foundry targeted at low-costs, trailing-edge technology products, respectively. In contrast, Richard Chang of SMIC and his senior managers all had extensive experience in top IDMs and foundries. They had also used their connections to recruit ethnic Chinese engineers from leading US and Taiwanese firms. As exposed in the TSMC-SMIC lawsuit, a senior executive at SMIC, Marco Mora, had lured dozens of seasoned engineers from TSMC.

Outcompeting Grace was an essential step for SMIC to achieve a status of the Chinese national champion, which greatly accelerated the growth of the firm. Admittedly, at their start-up phrase, SMIC received more funding from foreign investors, particularly those from Silicon Valley, while the Chinese state favored Grace more, possibly due to the political connections of its executive. In 2001, both companies were extended loans from the Chinese state-owned banks: $432 million loan for SMIC, and a more favorable

$830 million loan for Grace (Fuller, 2005). Yet the politics of Chinese industrial policy were characterized by uncertainty and discontinuity, reflecting a trial-and-error attitude of the bureaucracy system. As the early success of SMIC indicated a more promising outcome for state patronage, the Chinese state quickly reached out its helping hand to SMIC.

3.2.3 Finance, Growth and Technology Catch-up

From 2001 to 2006, SMIC received long-term loans of $2.28 billion[7] from Chinese and foreign banks (SMIC Annual Reports, multiple years). These loans, with details in Table 3.3, bear interest rates as low as 2.50% and extend the starting date of principle repayment to two to four years after the loan. From the stock market, SMIC raised $1.73 billion through its IPO on the New York Stock Exchange. More recently, SMIC has been receiving funds from the Chinese state-owned entities in the form of equity investment. In 2008, Datang Telecom, the state-owned inventor of the Chinese third-generation wireless standard (TD-SCDMA) invested $172 million in SMIC for a 16.6% share. In 2011, SMIC received $250 million from China's sovereign wealth fund, China Investment Corporation, for an 11.6% stake.

These committed financial resource allowed SMIC to grow rapidly. Within four years, wafer shipments grew from zero in 2000 to over 1,000,000 wafers and sales to

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[7] The $2.28 billion loan includes 2.12 billion in US dollars, 235.7 million in RMB and 85 million in Euros (See Table 3.3).

over $1 billion in 2004. During this period, SMIC commenced production at one 200mm mega fab in Shanghai, China’s first 300mm mega fab in Beijing, and acquired one 200mm fab from Motorola in Tianjin. In addition, SMIC also undertook management contracts to manage operations of the Chinese state-owned fabs at Chengdu and Wuhan. Currently, SMIC had another 200mm fab at Shenzhen under construction. To sustain operations on this scale, the workforce at SMIC expanded to over 10,000 employees within five years of its inception, and remained at around 11,000 employees throughout the financial crisis in 2009. Of all employees, half are engineers and managers with Bachelor or graduate degrees, and technicians accounted for the other half (Table 3.4).

SMIC became a serious competitor to leading pure-play foundries. In 2004, its share of the world market reached as high as 6 percent (SMIC SEC filling Form 20-F, 2004). This ranked SMIC the fourth biggest player in the world foundry industry, after TSMC, UMC and Chartered (with market share of 47%, 23%, and 7%, respectively). SMIC’s customer base includes not only established IDMs, such as Fujitsu of Japan, Infineon of Germany, Samsung of South Korea, but also leading fabless semiconductor companies of US and Taiwan, including Broadcom, Elite and Marvell. Large fabless semiconductor design houses are major revenue sources of Taiwanese pure-play foundries. Attracting large customers such as Broadcom away from the Taiwanese foundries is a very strong indication of SMIC’s competitive advantage.

Table 3.3 Major long-term loans to SMIC

Date	Facility	Source of loans	Amount	Interest rate	Principle repayment starting date
2001	SMIC Shanghai	Chinese banks syndicate	USD 432.0 million	2.82% - 7.05%	2005
2004	SMIC Shanghai	Chinese banks syndicate	USD 256.5 million and RMB 235.7 million	2.75% - 7.05%	2006
2005	SMIC Beijing	Chinese banks syndicate	USD 600 million	3.46% - 7.17%	2007
2005	SMIC Tianjin and Shanghai	ABN Amro Bank N.V. Commerz Bank (Nederland) N.V. (Shanghai)	EU 85 million	3.01% - 6.12%	N.A.
2006	SMIC Tianjin	Foreign and Chinese banks syndicate	USD 300 million	3.11% - 6.58%	2010
2006	SMIC Shanghai	Foreign and Chinese banks syndicate	USD 600 million	2.47% - 6.72%	2006

Source: Compiled by the author from SMIC Annual Reports, multiple years

Table 3.4 Employee composition at SMIC

	2002	*2003*	*2004*	*2005*	*2006*	*2007*	*2008*	*2008 (%)*
Managers	224	338	570	679	871	916	1015	9.58%
Professionals (mainly engineers)	817	961	3109	3648	3790	4096	4465	42.13%
Technicians	1837	2746	3389	4127	4804	4806	4837	45.64%
Clerical staff	315	398	572	642	583	287	281	2.65%
Part-time (Temporary workers)	99	38	14	283	275	276	50	0.47%
Total	3193	4443	7640	9096	10048	10105	10598	100.00%

Source: Compiled by the author from SMIC Annual Reports, multiple years

Financial commitment allowed SMIC to maintain aggressive investments in fabs and equipment, a necessary condition for catching up and keeping up with the rate of technology change. From 2003 to 2008, annual capital spending at SMIC exceeded $500 million. In 2004, SMIC reached a peak of its capital spending. The company was forecasted as the fifth largest semiconductor capital spender in 2004 for its budget of $1,950 million, trailing only the top-ranked firms (Samsung, Intel, UMC and TSMC). Though other semiconductor companies added spending that year, SMIC was still ranked number seven for its realized investment of $1,839 million (Table 3.5). Still, SMIC invested more than the major Korean pure-play foundry Dongbu or Singapore pure-play foundry Chartered. No Chinese semiconductor firm had ever achieved such a scale of investment before.

Table 3.5 2004 Top Semiconductor Capital Spenders

2004 Rank	**Company**	**Headquarters**	**Actual spending ($M)**	**Budget ($M)**
1	Samsung	South Korea	4,735	4,100
2	Intel	U.S.	3,843	3,800
3	UMC Group	Taiwan	2,480	2,120
4	TSMC	Taiwan	2,275	2,000
5	ST	Europe	2,050	1,600
6	Toshiba	Japan	1,875	1,430
7	SMIC	China	1,839	1,950
8	Infineon	Europe	1,585	1,585
9	Micron	U.S.	1,500	1,450
10	Sony	Japan	1,480	1,520
	Top 25 Total		37,548	
	Others		8,161	
	Total		45,709	

Source: IC Insights, Company reports

Those investments were translated into rapid technology catch-up. By 2009, SMIC had aggressively licensed process technology from various sources. Most of them are major semiconductor firms, such as IBM (for 45nm CMOS logic), Chartered of Singapore (for 0.10-micron logic), Fujitsu of Japan (for 0.11-0.22micron DRAM), Infineon of Germany (80 and 90nm DRAM), Elpida of Japan (for 90nm and 100nm DRAMs) and Toshiba of Japan (for 0.13micron back-end logic). Some of them have taken stakes in the company for technology transfer, such as Chartered and Toshiba. In some cases, licenses were part of outsourcing agreements in which SMIC would implement the technology to produce chips for the licensors. Examples include Infineon and Fujitsu, which are also among SMIC's top customers. While older processes are relatively easy to license, developing a new process requires a combination of leading science and deep experience. SMIC has formed partnerships with Chinese and foreign research institutes to develop advanced technologies. Since its establishment, SMIC has cooperated with IMEC, Europe's premier semiconductor technology research center to co-develop process technology. But the latest breakthrough was with its Chinese partners. On April 2011, the collaborative efforts of the Shanghai Institute of Microsystem and Information Technology, SMIC and the design house Microchip Technology came out the invention of phase change random access memory (PCRAM) based on Chinese intellectual property, which may become a candidate for the standard of next-generation memory chip used in handsets.

