

**Rapid Advance: High Technology in China in the
Global Electronic Age**

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ABSTRACT

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This study examines how a critical high technology industry in China, the semiconductor industry, advanced from being an isolated, centrally planned industry in the mid 1980s to being an important participant in the competitive global semiconductor industry after 2000. The research examines the most important trends, projects, and enterprises in China, with attention to China's global partners and China's rapidly growing role in the global economy. In the 1990s, semiconductor enterprises in China proactively made key structural changes and global linkages that set the stage for the industry's growth after 2000. The study thus provides an industry level view of gradual industry reforms and technological upgrading in contemporary China, including examining the degree and character of so-called state led development. Finally, the study shows that the development of this high technology industry had direct and positive effects on China's larger policy and operating environment.

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Key Chinese Organizations and Data Sources:

CSIA	China Semiconductor Industry Association
CCID	China Center for Information Industry Development
MII	Ministry of Information Industry
MEI	Ministry of the Electronics Industry (now MII)
CAS	Chinese Academy of Science

CSIA and CCID are the official sources for semiconductor industry data in China. CSIA and CCID data is tied to MII data. See the CSIA and CCID annual reports below. Also, PriceWaterhouseCoopers annually compiles CSIA and CCID data in their report on China's semiconductor industry. See the Bibliography for PriceWaterhouseCoopers' "China's Impact on the Semiconductor Industry."

Recurring Terms:

Semiconductor (chip)	半导体	<i>bandaoti</i>
Integrated Circuit (I.C. or chip)	集成电路	<i>jichengdianlu</i>
Microelectronics (the field of study)	微电子	<i>weidianzi</i>

Discrete Devices: the electronic components that are integrated on a chip, i.e., transistors, capacitors, resistors.

Primary Semiconductor Industry Sectors:

1. Design, done in design houses
2. Manufacturing, called fabrication and done at foundries
3. Packaging-Assembly-Testing (PAT, often called SATS. or SPA&T)

Important documents and collections:

Project Records from Project 909 and Huahong-NEC compiled by Hu Qili, head of Huahong-NEC and former Minister of the Electronics Industry:

Hu Qili 胡启立. *Chao Daguimo Jichengdianlu Gongcheng Jishi* 超大规模集成电路工程纪实 (*Ultra Large Scale Integrated Circuit: Project Records*). Beijing: Dianzi Gongye Chubanshe 电子工业出版社 (Electronics Industry Publishing House), 2006.

Industry History by Wang Yangyuan, co-founder and former Chairman of SMIC and professor at CAS, with co-author Wong Yongwen:

Wang Yangyuan and Wang Yongwen 王阳元, 王永文. *Wo Guo Jichengdianlu Chanye Fazhan Zhilu: cong Xiaofei Daguo Zouxian Chanye Qiangguo 我国集成电路产业发展之路：从消费大国走向产业强国* (China's IC Industry Development Path: From a Big, Consuming Nation to a Strong, Industrial Nation.) Kexue Chubanshe Science Press 科学出版社 (Science Press), 2008.

Collection of works on China's semiconductor industry:

Zhu Yiwei 朱贻伟. *Zhongguo Jichengdianlu Chanye Fazhan Lunshu Wenji 中国集成电路产业发展：论述文集* (China's Integrated Circuit Industry Development: Collected Works.) Xinshidai Chubanshe 新时代出版社 (New Times Press), 2006.

Annual Industry Reports:

Zhongguo Bandaoti Hangye Xiehui he Zhongguo Dianzi Xinxi Chanye Fazhan Yanjiuyuan 中国半导体行业协会和中国电子信息产业发展研究院 (CSIA and CCID). *Zhongguo Bandaoti Chanye Fazhan Zhuangkuan Baogao 中国半导体产业发展状况报告* (China's Semiconductor Industry Development Conditions Report). Annual reports from CSIA.

Shanghaishi Xinxihua Weiyuanhui 上海市信息化委员会 (Shanghai Information Technology Commission). *Shanghai Jichengdianlu Chanye Fazhan Yanjiu Baogao 上海集成电路产业发展研究报告* (Shanghai Integrated Circuit Industry Development Research Report). Shanghai Jiaoyu Chubanshe 上海教育出版社 (Shanghai Education Publishing House), annual reports.

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Dedication

This work is dedicated to my parents,
John Mays and Margaret Ann Mays, for their love.

Chapter One

Introduction

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The evolution of China's economy since 1978 is one of the most fascinating phenomena in contemporary economic history, especially considering the diverse range of industries in China that have engaged with global trade and moved into higher value added activities. The opening of China's centrally planned economy, reforms to China's state owned industries, and China's opening to foreign trade have resulted in rapid advances in commerce, industry, and technology, raising the living standards of hundreds of millions of people in the world's most populous nation. China's late 20th century economic growth occurred on the heels of rapid growth in a number of East Asians, notably Japan, South Korea, and Taiwan, and in the context of the electronics-based Information Revolution. How China's domestic economy transformed and how this transformation was linked to global economic trends are questions of both Chinese history and global economic history.