Figure 3.2 illustrated the closing gap of chip fabrication process between China and United States, particularly with the establishment of SMIC in 2000. Process technology is measured in terms of feature size, which is the size of microelectronic components produced in the CMOS (complimentary mental oxide silicon) fabrication process. The CMOS process has been not only the mainstream fabrication technology since at least the 1980s, but also widely recognized as a measure of technology sophistication. Since it is commercial technology that has been measured, each country is represented by its leading firms. SMIC has been the technology leader in China since 2001. SMIC had narrowed the technology gap with the global frontier to about one generation in the 2000s.

3.2.4 Cities, Capital and Competition

Even with its spectacular start, there were serious challenges for SMIC to maintain the momentum of growth. From 2005 to 2009, the company was struggling to earn a positive operating margin. The difficulty of achieving profitability was the result of the underestimation of difficulties in improving product mix and customer base. To quickly ramp up fabs and attain full utilization of the facility, SMIC started by producing commodity-type DRAM and flash memory to complement orders from foreign IDMs and fabless houses. Such a strategy was used to buy time for cultivating the domestic fabless market. The Chinese fabless design houses, particularly those whose products embodied advanced processes with substantial margins, however, turned out to emerge and grow much slower than expected. Without the support of a strong revenue base, SMIC faced challenges in sustaining continuous investments in capacity and equipment.

To finance its rapid expansion, SMIC raised capital from global share offerings, several rounds of private financing, and bank borrowing. But in 2005-06, none of these sources seemed to be sufficient. Years of operational losses severely affected its stock price, and a large portion of loans borrowed in 2006 had already been used to repay borrowings made in 2001. SMIC had to find new sources for its ever-expanding production lines to continue to pursue its strategy of competing with the largest players.

SMIC first found its opportunity in the Sichuan city of Chengdu. In 2004, it partnered with United Test and Assembly Center (UTAC) of Singapore to build an assembly and test facility at Chengdu to package chips, mainly for its only products. In the same year, Intel had also established an assembly and test facility nearby. The city government thus saw a window of opportunity in building a semiconductor cluster by moving upstream to the chip fabrication segment.

By 2005, the Chengdu city government established Cension Semiconductor Manufacturing Corporation to partner with SMIC in chip fabrication. The city-owned firm built and owned the fab, then contracted with SMIC to manage and operate. In the process, SMIC provided technology expertise, directed orders to the fab, and gained a share of profits from the fab. Cension bought used 200mm equipment from SMIC’s Shanghai and Tianjin fabs, and produced a similar mix of products, including DRAM, CMOS sensors, and ASICs. The designed capacity of Cension was 25,000 wafers per month (SMIC Annual Reports, 2009).

In 2006, SMIC struck a similar but bigger deal with the Hubei city of Wuhan. The Wuhan city government invested $1.5 – $3.0 billion in a 300mm fab named Xinxin Semiconductor Manufacturing Corporation, and contracted with SMIC to design, build and operate the facility. SMIC earned a management fee from the operation, and was allowed to buy the fab eventually.

In 2008, SMIC announced that it would construct two fabs (a 300mm line and a 200mm line) and an R&D center at Shenzhen, with support from the city government. The Shenzhen operation was set up as a subsidiary of the company, doing business under the name Semiconductor Manufacturing International (Shenzhen) Corp. Like the Wuhan Xinxin deal, the Shenzhen city government would provide finance to construct and equip the fabs, and SMIC would buy the plants in a later stage.

Since 2006, capital spending at SMIC had been kept low, with an annual budget of around $600 million. In 2008, the spending was down to a mere $300 million. Yet, the company continued to add capacity through the strategy of building and managing fabs for municipalities. By arranging for SMIC to buy the plants after years of operation, the investments made by the cities were similar to long-term loans to the company. Compared to loans, such an arrangement has advantages and disadvantages. A major benefit is that SMIC could avoid the negative effects of large depreciation on cash flows, which is good news for a company struggling for profitability. The “disadvantage”, from the perspective of business executives, is the involvement of the municipalities as stakeholders. The interests of the cities have been in economic development, i.e., the multiplier effects of having the facilities of a major company in its boundaries, and the stability of high-quality of employment. As a NYSE-listed company, SMIC has claimed its goal to be delivering shareholder value, at least in its annual reports. Thus, there are scenarios in which the company may pursue a short-term profit goal for the shareholders at the expense of the employment goal of the cities, such as laying off workers to save costs.

Yet in the long run, the stability of employment helps to integrate the business organization, leading to innovation that ultimately delivers values to all stakeholders. The possibility of potential conflicts between SMIC and the cities, thus, largely depends on the company's innovation and employment strategies.

3.2.5 Hire, train and retain

By 2010, SMIC employed more than 11,000 people (employees of Chendu Cension and Wuhan Xinxin are not counted by SMIC), with 6,500 located in the Shanghai campus and 2,000 working in Beijing and Tianjin each. Almost half of the employees are managers or engineers with college degrees or above (see Table 3.2). The rest are technicians, who are shop floor workers operating the fabs. Since the company hired two types of employees, i.e. managers/engineers vs. technicians, from distinctive sources, it employed different human resource strategies.

SMIC hired a large portion of its managers and engineers from the expatriate community when it was first founded. In 2001, among SMIC's 1,043 engineers, 393 were expatriates relocated from outside of China or non-Chinese foreign citizens. Localization went on well as the company continued to recruit fresh graduates and have them trained by the seasoned staff. By 2008, staff with overseas backgrounds accounted for around 10% of the pool, which is 1,100 out of 5,500 (SMIC Annual Report, various years).

As mentioned earlier, to attract these people to return to China, SMIC offered the most popular compensation tools used by technology companies in the West, most notably stock options. Shortly after the completion of its IPO in 2004, SMIC granted stock options to more than 7500 recipients, covering most of its managerial and technical staff and certain external consultants (SMIC, 2004). The company also has an Employee Equity Incentive Plan to retain and motivate new employees, who are granted restricted shares vested over a period of four years. However, some scholars regard housing benefits and educational programs to be very, if not the most, effective attraction and retention strategies.

When setting up its Shanghai campus, SMIC spent over a million dollars on two support projects for its employees: the housing project and a school. The housing project built villas, houses and apartments occupying 260,000 square meters close to its Shanghai plants. SMIC rented these accommodations to its employees at below market prices, and even sold them at a discounted price to certain qualified employees, often those who had served the company for an extended period of time. As housing prices in Shanghai had almost tripled over the past decade, such housing bonuses may be more attractive to employees than stock options, which had limited value due to the company's poor performance in the stock market.

The SMIC School, a bilingual school, is the major educational benefit offered to employees with school-age children. With money from the corporation, the school is one of the best in Shanghai. It has hired teachers from the United States, implemented a US high school curriculum, and sent many of its graduates to leading American universities (SMIC CSR report, 2008). Such an opportunity is particularly attractive to expatriate employees who intend to retain US citizenship. It is said that, in some cases, the reason why some families of employees stay an extended time at SMIC is so that their children can continue to attend the SMIC School (Shih, 2009).

To the technicians who account for the other half of its employees, SMIC offers a different bargain. Rather than hiring the locals, SMIC recruits most of its technicians from China's remote hinterland provinces, often youngsters with high-school diplomas. Instead of paying higher than prevailing wages, the company provides cheap dormitories to these young immigrants who otherwise would pay a large portion of their wages for housing. The other offer of the company is the opportunity to receive education. In addition to on-the-job training and mentoring, SMIC has partnered with local universities in Shanghai, Beijing and Tianjin to offer bachelor's degree program, often in either microelectronics or solid-state circuitry, to these technicians (SMIC CSR report, 2008). Obtaining a college degree gives these youngsters a much better chance of climbing the corporate career ladder. Over the course of four to five years of part-time studies, these young technicians have to stick with SMIC. All of these monetary and social incentives are helping to buy loyalty from the employees.

The Shanghai model of providing housing, schooling and training to employees extends to every SMIC site, including the contract-managed plants in Wuhan and Chengdu. As a result, employment turnover in SMIC has been the lowest among the Chinese high-tech industries, where talent has always been scarce (Shih, 2009). The main components of SMIC's retention strategy, i.e., providing social services to employees, used to exist widely in the days of China's planned economy, but since the 1990s have been abandoned by most Chinese industrial firms. Providing such services is deemed as too expensive and a drag on competitiveness. Nevertheless, the SMIC story seems to confirm the attractiveness of old values in the contemporary society, which, if adequately implemented, could be a worthy investment.

The financial crisis of 2009 was a major test for SMIC's employment strategy. Since the chip industry has the habit of selling chips at the price below variable costs, most semiconductor companies opted to keep their fabs idle during the downturn. SMIC has maintained its workforce without laying off workers (SMIC Annual report, 2009). The potential conflicts between SMIC and the cities may be much less intensive than some have perceived.

3.2.6 A foundation of innovation and growth

By the end of 2010, SMIC had constructed and operated five 200mm and four 300mm fabs across China, in addition to one 200mm and one 300mm fab managed for Cension and Xinxin, respectively. The accumulated capital investment for these fabs has exceeded well over $10 billion, larger than the sum of all investment China made in the semiconductor industry prior to 2000. The rise of SMIC, with its enormous scale, benefited the national economy in numerous ways. It established world-class chip manufacturing capabilities in China that narrowed the technological gap between China and leading industrial economies. It employed and trained a high-skill workforce who lived on Chinese wage but competed in areas of the most cutting-edge technologies. From a long-run view, the strengthening of semiconductor manufacturing capabilities will spillover to the whole Chinese electronics industry.

The continuous operating loss of SMIC from 2005 to 2009, however, raised concerns about the viability and sustainability of investment of this scale. Competing in the memory chip market, as SMIC did prior to 2008, contributed to global overcapacity and lower prices, and to the benefit of consumers, but generated little benefit to the producers. One needs to recognize the strategic importance of SMIC in the Chinese market, where over one third of world's semiconductors are consumed but only one-third of consumption is met by local production. Any ambitions to close this gap, however, require an equally vibrant fabless semiconductor industry that utilizes the capabilities of foundries to deliver chips to meet the needs of local system integrators.

Recent news seems to indicate that the long-term investments made by SMIC and the Chinese government are about to pay off. With sales reaching $5.2 billion in 2010, the continuing growth of the Chinese fabless industry seems inevitable. While the Chinese fabless firms used to concentrate on telecommunication and consumer electronics chips, since 2009 leading firms are increasingly seeking to produce high-end products by licensing from leading IP suppliers (Yoshida and Clarke, 2011). Others even began to talk about the potential of emerging disruptive chip technologies in China (Clarke, 2011). Among the many causes underlying the growth of and innovation in the fabless sector is the availability of established foundries, particularly SMIC.

IV. CHANGING INDUSTRIAL CONDITIONS

In early 2000s, the transformation of the Chinese semiconductor industry was accompanied by a series of changes in the developmental environment of the industry. These changes include a decisive shift in national policy, the emergence of a less hostile international trade regime, and changes in attitudes towards China as an industrial location by foreign investors and competitors. All these changes have made an impact on the development of the industry, and all of them contributed to the industrial transformation. From the perspective of the theory of innovative enterprise, these changes in market, technological and competitive conditions were indeed changing the innovative challenges faced by business enterprises. What, then, did they contribute to the dynamics of innovation and growth?

4.1 Changes in national policies

The most important change in the developmental environment for Chinese the semiconductor industry in the 2000s was a dramatic shift in state industry policy. 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”, also known as Circular 18. As a part of the 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:

- 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..
- Value-Added Tax (VAT) and import duty exemptions on imported raw materials, equipment and machinery. Import duty and the 17 percent VAT applied on imports of IC manufacturing machinery and equipment and raw materials are exempted. Tariffs will be eventually eliminated.
- 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. 8
- Infrastructure investment. Direct budgetary funds shall be allocated to provide financial support for construction of infrastructure (usually by local governments)
- 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

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[8] 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."[9] (article 45)

- Capital provision. The state provides assistance in the form of favored status and financial support to the establishment of venture capital firms.
- National treatment of foreigners. The policies are applied to both foreign and domestically owned firms that qualify (article 52).
- Training programs. Universities are encouraged to provide courses and degrees on electronic engineering through increased budget allocations on the basis of increased enrollments.

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. It seems that China is now playing the game of market-based incentive policies.

What changed the perceptions of China's industrial promoters? From the outside, pressures came from China's preparation for admission into the World Trade Organization (WTO) in 2001. As a WTO member, China had to become a signatory of

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[9] In the past, the Chinese government required companies to have foreign currency acquired from international trade to be exchanged into RMB. It was a measure taken to prevent the flight of capital.

the Information Technology Agreement (ITA), which required reducing tariffs on all ITA products, including semiconductors, to zero as of January 1, 2005. To comply with WTO rules, China had to make large-scale legal amendments in line with those in other WTO countries (Lin, 2005). 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.

Project 909-style large-scale technology development projects were losing support from the central government because of personnel changes at the ministry level. In 1998, the Ministries of Electronics Industry (MEI), Post and Telecommunication (MPT), and Radio, Film and Television (MRFT) were merged to form the Ministry of Information Industry (MII), which would be overlooking the converging telecommunication and information industries. MEI's minister Hu Qili, the keen supporter of Project 909, was promoted to vice chairman of the Chinese People's Political Consultative Committee's standing committee, a government advisory body. Wu Jichuan, head of former MPT and his team, took over administration of the new MII. During Wu's time in office, he systematically purged the former MEI personnel (Business China, 1999). Though Hu was still looking after Huahong as its chairman of board, MII was not going provide the same level of support for new projects. In fact, MPT had not carried out any large-scale industrial projects during the 1990s (which actually left space for the emergence of non-government companies Huawei and ZTE, see Feng 2010), and MII had not tried to do so in the semiconductor sector during the 2000s.

The changes in developmental strategies starting from Circular 18 had an enormous impact on the semiconductor industry. 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. Many analysis of Circular 18 focused on its effects in encouraging foreign direct investment (Yinug, 2009). However, the space created by the new development strategies created for non-government firms to grow, reflected in the largest-scale ever of entry into the industry around 2000 might have been more critical. In China’s history of developing the computer, telecommunication and automobile industries, the entry of non-government firms was always linked with strong growth (see Lu 2000, Feng 2010). The question is then whether the semiconductor industry followed a similar logic.