This study examines how one particular high-tech and capital-intensive industry in China, the semiconductor industry, advanced from being an isolated, centrally planned industry in the mid 1980s to being an important participant in the global semiconductor industry after 2000. The semiconductor industry is a globalized industry with ramifications for commerce, industry, and national security, because semiconductors are the "brains" in all electronic products and systems.¹ Using industry sources and interviews, this study assesses: reforms to China's centrally planned semiconductor industry in the 1980s (Chapter Two); major state supported projects and Sino-foreign partnerships in the 1990s (Chapters Three and

¹ The global semiconductor industry is described later in the Introduction, but generally, the semiconductor industry originated with the development of the transistor at Bell Labs in the U.S. in 1947. By the late 1950s, both Texas Instruments and Fairchild had developed "integrated circuits" (semiconductors), the first of which had only about twelve transistors integrated on a circuit. Semiconductors are thus called integrated circuits or chips, and the field is generally called micro-electronics. Over the years, the number of electrical components (called "discrete devices," e.g., transistors, capacitors, etc.) that can be integrated on a single chip has grown, and now billions of devices can be integrated on one chip. With more discrete devices integrated on a chip, a chip can process faster or store more information.

Four); China's integration with the global semiconductor value chain (Chapter Five); China's changing institutional and policy environment from the 1980s to the early 2000s (Chapters Two and Five); and the trajectory of this industry in China compared to its trajectory in Japan, South Korea, and Taiwan (Chapter Six.)

The primary finding is that, just after reforms to China's centrally planned semiconductor industry in the 1980s, there was a period of approximately twelve years (1988 to 2000) when a combination of "state led development" (that is, state supported enterprises, programs, and policies) and what this study terms "enterprise led development" worked in tandem to enable the semiconductor industry in China to advance. In terms of state led development, from the late 1980s and through the 1990s, Chinese officials and semiconductor industry leaders established (or re-established) a handful of large semiconductor production enterprises, most of which were Sino-foreign joint ventures, as well as establishing new semiconductor design organizations. Officials formed these few large production enterprises not to create a new Chinese "national" semiconductor industry, but rather, officials hoped that the existence of even just one relatively advanced semiconductor enterprise would demonstrate to the global industry that such an enterprise could operate in China's admittedly difficult business environment. Chinese leaders hoped to attract and foster a full semiconductor industry chain in China, including domestic firms, foreign firms, state-affiliated firms, and private firms. Thus, Chinese leaders' state led development efforts in the semiconductor industry were not significantly domestic favoring nor nationalistic, relative to common conceptions of "state led development" in other nations.

In the latter half of the 20th century, industry and government leaders in Japan, South Korea, and Taiwan had successfully sought to develop the semiconductor industry for

national economic and technological upgrading, and Chinese leaders certainly took lessons from their East Asian neighbors. Yet, China's domestic context and its timing and approach differed. In the mid to late 1990s, China was increasingly the site of global manufacturing and assembly for electronic products, and this created a huge and growing domestic market for semiconductors in China. At the same time, advances in electronic communication and standardization in the late 1990s led to vertical dis-integration in the electronics and semiconductor industries. With these trends, Chinese semiconductor enterprises were able to take the approach of entering the industry by sector and providing low-end and mid-range products for the ever-expanding (and increasingly China-based) electronics industry.

In the 1990s, China's state led development efforts were limited mainly to supporting a few production enterprises and R&D programs, and thus much progress in the 1990s occurred through what this study terms "enterprise led development." The few semiconductor enterprises in China in the 1990s faced many difficulties owing to China's still-reforming economy, weak institutions, and inconsistent and disadvantageous trade and investment policies. In particular, this capital-intensive industry suffered for lack of access to capital. Further, China's managers and engineers were stymied by their background in inefficient and low-tech state owned enterprises. For all these reasons, attracting foreign partners was difficult. Nevertheless, the difficulties that China's new enterprises faced in the 1990s led them to undertake organizational, technical, and managerial advances. At the same time, these enterprises did manage to forge partnerships with global firms, thereby integrating the industry in China with the global industry. After about twelve years of this "enterprise led" learning, Chinese officials enacted new and supportive industry-wide policies after 2000 to

address some of the obstacles that enterprises had faced in the 1990s. These policies fostered a new era of growth for both Chinese and foreign semiconductor firms in China after 2000.

Accounts of the semiconductor industry in China in the 1990s mostly cite its under-developed status and its ineffective state led projects and state owned enterprises. And yet, this study shows that between 1995 and 2000, enterprises made significant organizational changes and semiconductor production took off. Indeed, the pioneer enterprises of the 1990s retained their position as leading Chinese enterprises in the early 21st century, joined by a host of foreign and private firms, as was envisioned by Chinese leaders. How should the enterprises and major projects of the 1990s be judged? If judged on profitability, technology, or market share, then certainly they were not global leaders. But if we want to understand the complex process of industrial development in China in the late 20th century, then these enterprises merit our attention. Thus, this longitudinal study is mostly concerned with *how* a particular global, high technology industry evolved in China in the decades immediately after China's "reform and opening" in 1978, but the study also has broader implications for China's contemporary economic evolution and economic development more generally.