4.2 The role of U.S. and SEM export controls

One of the major external barriers that hindered China from developing an advanced semiconductor industry prior to the 2000s was US exports controls on semiconductor manufacturing equipment and materials (SEM). Under the Wassenaar

Arrangement[10], 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 US government was quite stringent in adhering to these controls. It was said that the US 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).[11]

Though Europe and Japan generally had not linked semiconductor manufacturing equipment to potential military end use, and Netherland's Philip and Japan's NEC had been heavily involved in technology transfers to China since the 1980s, it was not until the late 1990s that China could close the "two generations" gap with Project 909. Such a reality partly reflected the effectiveness of the US policy. But as indicated when Motorola and the Chinese government both announced billion-dollar investment plans in late 1990s, the Chinese market proved to be too lucrative for the US SEM suppliers to give up. When Motorola announced its plan for the construction a state-of-the-art 200mm fab in Tianjin in 1995, the technology to be implemented was around one generation behind. It was suspected that Motorola was expecting that US export controls would be loosened. Nevertheless, at the same time, Project 909 still chose NEC rather than competing bids

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[10] The multilateral Wassenaar Arrangement on Export Controls for Conventional Arms and Dual-Use Goods and Technologies was ratified by thirty-three countries in July 1996.

[11] In the comments attached to the GAO report "EXPORT CONTROLS: Rapid advances in China's semiconductor industry underscore need for fundamental U.S. policy review", both the U.S. Department of Commerce and U.S. Department of Defense dismissed the "two generation gap" policy. Officially, they stated that export licenses were granted or denied on a case-to-case basis. But "the generation gap" view was held widely by the industry, policy makers, and academics (see Hu, 2006).

from IBM or Rockwell, partly due to the concerns of the inability to obtain equipment from the United States.

In 2002, a report on SEM export controls to China by the US General Accounting Office (GAO) began to challenge the effectiveness of the existing export control methods, mainly due to the foreign availability of comparable technologies (GAO, 2002). Since then, the U.S. export control was increasingly shifting to focus on the recipients, rather the items involved. As a result, in 2003, SMIC, the world's third largest capital spender on SEM in that year, obtained a special import/export license from the US government allowing it to import the most advanced fab tools from the United States. In 2007, under a new program of the US Department of Commerce called the Validated End-User program, three semiconductor firms in China were certificated as "trusted" end-users to import controlled items, including Applied Materials China, Ltd., SMIC, and HHNEC (GAO, 2008, p.17). US SEM suppliers applauded the policy change, arguing that the new program will "make U.S. exports more competitive in China" (Leopold, 2007). Indeed, by 2006, China's spending on semiconductor equipment, mainly imported from abroad, had already reached $1.6 billion (GAO, 2008).

4.3 The absence of Taiwanese competition

Taiwan had been a complicating factor in the development of China's semiconductor industry. With one of the largest semiconductor clusters in the world, Taiwan, however, had largely prevented its semiconductor firms from migrating to China in the process of the economic integration across the Taiwan Strait. The stringent restrictions on semiconductor investment came from concerns for both security and economic reasons, i.e., to maintain Taiwan’s technological and competitive advantages over the mainland. The result is relatively little presence of Taiwan-owned semiconductor fabs in China, in contrast to sectors such as consumer electronics where major Taiwanese vendors have based their operations heavily on the mainland. But indigenous Chinese foundries have still been able to tap into Taiwan’s deep skill base in the semiconductor industry, thanks to the intimate personal network and capital flows across the strait. Thus, when indigenous Chinese foundries arose in early 2000s, they largely avoided direct competition in the Chinese market from Taiwan’s TSMC and UMC, the world’s two largest pure-play foundries.

Since the 1980s, Taiwanese firms had offshored the labor-intensive industries to China’s costal export-processing zones. Initially such investment was illegal under Taiwan’s legal framework until late 1980s, given the political confrontation across the Taiwan Strait. In 1990, the Taiwanese government started to regulate the island’s capital flows to the mainland. The “Regulation on Indirect Investment or Technical Cooperation in the Mainland Area” issued in that year included a list of some 3,353 products, mostly in labor-intensive industries, that Taiwanese firms were permitted to produce on the mainland. The list was gradually expanded in the following years. But in the mid-1990s, the increasing scale of capital flight to the mainland began to raise economic and social issues for Taiwan, resulting in a “Be Patient, Go Slow” policy from the Taiwan government. The new policy not only capped investment for individual projects at $50 million, but also banned investments in several sensitive sectors, including semiconductors (Sutter, 2002). It was not until 2002 that such restrictions were partially lifted, allowing 200mm wafer manufacturing investment on the mainland on the condition of ramping up state-of-the-art 300mm fabs in Taiwan and upon government approval (Yang and Huang, 2003). But until recently, among foundry firms only TSMC has been approved to construct 200mm fabs on the mainland.

By 2000, China had emerged as an attractive location for new fab investment in terms of cost advantages. According to a survey of industry executives, the top five reasons for location decisions for fabs were tax advantages, supply of an engineering and technical workforce, reliability of utilities (e.g., quality of water supply), proximity to existing facilities, and environmental regulations (Leachman and Leachman, 2004, p. 226). In the early 2000s, Taiwan had already been suffering from a significant cost disadvantage in fab construction and operation over the rival semiconductor clusters in Shanghai, where two decades of investment had been able to provide world-class infrastructure at a low cost. For example, overall construction costs of fabs, water supply costs and bulk gas costs in Shanghai were 35%, 60%, and 30% lower respectively than those in Taiwan (Clendenin, 2002). In addition, Circular 18 had given major tax breaks to China-based IC manufacturers, including income tax breaks and VAT rebates, since 2000.

Meanwhile, there had been a split in investment strategies towards the mainland among the Taiwanese foundries, particularly between the dominant TSMC and the rest of the smaller ones. As the world's largest and most advanced pure-play foundry, TSMC rests its competitive advantages on Taiwan's deep skill base, supporting infrastructures, close collaboration with government-sponsored research institutes and vibrant fabless design clusters that have enabled TSMC to constantly move up the technological frontier.

Thus for TSMC, the benefits of migrating to China are minimal, except for accessing a large market. Indeed, after the legalization of semiconductor investment on the mainland, Morris Chang, Chairman of TSMC said in a TV interview in 2003:

> "TSMC's policy is to keep its headquarters, R&D center, and manufacturing business in Taiwan, and to market around the world, except some special places such as China. China is a conservative market. We need to manufacture the wafers there to enter the market."(Yang and Huang, 2003, p.691)

But for TSMC's smaller competitors, the potential of Chinese operations represented a way to strengthen their positions against TSMC's overwhelming competition. In late 1990s, TSMC had been continuously adding capacity through merger and acquisition, consolidating the island's foundry sector. Just between June 1999 and January 2000, TSMC acquired Acer Semiconductor Manufacturing Inc. (ASMI), the semiconductor subsidy of the Taiwan computer giant Acer and Worldwide Semiconductor Manufacturing Corporation (WSMC) for $260 million and $550 million in stock, respectively. The acquisition of WSMC was particularly influential. Established in 1996, WSMC had become Taiwan's third largest pure-play foundry by 2000, with two 200mm fabs using state-of-the-art 0.25- and 0.18-micron processes. The foundry was founded and headed by Richard Chang, who then used the fortune from the acquisition deal to start SMIC on the mainland.

By 2000, in terms of revenue, TSMC had been two to three times larger than its closest Taiwanese competitor, UMC, the world's second largest pure-play foundry. And more importantly, behind the revenue gap is a premium that TSMC is allowed to charge from its more advanced technology. The enormous pressure urged UMC to develop capabilities elsewhere, particularly in China. It was said that UMC began to plan for 200mm fabs on the mainland as early as 2001 under the guise of an independent Chinese firm, Hejian. Legally speaking, there is no connection between UMC and Hejian except that Hejian was founded by a group of UMC's former employees. But UMC secretly sold used 200mm fab tools, shared technologies (by allowing Hejian to violate UMC's patents) and even passed orders to Hejian. Even some of UMC's long-term partner design houses followed to Suzhou, where Hejian is located. Such under-the-table arrangements, however, required Hejian to behave more like an autonomous organization than a foreign subsidiary, even though its relationship with UMC is "Taiwan's worst kept secret" (Clendenin, 2005). Lack of formal support from UMC means that Hejian had to, and indeed did, train its own workforce and establish a local production network of downstream system companies and upstream fabless designers. Such localization behavior was in sharp contrast to TSMC's Shanghai subsidary, which mainly concentrated on wafer fabrication (Fuller, 2005). As Hejian's capabilities grew, UMC made several attempts to take controlling shares of the foundry, which, however had all been blocked by the Taiwanese government. To this day, the Taiwanese government is still reluctant to approve UMC's investment on the mainland

Hejian commenced production in mid-2003, while TSMC's 200mm fab in Shanghai entered production in 2004, two years after lifting the ban. But for China's indigenous foundries, there had been sufficient time to launch their businesses.

4.4 Conditions or outcomes?

The changing industrial conditions in government policies, trade environment and international competition did provide a more favorable context for non-government companies to grow. But they are not sufficient conditions for innovative success.

The changing framework of industrial policy created spaces for business enterprises with organizational structures different from the state-owned ones to emerge, and even created incentives for doing so. Such a move to a diversified industrial system, however, was no guarantee of being more innovative.

The absence of leading Taiwanese firms has protected the young Chinese companies from excessive competition, and very likely, has helped to increase the supply of ethnic Chinese engineers and managers available to the Chinese firms. Yet, this factor did not determine how such a rich source of human resources would be finally employed and utilized by business enterprises.

The relaxed exports control of SEM from United States was a response to the exploding demands from Chinese semiconductor companies, which was very clear in the GAO report of 2002. Since the demand for SEM was a result of the innovative investment strategies of the companies, the relaxed export controls should not be taken as a cause of the development of productive capabilities in China.

These changing industrial conditions do not explain why some investment strategies and business structures generate innovation while others do not. This, the most critical question of this thesis, remains to be answered.

V. AN INNOVATIVE ENTERPRISE EXPLANATION

At the end of Chapter 1, I argued that the emerging Chinese semiconductor enterprises had to achieve successes in strategy, organization and finance to attain innovative success. The non-government semiconductor firms, if the theory predicts correctly, should have been better suited to the innovation process. An explanation of the success of the non-government firms and the failures of projects in the 1990s, thus, has to start by evaluating strategy, organization and finance at the firm level. In each case, these questions to be asked should include:

- Who made the strategic decisions? What kinds of market access and technology transformations have been implemented?
- What kinds of human resource strategies have been used to attract, train and retain skilled personnel?
- Where does the enterprise raise capital? And what is the nature of the capital?

Furthermore, understanding the source of the growth of the firm requires an explanation of how the changes in strategy, organization and finance occurred. That is, what kinds of institutional changes in the society enabled the emergence of an effective social organization of innovation?

5.1 The transformation of strategy, organization and finance

Innovative success requires the business enterprises to transform a high fixed-cost investment into higher quality, lower costs products through strategy, organization and finance. A comparison of strategy, organization and finance prior to and after 2000, thus, reveals the process of successful or failed innovation in the two eras.

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. Given the strategic implications of the industry for China and the lack of experience of SOE managers in managing semiconductor enterprises, such an arrangement made sense in the pre-2000 setting. In fact, to overcome the prolonged delays and confusions of the decision-making structure inherent in the bureaucratic hierarchy, as demonstrated clearly in the case of Project 908, the Chinese leadership responded by concentrating power in the hands of a seasoned party cadre, Minister Hu Qili, to oversee its next big project. Hu was probably more aware of the dire state of domestic capabilities than his fellow officials Under his management, the Chinese state made its 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. The disqualification of Chinese managers from exercising strategic control is further evidence of the deficient capabilities of Chinese managers in 1990s.

The SOEs and JVs had also overly relied on their foreign partners to train their workforce. Such a strategy was almost inevitable given the endowment of the Chinese semiconductor industry. Project 909 had initially sought technical support from the Chinese Academy of Science, intending to implement the 0.13-micron process developed in the institute's lab. Yet scientists at the institute considered the potential process of technological migration to be costly, prolonged, and bearing high risks of failure (Hu, 2006). It makes sense as semiconductor mass manufacture requires a combination of high technology and deep experience, while the institute can offer technology but not experience. But, to what degree did the technology transfer from foreign partners accelerate skill formation in this industry? The incentives of foreign companies could be easily undermined by the fear of making potential competitors. The experiences of Project 908 and 909 provide mixed evidence. Lucent was very willing to help, perhaps because of the Chinese telecommunication market was so lucrative and the Chinese partner was so weak. Some researchers observed that NEC withheld some key knowledge (Fuller, 2005), reflecting foreign partners' increasing concern about creating potential competitions. Indeed, Mr. Hu Qili himself had tried to get technology transfer, in the form of staff training, from more than one foreign source (see Chapter 2). The organizational integration theory predicts that a learning organization needs to be built on the aligned interests and efforts of its members. But the foreign partners had good reasons not to commit themselves in the venture.

Government investment is the most important source of capital for the SOE and JV (in which Chinese SOE must hold the dominant share). Although government investment has played the role of "patient capital" in developing the semiconductor industry in many countries, at this stage of China's development, state finance was not that committed. When Project 908 required additional investment, which was almost inevitable given the extended running time of the project, the Ministry of Finance was reluctant (Chapter 2). Nevertheless so-called "financial discipline" did exist in the state-owned businesses. In his memoir, Minister Hu Qili repeatedly stated that he had felt great pressures to maintain and increase the value of state-owned assets, referring to the government investment in Huahong. The objective for profitability was a major incentive to give managerial control to the Japanese, who had promised to keep HHNEC profitable in the first five years of operation (Hu, 2006). Surprisingly, for such a senior party cadre, profitability was recognized as a high principle. But clearly, the state did not have faith in the potential for these enterprises to attain long-term innovative success, and thus was not ready to support the long-term investment that might compromise short-term profitability. The slow investment pace at HHNEC, possibly a legacy of Hu, meant that the company lagged behind in advancing technologies in the 2000s.

In comparison, the types of strategy, organization and finance of non-government semiconductor companies in the 2000s conform more closely to the types of investment strategies and business structures that can generate innovation. Founded and managed by expatriate techno-entrepreneurs, these enterprises possibly had the most capable decision-makers who were available in China. The major concern for the exercise of strategic control in these companies was whether the authority of the techno-managers could be undermined by providers of capital. At its post-IPO stage, the shares of SMIC were distributed to a variety of foreign and Chinese entities. The management team had held as much as a 28 percent share of the company, allowing managerial control to be separated from the share ownership. More recently, however, the increasing share held by Chinese SOEs in SMIC has raised concerns that SMIC may diverted from its primary commercial interests to serve political ends, as was often the case with SOEs (Breznitz and Murphree, 2011, p.150). The increasing power of the Chinese state has been demonstrated in the changing composition of SMIC's board of directors: at post-IPO SMIC, there were only two directors out of eight with a close connection to organizations linked to the Chinese state, Shanghai Industrial Holdings (Shanghai government) and Beida Jade (SMIC SEC form 42484, 2004); in 2010, three directors out of six came from Chinese SOEs with two of them appointed by Datang Telecom and one by Shanghai Industrial Holdings (SMIC Annual Report, 2010).