1. Economic Development in Modern Chinese History

In considering China's economic achievements since reform and opening in 1978, we must recognize that the late 20th century is not the first period in China's modern history when Chinese leaders have pursued specific plans for economic change and technological advance. Indeed, these were explicit goals of Chinese officials in different eras. In only the last 150 years, Chinese leaders have made several pushes for industrialization. These include: the Self-Strengthening Movement in the late Qing Dynasty (late 1800s) which sought to use

Western technology to “strengthen” China; the Chinese Nationalist government’s efforts in the early to mid 20th century to develop foreign partnerships and build industrial capacity in China; the Chinese Communist Party (C.C.P.)-led industrialization after 1949, with Soviet organizational and technical assistance; and since 1978, the C.C.P.’s pursuit of the “four modernizations” including the modernization of agriculture, industry, national defense, and science & technology. Thus, China’s push for industrial development via foreign assistance since 1978 is not entirely new in Chinese history.

In earlier periods of industrialization, however, Chinese leaders sought to enhance China’s self-sufficiency and independence vis-à-vis other world powers, despite China’s need for foreign technology, and Chinese leaders were keenly aware of potential dependence on foreigners. In contrast, in the contemporary period, Chinese leaders have sought greater integration with other world powers, and while economic self-sufficiency is still a consideration, it has not been an overriding goal.

2. China’s Contemporary Economic History and the Scholarly Literature

China’s late 20th century push for economic development has been particularly effective, garnering much attention from scholars. China has moved from being the world’s tenth largest economy in 1978 to being the world’s second largest economy in 2010, and median per capita income in China has risen dramatically. The 1980s and 1990s were a foundational period in China’s transition from central planning to its “socialist market economy,”² and these decades set the stage for China’s rapid economic advance, especially

² The concept of the socialist market economy was articulated by Chinese leader Deng Xiaoping after 1978. It connotes a mix of state ownership in the economy along with market-based activity.

after 2000. Broadly, China's contemporary economic history from the 1980s to the early 2000s includes central planning, state ownership of enterprises, and state led development, as well as the emergence of private and foreign invested firms and international trade. Scholars have addressed all these diverse topics as well as many other issues that relate to China's contemporary economy. Most of the research on China's contemporary era has been the work of economists, political scientists, and others. Historians are only just beginning to study China's economic evolution since 1978, but this is an opportune time for historians to investigate events, trends, and issues during those decades while records are accessible and memories are still fresh.³ Before assessing how the existing research informs this study, let us first consider the broad outlines of China's history of central planning and China's general approach to economic reforms after 1978.

China's economy was under central planning for only a limited period of years, yet the era of central planning and state ownership of industries greatly influenced China's economic reforms and economy in the 1980s and 1990s. The C.C.P. came to power in 1949, but China initiated central planning under its first "five year plan" for industry in 1953.⁴ However, just twelve years later, China's tumultuous Cultural Revolution disrupted China's economy from 1965 to 1975. Then, from 1978 through the 1980s, Chinese leaders were gradually dismantling central planning. Thus, China's period of central planning was inconsistent and totaled less than thirty years. (In contrast, the U.S.S.R. was under central planning for about sixty years, from 1928 to 1990.) Nonetheless, China's relatively short and inconsistent period

³ Sources for this study are discussed at the end of the Introduction.

⁴ From 1953, the C.C.P. used five year plans for macro-level planning and for setting priorities and goals for China's economy. Since 2006, the C.C.P. has used "five year guidelines," e.g., 2011-2015 falls under the twelfth five year guideline. However, the central government no longer engages in central planning in terms of creating detailed resource allocation plans for production and distribution across industries.

of central planning deeply affected China's economy, institutions, and industries. As Chinese leaders pursued economic and technological advances in the 1980s and 1990s, they had to reform deeply entrenched economic structures, while also fostering new structures and entering into new global processes, i.e., foreign trade and technology transfer.

In the 1990s, Chinese leaders were able to observe the experiences of former Soviet economies that were transitioning away from central planning but they were also able to learn from neighboring economies in East Asia, several of which had experienced rapid economic growth after World War II largely through trade globalization and "state led development."⁵ C.C.P. officials opted not to follow the path of Soviet economies, as these economies had attempted relatively rapid privatization of the state owned sector before the necessary supportive institutions (e.g., law, finance) and services (e.g., marketing, distribution) were in place. Instead, Chinese leaders experimented with some of the development tactics of their East Asian neighbors. Yet, given China's history of central planning and state ownership of industries, China's domestic context was different than that of Japan, South Korea, and Taiwan when those nations initiated state supported industrialization programs and increased global trade in the decades after World War II. In the 1980s and 1990s, Chinese leaders faced the difficult task of having to both reform a vast state owned sector while initiating some of the tactics that had been successful elsewhere in East Asia, such as leveraging low wage labor to produce goods for export markets and providing state support to large industrial enterprises.

⁵ State led development refers to various government policies and programs to foster economic growth, often through trade related policies and often with the goal of strengthening domestic industries relative to foreign competitors. The post World War II economic histories of Japan, Korea, and Taiwan are discussed more fully in Chapter Four, Section 4.41, and Chapter Six.

As a further complication in the 1980s and 1990s, China's institutional and policy environment did not fully support market-based economic activity and international trade.

The following section surveys three areas of existing research that are most relevant to this study of the semiconductor industry in China. First, literature on the reforms to China's state owned sector helps us to understand China's transition from central planning and the ongoing role of state ownership and state support for industrial enterprises. Second, the research on China's weak institutional and policy environment reveals the constraints in China to, for example, firm formation, trade, and technological innovation. This literature shows why many industries in China in the 1980s and 1990s were not operating under neoclassical dynamics, i.e., many for-profit firms in competition balancing supply and demand through price equilibrium. Finally, the field of evolutionary economics offers a rationale for this type of "on the ground" study of a particular industry in China. In particular, the economist Richard Nelson has argued that investigating actual activities, forces, learning, and changes in a particular industry or realm elucidates the evolutionary nature of economic, technological, and institutional advance.⁶

1.1. Extant Literature on China's State Owned Sector

Given China's efforts to reform the state sector and the simultaneous growth of non-state sectors, a number of scholars have addressed different ownership sectors within China's economy. These include the state owned sector, the foreign invested sector, China's

⁶ Richard Nelson, *Understanding Technological Change as an Evolutionary Process* (Amsterdam: Elsevier Science Publishers, 1987), page 8; Richard Nelson, *The Sources of Economic Growth* (Cambridge: Harvard University Press, 1996), pages 6, 292-294; Richard Nelson, editor, *National Innovation Systems* (New York: Oxford University Press, 1993); Richard Nelson, *Technology, Institutions, and Economic Growth* (Cambridge: Harvard University Press, 2005), pages 1-5, 41-43, 54-57, 106-108.

“township and village enterprises,” the informal sector, and the private sector.⁷ A majority of these studies have addressed China’s state owned sector, which is reasonable given the prevalence of state ownership in China since 1949 and the complexity of dismantling central planning and reforming China’s vast state sector after 1978. The state sector was the largest sector in China’s economy in 1978, but from the 1980s to the early 2000s, the sector’s share of China’s gross domestic product decreased relative to other ownership sectors.⁸ In 1980, the state owned sector accounted for approximately 75 percent of China’s gross domestic product of 306 billion. By 2010, China’s economy was about 20 times larger than it was in 1980, and the state sector may have accounted for 35 to over 40 percent of China’s gross domestic product of 6 trillion.⁹ The sector was (and remains) dominant in China’s so-called “strategic” industries, such as infrastructure and banking, and it has significant government influence. The structure and role of this sector has continued to evolve up to the present, thus garnering the ongoing attention of researchers.

The literature on reforms to China’s state sector is directly relevant to this study because the electronics and semiconductor industries in China were centrally planned and

⁷ Just of few of these include: Hongyi Chen, *The Institutional Transition of China's Township and Village Enterprises* (Ashgate: 2000); Yasheng Huang, *Foreign Direct Investment in China* (Hong Kong: Chinese University Press, 1998); Kelley Tsai, *Back-alley Banking* (Ithaca: Cornell University Press, 2002); Peter Nolan, *China and the Global Economy* (New York: Palgrave, 2001.)

⁸ Since perhaps 2009, the state sector may have grown in terms of its contribution to China’s GDP. China’s stimulus package for the financial crisis of 2008-2009 went mostly to state owned enterprises. Since that time, the notion that “the state sector advances, the private sector recedes” (*guo jin min tui* 国进民退) has become increasingly popular. Here, the state sector refers to both state owned enterprises, enterprises in which the state is the largest shareholder, and “collective” enterprises. For an analysis of the size of China’s state sector, see the U.S.-China Economic and Security Review Commission, “An Analysis of State owned Enterprises and State Capitalism in China,” October 26, 2011.

⁹ Gross domestic products figures are from the United Nations and World Bank. The share of the state owned sector is difficult to determine, but these estimates are from the U.S.-China Economic and Security Review Commission, “An Analysis of State owned Enterprises and State Capitalism in China,” October 26, 2011.

state owned prior to 1978,¹⁰ and the semiconductor industry was designated as a “strategic” industry in China. Thus, this study uses existing cross industry research on China’s state owned sector as well as sources specific to the semiconductor industry to analyze how Chinese officials dismantled central planning in China’s semiconductor industry and reformed the structure and guidance mechanisms of the national semiconductor industry in the 1980s and 1990s.

Existing research on China’s state owned sector has addressed the sector’s overall organization as well as the governance and ownership structures of state owned enterprises and enterprise management.¹¹ In the 1970s, China’s state owned enterprises and research institutes were organized into vast vertical hierarchies under various industrial ministries. China’s state sector has been through several rounds of reform and restructuring since 1978, including re-organizations within industries, ownership restructurings, mergers, and the “releasing” (de-funding) of certain state factories and institutes.¹² Most studies of China’s state sector do not differentiate between industries, but rather they identify general structures, practices, and problems in China’s state owned sector across industries. In the 1990s and 2000s, scholars noted progress in China’s state owned enterprises in terms of product diversity and quality, managerial independence, technical skills, assets held, and international

¹⁰ Denis Simon, *Technological Innovation in China* (Cambridge: Ballinger Publishing, 1988.)