Yet it can be argued that the key decision-makers in a firm are not its directors but its senior managers. In 2009, the failed law suit against TSMC caused Richard Chang, CEO and founder, to resign. The newly installed CEO, David Wang and his management team provides a natural experiment for observing management autonomy under the influence of the state. A comparison of senior management at SMIC in 2004 and 2010, as shown in the table below, reveals no clear difference in the qualifications of management. Even though all the members of the new management team are Chinese, whereas the old management had some Japanese and Italian, people in the two groups come from the same pool of talent: seasoned professionals with extensive experience in US IDMs and Taiwanese foundries. Though the new CEO David Wang served at the state-linked HHNEC before joining SMIC, he did not bring any of his management team there into SMIC's new senior management. Given that the Chinese state-owned shareholders still do not intervene in the management of SMIC, strategic control of this non-government enterprise is still held by the techno-managers.

Table 5.1 A comparison of SMIC senior management in 2004 and 2010

	Executive Position	Primary Experience
2004 Management		
Richard Chang	President and CEO	TI, WSMC
Jenny Wang	Chief Financial Officer	Motorola China
Marco Mora	Chief Operating Officer	TI, STMicro, WSMC
Toshiaki Ikoma	Chief Technology Officer	TI Japan
Akio kawabata	Vice President of Marketing	Toshiba
Jason T. C. Hsien	VP of Human Resource	Walin Lihwa Co. (Taiwan)
2010 Management		
David Wang	President and CEO	HHNEC, Applied Materials
Gary Tseng	Chief Financial Officer	UMC, TSMC
Simon Yang	Chief Operating Officer	Chartered
Chris Chi	Chief Business Officer	Freescale, UMC
Barry Quan	Chief Administrative Officer	Applied Materials
Zhou Mei Sheng	VP of Technology and R&D	Chartered

Source: SMIC SEC form 42484, March 12, 2004; SMIC Annual Report 2010

The ability of the non-government firms to quickly build a base for learning relies on attracting senior engineers from outside of China and leveraging their experience to localize the workforce. To attract the seasoned staff to come to China, SMIC, for example had offered internationally competitive compensation packages, including stock options and privileged access to schools and housing (Chapter 3). By Chinese standards, such investment in employees is expensive, given the country’s prevailing cheap wages and shrinking social benefits since the late 1970s economic reform. Yet such investment had enabled the company to: 1) catch up with the leading process technologies; 2) expand its technical labor force through internal training that is needed for aggressive capacity expansions. In fact, in-house training is cheaper than sending staff to train at overseas sites. As members of the organization, in-house training staff members are naturally more committed than outside instructors. From 2001 to 2008, the total engineering labor force at SMIC expanded from 1,043 to 5,500, with the number of overseas engineers increasing from 393 to 1,100, while local engineers expanded from 650 to 4,400 (Table 5.2). In comparison, the number of employees at HHNEC was merely 1,900 by 2008 (http://www.hhnec.com). Such a fast pace of skill formation at SMIC is evidence of a good organizational integration strategy.

Table 5.2 Local and Overseas Engineers at SMIC

Date	**August 2001** (DYBG No. 12)	**August 2002** (Fuller, 2005, p. 277)	**2008** (Company report)
Local Engineers	650	700-800	4400
Overseas Engineers	393: 240 Taiwan; 120 US; 30 Italy; 3 Japanese	470 Taiwan; 150 returned Chinese; a few foreigners	1100
Total Staff	1043	2600	5500

Source: DYBG No. 12; Fuller, 2005, p. 277; SMIC Annual Report 2010

There were three main funding channels for the non-government semiconductor firms: foreign investment, bank loans and government investment. Though not all of them are long-term capital providers for the firm, they have effectively provided financial commitment in different stages of the firm’s growth. Foreign investment came in the form of venture capital investment, which played a key role in funding the startup stage of the company. For example, prior to the initial public offering, foreign venture capital firms Walden, H&Q Pacific and Goldman Sachs[12] combined owned 52 percent of SMIC (Dewey-Ballantine, 2003, Figure 25). These venture capital firms, thus, provided capital of at least $1 billion to SMIC before its IPO in 2004. Once the companies have become going concerns, banks provide massive amounts of long-term, low-interest loans (Table 3.3). Government investment comes from local governments and state-linked companies rather than from the central government as was the case in the previous decade, and sometimes through the vehicle of joint ventures, such as Wuhan Xinxin and Chengdu Cension. It needs to be noted that the extremely high fixed costs in semiconductor equipment are reflected in very high depreciation rates that have negative effects on reported earnings. For SMIC, depreciation can be as high as $700-800 million annually. Thus even when the company is generating ample cash from its sales, it may still be show losses on its operating statement. Such accounting issues caused SMIC to favor joint ventures with municipal governments rather than bank borrowing since 2007. Because capital costs in joint ventures are not recorded on the company's book, the negative effect of depreciation on reported earnings can be avoided (Shih, 2009). In another word, the city governments are both making long-term investments in and subsidizing the business.

The transformation of strategic, organizational and financial conditions of the semiconductor firms, as the theory of innovative enterprise predicts, brought about the increase in innovative capabilities. But the translation of the innovative capabilities of the business organizations into actual economic growth and technology catch-up requires

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[12] Strictly speaking, Goldman Sachs is an investment bank.

market access and technology upgrading. Tracing the evolution of market and technology strategies is the other aspect of the historical process of growing innovative capabilities.

In the 1990s, market access was a huge problem for the state-owned integrated chipmakers. Huajing, as the primary example, demonstrated that owning the advanced production lines alone could not guarantee the generation of salable products. Huahong had had relative success in innovating in a handful of killer applications for the Chinese market such as cell phones, SIM card chips, and smart card chips. These innovations were not technically superior to those of its foreign competition, but Huahong consistently brought down domestic prices, and thus contributed to China’s economic development. The ability of Huahong Group to generate these lower-cost import substitutes rests on better capabilities in coordinating its advanced manufacturing activities (HHNEC) with design divisions, research institutes and end users. To complement its investment in wafer fabs, Huahong established joint-venture design houses with Chinese research institutes, provided venture funded to the fabless startups, and secured government contracts in product development. Yet given the limited semiconductor skill base in China, these innovations were not able to keep up with the pace of advancing fab capabilities.

The main technology strategy in the 1990s was to leverage from the Chinese market to acquire foreign technology, known as “trading markets for technology” (Feng, 2010). The Chinese government offered foreign companies access to various segments of the Chinese market in exchange for the transfer of technology to Chinese firms. This seemingly smart strategy actually suffered from several problems. The price of technology transfer, first of all, could be very high. To lure foreign companies to provide technologies for Project 909, or Huahong in 1996, the government was willing to trade the contracts of giant national projects. Germany's Siemens was offered the contracts to supply the Three Gorges Dam. America's Rockwell was hoping to monopolize the Chinese chip market for a range of office equipment, such as fax machines and wireless handsets. IBM, partnering with Japan's Toshiba, wanted to transfer technologies for the contracts of building the country's internet infrastructure, starting from Shanghai. In comparison, a technology transfer without strings attached asked for $4.4 billion. Just, when the Chinese government was about to reaching a deal with IBM and Toshiba, NEC approached with the most favorable conditions, a response to protect its existing semiconductor investment in Beijing (Hu, 2006, p. 48-53). Secondly, the perceived potential competition from the Chinese venture undermines the incentive for foreign companies to commit to technology transfer. Finally, given the monopoly position of the joint venture, foreign partners may intentionally slow down the pace of technology migration to extract more rents from the obsolete ones.