¹¹ See Peter Nolan, *China and the Global Economy* (Houndsmill: Palgrave, 2001); Dyland Sutherland, *China’s Large Enterprises* (New York: Routledge, 2003); Edward Steinfeld, *Forging Reform in China* (Cambridge: Cambridge University Press, 1998); Chen Derong, *Chinese Firms Between Hierarchy and Market* (Britain: Macmillan Press, 1995.)

¹² Chapter Two details reforms to the state owned electronics and semiconductor industries in China in the 1980s. Chapter Four, Section 4.42, further addresses China’s state owned sector in the 1990s. At this writing, China now has over 100 large state owned “enterprise groups” under the State Owned Assets Supervision and Administration Commission (SASAC), under China’s State Council. The SASAC is the controlling shareholder in the large enterprise groups. Each large enterprise group has a number of state owned or state invested enterprises “under” it in a vertical hierarchy, usually within an industry, resulting in tens of thousands of organizations falling under China’s large enterprise groups.

cooperation and expansion. Nonetheless, significant problems endured, e.g., ongoing political interference, deficiencies in governance structures, operational inefficiencies, “soft” budgets, and corruption, among other problems. Studies of state owned enterprises in China from the 1980s, 1990s, and early 2000s often suggested that this colossal and troubled sector was a hindrance to China’s economy.¹³

And yet, economic growth in China was rapid. How do we reconcile the studies of China’s state owned sector with the rapid growth of China’s overall economy in the 1980s, 1990s, and beyond? Studies of China’s state sector identified the broad elements of reform and ongoing problems, yet in a number of industries, China’s state owned sector gradually evolved from being a dominant and self-contained sector to being integrated with other ownership sectors. Studies of the state sector, several of which are set in the state dominated iron and steel industries, do not necessarily show how reforms to the state sector were executed in other industries or how other industries evolved from state ownership to mixed ownership in the 1990s and beyond. The dominance of the state sector varied by industry. Heavy industries, infrastructure, and banking, for example, were (and remain) dominated by the state sector, but other industries, e.g., light industries, certain service industries, and high technology industries, either were not dominated by the state sector or the dominance of the state sector decreased significantly during the 1980s and 1990s. Differences in state sector dominance by industry (i.e., steel versus textiles) and the state sector’s increasing integration with other ownership sectors (i.e., the foreign invested sector, the private sector) have rendered cross-industry generalizations about the state sector less useful for understanding the

¹³ Steinfeld, *Forging Reform*; Barry Naughton, *Growing Out of the Plan* (Cambridge: Cambridge University Press, 1995); Nicholas Lardy, *China’s Unfinished Economic Revolution* (Washington D.C.: Brookings Institute Press, 1998).

trajectory of China's overall economy and specific industries. An article from 2010 is worth quoting at length:

“It is no longer possible to characterize China's state owned enterprises in the simple bifurcated terms of decades past. ...The distinctions between state owned and private sector firms in China have blurred significantly. The “traditional “ or “pessimistic” view of China's SOEs ...[as]... dinosaurs ... stands in stark contrast to the profile of those state enterprises that have engaged in global partnerships and acquisitions. ... In the foreseeable future the traditional distinctions between [ownership sectors] of the Chinese economy will bleed even more, as state owned enterprises' ownership structures become of secondary importance to the level of flexibility and receptivity displayed in [their] corporate management and business practice.... given the progressive ability of state owned enterprises to attract managerial talent and develop innovative products and processes... There are of course relativities here in terms of [different industries] ... For example, political influence in ...[utility or oil companies]...would be far greater than in say the appliance giant Haier or computer maker Lenovo.”¹⁴

Thus, while studies of China's state owned sector have identified significant problems and changes in the sector, these studies alone do not identify the factors and processes that have contributed to China's economic and technological advances. In this study of the semiconductor industry, we see that in the 1990s a few new state supported semiconductor enterprises played an important role in integrating the industry in China with the global industry and in training a pool of semiconductor personnel that would eventually populate new (non-state) semiconductor-related firms. While these state supported semiconductor enterprises had some of the problems endemic to state owned enterprises across industries in China (operational inefficiencies, “soft” budgets, etc.), nonetheless, they did not stifle the development of the semiconductor industry. Rather, their particular activities and influences

¹⁴ John Hassard, Jonathan Morris, Jackie Sheehan, and Xiao Yuxin, “China's State-owned Enterprises: Economic Reform and Organizational Restructuring,” *Journal of Organizational Change Management*, 23.5, 2010. Nine of ten of the state owned enterprises studied for this article were iron and steel enterprises.

from the broader global industry moved the industry forward, as we will see in Chapters Three, Four and Five.

1.2. Extant Literature on China's Institutions and Policy Environment

In addition to dismantling central planning and reforming the state owned sector, China's contemporary economic history also includes the emergence of non-state and foreign invested firms and international trade. With these developments, scholars have rightly turned their attention to China's institutions and policy environment, especially in terms of China's legal and regulatory systems, financial system, educational system, and China's science and technology "system,"¹⁵ as scholars widely agree on the importance of institutions for economic growth.¹⁶ China's institutions have undergone significant change and development since the 1980s, but scholars such as Yasheng Huang, Edward Steinfeld, and Nicholas Lardy have shown that during the 1990s China's institutions were quite weak by Western standards.¹⁷ During that decade, China's weak legal protections, financial regulations, and trade policies indeed created obstacles for Chinese and foreign semiconductor firms.

¹⁵ On higher education, see Denis Simon and Cao Cong, *China's Emerging Technological Edge* (Cambridge: Cambridge University Press, 2009); on science and technology, see Tony Saich, *China's Science Policy in the 1980s* (Atlantic Highlands, New Jersey: Humanities Press International, 1989); on banking and finance, see James Barth (editor), *Financial Restructuring and Reform in Post-WTO China*, 2007; on China's legal system, see Guanghua Yu (editor), *The Development of the Chinese Legal System* (New York: Routledge, 2011.)

¹⁶ Peter Evans, *Embedded Autonomy* (Princeton: Princeton University Press, 1995 and 2001); Richard Posner, *The Economic Structure of Intellectual Property Law* (Cambridge: Harvard University Press, 2003); William Roy, *Socializing Capital: The Rise of Large Industrial Corporation in America* (Princeton: Princeton University Press, 1997); Richard Nelson (editor), *Sources of Industrial Leadership* (Cambridge: Cambridge University Press, 1999); Barth (editor), *Financial Restructuring*; Yu (editor), *The Development of the Chinese Legal System*; Simon and Cao Cong, *China's Emerging Technological Edge*; Saich, *China's Science Policy*.

¹⁷ See Yasheng Huang, Steinfeld, and Saich, *Financial Sector Reforms in China* (Cambridge: Harvard University Press, 2004); Huang, "An Institutional and Policy Approach to the Demand for Foreign Direct Investment in China" in *China Review 2000* (Hong Kong: Chinese University Press, 2001.)

In the 1990s, China's legal and regulatory systems were still developing. For foreign firms attempting to do business in China, there were regulations in place for establishing Sino-foreign joint ventures, Sino-foreign partnerships, and distributorships in China, but foreign firms had to negotiate with Chinese officials from an array of governmental organizations to establish such operations. In setting up operations in China, foreign firms were concerned about due diligence and transparency, contract development and negotiations, and contract enforcement in China. Further, China did not offer adequate protection for intellectual property, and foreign firms were reluctant to share intellectual property or trade secrets with Chinese partners or to manufacture higher end products in China. Uncertainties about property protection and contract enforcement and the need to negotiate agreements with multiple governmental bodies served to reduce foreign firms' activity in China in the 1990s.¹⁸

Yet, foreign firms' participation in China was important in the 1990s because China's lack of capital markets at that time meant that many industries in China sought foreign capital and foreign investment. Foreign firms, however, faced investment restrictions in China as well as restrictions on moving money out of China. As for Chinese firms, state supported enterprises could get capital infusions from Chinese government organs or state owned banks, but new, non-state firms in China (newly allowed under China's 1994 Company Law)¹⁹

¹⁸ Semiconductor Industry Association prepared by Dewey Ballantine LLP, "China's Emerging Semiconductor Industry," October 2003; Congressional-Executive Commission on China, statement by Semiconductor Industry Association's Daryl Hatano, "Is China Playing by the Rules?," September 24, 2003.

¹⁹ China enacted a new "Company Law" in July of 1994. This law established new forms of ownership as well as new corporate governance mechanisms. In the late 1980s and early 1990s, Chinese officials experimented with a number of reforms aimed at establishing some legal basis for corporate forms. Prior to the 1994 law, China's state owned enterprises were not independent legal entities and they lacked property rights commonly attributed to "property" in the West, such as the right of ownership, the right to use, the right of returns on property, and the right to transfer property ("alienation.") The Company Law of 1994 established the legal basis of joint stock companies and limited liability companies. For limited liability companies and joint stock companies, the new Company Law established shareholder rights and duties as well as structures of corporate

mostly did not have access to capital through options that are common in the West, i.e., vendor financing, lease financing for capital equipment, government-backed small business loans, bank loans, or venture capital.²⁰ In the capital-intensive semiconductor industry, particularly in the production sector, non-state firms' lack of access to capital ensured that such firms would not emerge nor play a significant role in the industry during the 1990s.

In the 1990s and into the 2000s, scholars and industry personnel expressed valid concerns that China's economy would eventually be stalled by inadequate institutions.²¹ As just one example, in 1999 the Chief Financial Officer of a Fortune 500 commented "China has had a good run until now, but China's economy will never really go anywhere without the rule of law and protection of property rights."²² And yet, economic growth continued apace, despite China's less than robust legal system. Of course, China's economy may still falter in some significant way, but since 1999, China has gone from being the world's seventh largest economy to being the world's second largest, with approximately ten percent annual growth.

Notably, in his 1995 book *Growing Out of the Plan*, China scholar Barry Naughton wrote that in China "institutional change has consistently lagged behind the changes in the economy."²³ Naughton suggested that as China's economy was growing in the 1980s and 1990s, Chinese officials came under increasing pressure to gradually develop the legal and

governance, i.e., the roles and duties of corporate boards and directors and the requirements for disclosure, transparency, and monitoring of company records.

²⁰ Stock markets and private equity are less relevant for start up companies in the West.