The market access and technology transfer dilemma was solved by the foundry strategy in the 2000s. Instead of competing directly with the foreign chipmakers, the Chinese foundry positioned as contract manufacturers for both domestic and foreign chip designers. This strategy could not be realized without the extensive business contacts of the expatriate techno-entrepreneurs. Such a business model expanded the customer base, thus releasing the company from the limits of the Chinese market. It increased revenue, and enabled the advanced production lines to be utilized in better ways through manufacturing state-of-the-art chips for leading fabless companies.

The transformed relationship with foreign semiconductor companies, at the same time, changed the calculation of technology transfer. Firstly of all, the American and Japanese semiconductor firms, now instead of perceiving Chinese foundries as their competitors, recognized them as competitors of the Taiwanese foundries, the market leaders. The strengthening of the Chinese foundries intensified the competition in the foundry market and thus weakened the market positions of the Taiwanese firms. Such competition drove the foreign companies to transfer technologies, so that the Taiwanese monopoly could be broken. Secondly, foreign semiconductor companies faced competition among customers. Toshiba and SST, for example, had taken stakes and transferred technologies to SMIC and Grace, respectively, to secure foundry capacities for producing their chips. In a word, leveraging capabilities to acquire technology is much more effective than leveraging regulation in market entry.

Table 5.3 Comparison of strategy, organization and finance prior to and after 2000

	State-led Development (Prior to 2000)	**Business-led Development** (After 2000)
Strategy	State agents withhold the ultimate decision-making power in state-owned enterprises and their joint-ventures	Newly established foundries are founded and managed by professional techno managers, often with oversea experiences
Organization	Relying on foreign partners to train the workforce	Attract high-skill engineers from abroad; develop internal training and retaining systems
Finance	State investment allocated through the budgetary system and banking system	Raise capital from both the Chinese state and foreign venture capital investors; joint investment of business and government

Market Access	Focus on domestic market by supplying (mainly low-end) chips to electronics manufacturers	Contract manufacturer for sophisticated foreign semiconductor companies; accumulate capabilities while waiting for maturity of domestic fabless firms
Technology Catch-up	"Trade market for technology"; technology transfer from foreign partners/competitors	Technology transfer from foundry customers; licensing from IP suppliers

Source: summary of text in section 5.1

5.2 Managerial revolution and imported institutions

The transformation of strategy, organization and finance resulted in innovation, and were translated into economic development and technology catch-up. But what has driven the transformation of social conditions in the semiconductor firms? In another words, what have been the institutional foundations for the social conditions of innovative enterprises constructed in the industry and the society at large? Does the Chinese experience in semiconductors provide a generalizable lesson for economic development?

There are two identifiable components of institutional changes in the industry's historical process. One is the transfer of strategic control of the firm from the hands of the state to that of the engineer-turned entrepreneurs and managers. The other is the importation of foreign institutions, particularly in employee compensation and finance, to accelerate the development of productive resources.

The descent of state's power on the firms has gone through the process of China's economic reform. Throughout the 1980s 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 1980s, the major effort was transferring responsibilities of decision-making to managers through a Contract Management Responsibility System (see Chen 1995 for a comprehensive review of CMRS). To overcome the prevailing short-term behavior encouraged by CMRS, in the 1990s 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". 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 is the obvious evidence.

Like the nature of China's entire reform process, any substantial changes in the system always were preceded by small-scale trial-and-error experiments. The earliest effort to look for managerial and engineering talent outside of China was started by Hu Qili in the preparation of launching Huahong. Hu personally was aware of the Korean history of developing the semiconductor industry by attracting expatriate talent from overseas, and thus in 1996 sent a team to the United States to approach the overseas Chinese engineer community. It was said that the Ministry of Electronics Industry made an offer to Richard Chang, later the founder of SMIC, but was rejected. The Ministry's team also met dozens of overseas Chinese students and engineers. But as the prospects of a joint venture with NEC became clear, the team eventually did not recruit anyone by contending that there was an incompatibility of the American-trained managers and engineers with the Japanese production system (Hu, 2006, p. 42-43). This explanation may not be valid since HHNEC eventually hired the entire team of its senior executives from overseas Chinese in 2002. More likely, there was too much at stake to experiment on such a big national project.[13]

The first experiment in transferring strategic control of a state-owned semiconductor firm out of the government's hands can be traced back to the aftermath of Project 908. In 1998, when Huajing was bearing the heavy loss from the operation of the 6-inch fabrication line, a Hong Kong-registered foundry startup, Central Semiconductor Manufacturing Corporation (CSMC), approached the struggling national champion, proposing to rent the fab for providing foundry services. CSMC was founded by a group of Taiwanese executives who left Mosel Vitelic, a small Taiwanese IDM firm designing and manufacturing DRAMs, to start a new business on the mainland. To get around Taiwan's restrictions on investment in the semiconductor industry in China, CSMC was registered in Hong Kong, but raised funds from Mosel Vitelic and China Resource, a Hong Kong-based conglomerate eager to diversify into the semiconductor business. The source of capital, however, did not make CSMC a case of foreign direct investment. When CSMC came into the deal with Huajing, the company's only assets were a dozen managers. Thus CSMC not only rented Huajing's fab, but also hired its engineers and workers and use the existing technology in the operation (DYBG, No. 12).

On the side of Huajing, the state-owned bank that financed the fab, China Construction Bank, was restructuring to improve its balance sheet, an act organized by

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[13] It might raise questions of why Huahong was willing to contract the management of HHNEC to the Japanese in 1999. Since NEC had a large stake in the joint venture, Huahong may have perceived it as more likely to succeed than placing strategic control in the hands of a number of Chinese managers and engineers.

the state to prepare its banking system for accession to WTO. The loans to Huajing that were classified as non-performing assets were transferred to another newly founded state-owned asset management firm, Cinda. Cinda was a pure financial management entity set up to repackage and sell such failed loans. Thus Cinda did not have an interest in holding the investment in Huajing, but only in seeking to sell the assets to investors when Huajing’s returns improved. And Huajing probably did not have a better choice than agreeing to the proposal from CSMC. Under such circumstances, the state allowed an experiment on the dying Huajing. So in 1998, CSMC commenced operations using Huajing’s fab, workers and technology, combined with Taiwanese managers. In 1999, CSMC and Huajing further established a joint venture on the basis of the fab, with CSMC taking a controlling 51 percent share of the new venture. By 2003, Huajing transferred all of its remaining 5-inch fabs to the joint venture, and China Resource acquired the rest of the Huajing Group.

The main offerings of CSMC were discreet circuits, which are generally less sophisticated than integrated circuits. Even though those were still low-end products, Huajing’s plant achieved profitability under the control of CSMC. The new managers were able to find sufficient orders to fill up the fab, while improving management – achieving higher yields though employing the same workers and technology. The fab even accumulated some earnings for reinvestment. By 2002, CSMC had implemented 0.35-micron process licensed from Singapore’s Chartered (Company website, http://www.csmc.com.cn). In terms of technology, the 0.35-micron process was only on a par with the technology transferred in Project 909 in 1997, but in terms of profitability and sustainability, CSMC was more successful than the state-owned semiconductor firms in the 1990s.

CSMC never grew into a dominant player in China's foundry segment, for it had maintained a small size as well as a low-cost fab strategy. It never aimed to employ cutting-edge processes but rather competed on the base of lower price. Nevertheless, CSMC marked the success of the first experiment of having Chinese semiconductor firms managed by interests outside of the state.

Via CSMC, the management talent of the overseas Chinese was recognized. For instance, Nasa Tsai, one of the executives of CSMC, later became president and chairman of Grace Semiconductor, the indigenous startup that grew to become the second largest foundry in China. In 2000, ASMC (formerly Shanghai Philip), one of the three major JVs, came into a crisis, as some management conflicts between Chinese and foreign partners resulted in the departures of Philip-appointed executives, while another foreign partner, Nortel, withdrew its investment. ASMC faced losing a major customer as well as management expertise. The Chinese eventually solved the crisis by having Shanghai Belling, another Chinese controlled JV, take Nortel's share and by hiring Tony Liu, another executive from CSMC (Fuller, 2005, p.267).