²¹ Steinfeld, *Forging Reform*, pages 24, 254, and 258. Steinfeld concluded that ownership restructuring within China's state owned enterprises would be ineffective if undertaken before reforms to China's institutional and regulatory environment. He argued the legal basis for ownership *itself* had to be established in China, regardless of whether the state or other actors were the owners. Lardy, *China's Unfinished Economic Revolution*, pages 124-127, 183-186, and 202-209 on structural problems in China's financial institutions.

²² Thomas Bindley, Chief Financial Officer of Whitman Corporation, 1999.

²³ Naughton, *Growing Out of the Plan*, page 322.

financial systems that global industries needed.²⁴ More recently, a 2011 article by legal scholars asked “How is [China’s] system, without a plethora of formal institutions deemed important to Western firms, producing a rapidly expanding list of Fortune 500 companies and supporting high and sustained levels of economic development?”²⁵ Indeed, how? It seems Barry Naughton’s 1995 observation about institutional development *following* economic development may have held true in 2011. Corporate governance in China’s state owned enterprises has evolved over the years, but the authors of the 2011 article show significant enterprise growth prior to the establishment of formal institutions presumed to be important. Economic growth might have been more rapid in China’s emerging economy from the 1980s if presumably important institutions and policies had been in place, but China’s institutional weaknesses did not totally thwart growth. In the semiconductor industry, this study shows that the industry’s development ultimately prompted improvements in China’s institutional and policy environment. That is, Chinese officials saw that certain institutional and policy weaknesses were a hindrance to the semiconductor industry, and they responded by enacting new and more supportive policies.

The preceding discussion addressed formal institutions, mainly China’s legal, regulatory, and financial systems, however, a number of scholars have also studied state led development in China and elsewhere, where state led development itself can create a type of institutional environment.²⁶ The literature on state led development is discussed more fully in

²⁴ Similarly, William Roy has shown that during the second industrial revolution large U.S. enterprises influenced national institutions.²⁴

²⁵ Lin and Milhaupt, “We are the (National) Champions: Understanding the Mechanisms of State Capitalism in China,” *Columbia Law and Economics Working Paper*, Number 409, November, 2011.

²⁶ Robert Wade, *Governing the Market: Economic Theory and the Role of Government in East Asian Industrialization* (Princeton: Princeton University Press, 1990); Alice Amsden, *Asia’s Next Giant* (Oxford: Oxford

Chapter Four, Section 4.4, but here, suffice it to say that for Japan, South Korea, Taiwan, Singapore, Hong Kong, China, and other nations scholars have argued that state policies designed to promote economic development created a supportive context in which certain industries were able to develop.²⁷ State led development may include industrial policies for: protecting infant industries; achieving import substitution; promoting exports; funding technology transfers from abroad; providing capital to domestic enterprises; supporting “national champion” enterprises; or funding education, research, and industrial parks. With this literature in mind, this study indeed examines state policies and programs for the semiconductor industry in China, which were undoubtedly influential, whether or not they were optimal.

1.3. Extent Literature on Industries in China and Evolutionary Economics

How did China’s economy transform from being relatively isolated and centrally planned in the early 1980s to being globally integrated and of mixed ownership after 2000, given China’s weak institutions and problematic state sector? Could we learn something about China’s post 1978 economic growth and change by looking at events and trends in particular industries, rather than by looking at certain ownership sectors *across* industries, as has been the more common approach? Industry-specific, longitudinal studies seem appropriate given that much of China’s “take off” is located in particular industries or groups

University Press, 1989); Chalmers Johnson, *MITI and the Japanese Miracle: The Growth of Industrial Policy, 1925-1975* (Stanford: Stanford University Press, 1982); Dylan Sutherland, *China’s Large Enterprises and the Challenge of Late Industrialization* (London: RoutledgeCurzon, 2003).

²⁷ Not everyone is convinced that state led development was the primary cause of rapid growth in East Asia. The neoliberal, orthodox view challenges the results of industrial policies in East Asia, arguing instead that the rapidly developing nations of East Asia in the latter half of the 20th century “got the fundamentals right” and relied largely on market orientation and trade liberalization. For a further explanation of the neoliberal, orthodox view, see the footnote on this topic in Chapter Four, Section 4.41.

of industries. China's economy has expanded through growth in agriculture, various light manufacturing industries, electronics, and raw materials and natural resources. Further, China's five year plans (now called "five year guidelines") are largely organized by industry, with each five year plan proffering policies, goals, and support mechanisms for specific industries and technologies. Thus, it seems that China's government has viewed industry-specific development as germane to China's overall economy. Finally, business historians of modern China have chosen to study specific industries, including the salt industry, pharmaceutical industry, tobacco industry, and others, and their studies elucidate organizational structures, mechanisms, and practices in China's economic history.²⁸

There are just a few book length studies of specific industries in contemporary China, and three such studies that relate to the electronics industry were influential to this study, either in approach or content. This study in effect picks up where Denis Simon and Detlef Rehn left off in their 1988 book *Technological Innovation in China: The Case of the Shanghai Semiconductor Industry*. Actually, Simon and Rehn's book concludes that until the mid to late 1980s there was little actual technological innovation in the semiconductor industry in China because of the rigid and still fairly isolated nature of China's centrally planned and state owned semiconductor industry. In the mid 1980s, China's semiconductor