CSMC thus provided a background for expatriate techno-entrepreneurs to start foundries in 2000. By 2002, HHNEC, the largest and most successful state-owned semiconductor firm, decided to hire all its senior executives and engineers from the pool of overseas Chinese, as management decided to transform the firm into a pure-play foundry. Many of these executives were first contacted as early as 1996. At this time, all of the leading semiconductor foundries in China were managed by personnel with overseas experience. It marked a managerial revolution in this industry.

The Chinese embrace of stock-based compensation and venture capital financing in the semiconductor industry was linked to the returnees and the United States, where they gained work experience. The rise of the US semiconductor industry went hand in hand with the emergence of so-called "New Economy". In the "New Economy" business world, particularly in places like Silicon Valley, the norms for business have been technology startup, venture capital and stock options. Engineers and managers with innovative ideas and capabilities are encouraged to start new technology firms instead of staying in established companies. Venture capital firms are the industry that helps the process of firm creation; they provide not only millions of dollars of capital but also management consultancy to these entrepreneurs. Stock-based compensations, particularly stock options, are used to attract, retain and motivate the employees. The options save the cash for the startup, but also raise the expectation of handsome rewards of millions of dollars when they can cash in their options in the stock market after the company draws on a larger pool of investors through an Initial Public Offering (IPO) (see Lazonick 2009 for further discussions on the "New Economy" business model and its various implications for the US economy).

Unlike the step-by-step experiments of the transfer of strategic control, the "importing" of venture capital occurred rather rapidly. Foreign venture capital came to China in the late 1990s during the dot-com boom. They funded the first wave of returned Chinese entrepreneurs and their internet startups to test the business water. Some of these companies, such as Sohu.com, AsiaInfo.com, and UTstarcom, were very successful, bringing wealth and fame to their founders in a short period (Sheff, 2002; Zhou, 2008). The venture capital financing model gained recognition in Chinese society, and the US venture capital firms that were involved found China to be a favorable location to do business. By 1999, when Huahong was involved in venture funding of fabless firms based in Silicon Valley, the venture-capital financing model had been perceived as legitimate in the Chinese semiconductor industry (Chapter 2).

Stock options came to be known in the industry in 1996. When Huahong began to approach the overseas Chinese professionals, it was said that these potential employees raised two concerns about jobs in China. In addition to concerns about bureaucratic management in SOEs, these engineers and managers hoped to maintain a living standard on par with that they had experienced in the United States. To provide this potential income, they wanted stock options (Hu, 2006, p. 44). At that time, Huajing did not even have a plan to be listed on the stock market, not to mention state-approved experiments of stock option plans.

In 1999, Shanghai Belling, the first Chinese semiconductor company listed on the stock market, was also the first Chinese company to introduce a stock option plan (company website, http://www.belling.com.cn). But their stock options were not real stock options in the sense the options were limited. They were given to senior executives and engineers but they could not cash them in on the open market. Instead, they could only be sold back to the company at the stock market prices after certain years of vesting. Since the liquidity of such options was bounded by the financial condition of the company rather than the open market, there were considerable differences between Chinese and US stock options.

SMIC was the first Chinese semiconductor company with the ability to adopt a US-style stock option plan. As the company raised over $1 billion from overseas venture capital firms, it was aiming to be listed on the US stock market from the outset. Shortly after the completion of IPO in 2004, an aggregate of over 900 million units of outstanding options was granted to approximately 7,500 recipients under SMIC's employee stock option plan announced in 2001 and 2004 (SMIC, 2004). Recipients of the stock options include employees, members of the board of the directors and external consultants. Most of the shares went to employees and board members, as only 25 million options were granted to external consultants by the end of 2004 (SMIC, 2005, p. 40). At a time when SMIC only had approximately four thousand managerial and technical staff in total, 7500 recipients of the stock option plan could have covered most of the mangers and engineers. Given that these options entail rights to purchase ordinary shares floated on the Hong Kong stock exchange or ADS[14] in NYSE, they are no different than stock option schemes prevailing in the West.

In 2002, for the state-owned sector to remain competitive in the labor market, the Ministry of Finance and Ministry of Science and Technology jointly issued several regulations that allowed the granting of stock options in the state-owned high-tech companies, including semiconductors. In 2005, after the State Council signaled further liberalization of capital markets in the previous year, permission to grant stock options

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[14] ADS stands for American Depository Shares. Since foreign companies listed in other markets are not permitted to make direct second listing in the United States, ADS was invented as the vehicle for American investor to hold shares of foreign companies. Each ADS represent one or more ordinary shares, which are held on deposit by a custodian bank in the company's home country.

were extended to all companies listed in China, regardless of state-owned, private or owned by foreign investors. In the same year, SASAC[15], the management entity of all state-owned assets, introduced a management stock option program for overseas-listed SOEs. Stock option schemes have, thus, gained legitimation in China.

5.3 Ending Remarks

The development history of the Chinese semiconductor industry provides a lesson for business organization and economic development. Many perceived it as a triumph of the market-oriented, global-integrated business sector over the state-directed, inner-looking public sector (Chesbrough, 2005). But it was never that simple.

As this thesis concluded, 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 attract and utilize experts from overseas, and reorganization of the financial system to support the needs for investment. Without such profound changes in business practices, the convergence to the social conditions that support the uncertain, cumulative and collective process of innovation

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[15] SASAC stands for State-owned Assets Supervision and Administration Commission.

would not occur. Such institutional changes did not happen as an “exogenous shocks”. It happened because of the intensive trial-and-errors in adopting new ways of business organization, guided by the strategic vision of the leadership in both business and government. Such may be the ultimate secret of the success of the Chinese economy.

Appendix

China's semiconductor Industry: A brief history

1956	First semiconductor research department is jointly established by five universities
1957-1964	First transistors are produced; several semiconductor labs are established
1965-1980	Over 40 small IC factories are launched, though many stay in laboratory phrase
1980-1990	Over 24 semiconductor lines are imported, most of which were obsolete 3-inch lines
1988	Shanghai Belling established
1989	Huajing established
1990	Project 908 initiated
1991	Shougang-NEC, a JV between Shougang and Japan's NEC, established
1992	Shanghai Philips, a JV with Netherland's Philips, established
1993	Lucent begins to transfer 6-inch fab related technologies to Huajing
1995	Nortel takes stake in Shanghai Philips, JV renamed ASMC
1996	Project 909 initiated
1997	Huahong NEC established; HHNEC starts to construct China's first 8-inch fab in Shanghai; technology transfer between Lucent and Huajing completed
1998	CSMC took over management of Huajing's 6-inch lines; Belling listed on Shanghai Stock Exchange
1999	CSMC-HJ, a JV between CSMC and Huajing, established as China's first pure-play foundry; HHNEC starts production; Belling takes over Nortel's share in ASMC; Huahong becomes Belling's largest stakeholder
2000	SMIC and Grace established
2002	SMIC enters production; Jazz takes a share in HHNEC; 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
2003	Grace enters production; HHNEC becomes a pure-play
2004	SMIC is listed on New York and Hong Kong; Motorola's fabs in Tianjin is acquired by SMIC, and Motorola becomes the second largest shareholder in SMIC; Shanghai Belling takes a stake in HHNEC; CSMC is listed on Hong Kong
2008	SMIC becomes the first Chinese foundry to have 45-nanometer process technology, licensed from IBM; Datang takes a share in SMIC

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