²⁸ See Madeleine Zelin, *Merchants of Zigong* (New York: Columbia University Press, 2005), Sherman Cochran, *Big Business in China* (Cambridge: Harvard University Press, 1980), and Robert Gardella, *Harvesting Mountains* (Berkeley: University of California, 1984.) These studies address particular industries and their contexts during the Qing Dynasty and Republican Era. Beyond China, prominent business and economic historians including Alfred Chandler have used industry case studies to understand economic history. See Alfred Chandler, *Strategy and Structure: Chapters in the History of the Industrial Enterprise* (1962) and *The Visible Hand: The Managerial Revolution in American Business* (Cambridge: Harvard University Press, 1977) and *Scale and Scope* (Cambridge: Harvard University Press, 1991); Naomi Lamoreaux and Daniel Raff (editors), *Learning by Doing in Markets, Firms, and Countries* (Chicago: University of Chicago Press, 1999); Charles Sabel and Jonathan Zeitlin (editors), *World of Possibilities: Flexibility and Mass Production in Western Industrialization* (New York: Cambridge University Press, 1997); Louis Galambos, *Networks of Innovation: Vaccine Development at Merck, Sharp, and Dohme, and Mulford, 1895-1995* (New York: Cambridge University Press, 1995.)

industry officials were just beginning to plan significant organizational reforms, so Simon and Rehn's study is mostly a very detailed study of China's policy-making processes and China's semiconductor bureaucracy, rather than actual technological innovation. The difference between their study and this research is stark. This research builds on Simon and Rehn's exposition of the semiconductor industry's institutional structure, and it describes and analyzes the dynamic and uncertain period that followed initial introduction of reforms in the mid 1980s. Another study that was directly helpful to this research was Anthony Saich's 1989 *China's Science Policy in the 1980s*. Saich's study addresses the structure and intended reforms to China's scientific and research organizations during the 1980s. Finally, a study that was similar in approach to this one is Lu Qiwen's 1999 *China's Leap into the Information Age: Innovation and Organization in the Computer Industry*, which identifies the institutions, human capital, and key enterprises in China's growing computer industry in the 1980s and 1990s.²⁹ Lu was a former engineer who worked for several years in technical organizations in China. Lu later researched the evolution of China's computer industry as a sociology Ph.D. candidate at Harvard. Lu's study and this study are quite similar in approach,

²⁹ Saich, *China's Science Policy in the 1980s* provides excellent background on the organization and policies of China's research activities. Qiwen Lu, *China's Leap into the Information Age* (Oxford: Oxford University Press, 2000.) Lu argues that China's computer industry was able to advance rapidly in the 1990s due to the existing domestic market demand and the domestic knowledge base (science and R&D base) already in place from the central planning era. Lu died young, and an advisor, William Lazonick, had his dissertation published as a book after his death. Lu's wonderful book served in part as a model for this research. Further, Adam Segal, *Digital Dragon* (Ithaca: Cornell University Press, 2003) focuses on different government policies by region in China for a diverse group of high technologies industries. Finally, two dissertations have in part addressed China's semiconductor industry. A political science dissertation from MIT in 2005 dealt with the financing of semiconductor firms in China. Its purpose was to identify whether firms in China had better technological outcomes if they used foreign financing rather than Chinese state financing. The research also sought to show the futility of Chinese industrial policy. Another dissertation, from University of Wisconsin's sociology department in 2005, attempted to make a "sweeping analysis of the commodity chains of different sectors" across what the author called the "information industries" in China. The semiconductor industry fell into this broad sweep. The author analyzed why the "information industries" are moving to China and concluded that the main reason was China's growing domestic market.

except that Lu's writing was contemporaneous with events, leaving less time to assess transitions in the industry. A second difference between Lu's study and this one has to do with industry characteristics. Sectors of the computer industry are far less capital intensive than the semiconductor industry, leading to the two industries having different approaches and timing in their development in China in the 1980s and 1990s.

There are other studies that ostensibly focus on particular industries in China, but these studies are actually about broader issues such as the efficacy of different ownership sectors in China, China's institutional environment, or state led development in China. These studies use case studies of particular industries to support theses on broader topics or to support proposals for future policies, and so the studies are not primarily concerned with how particular industries evolved in China. A good example of this type of study is Edward Steinfeld's 1998 *Forging Reform in China: The Fate of State Owned Industry*. Steinfeld studied state owned enterprises in the steel industry in China, and he identified "soft" budgets and the lack of institutional and regulatory support for ownership as problems in China's state owned sector as well as in China's broader economy. His study does indeed trace the evolution of the steel industry, but Steinfeld's real contribution is his critique of China's legal and regulatory environment and the functioning of the state owned sector *across* industries in China. Steinfeld called China's state dominated steel industry a "bellweather" for state owned enterprise reform and governance across China, and he concluded in 1998 that China's "modern industrial sector [is] on the verge of collapse, and [China]... is contemplating... industrial stagnation." With the benefit of fifteen years of hindsight, Steinfeld's research correctly identified important problems in China's state owned enterprises and institutions,

but it told us less about the overall trajectory of diverse industries in China, many of which were not dominated by the state sector and advanced significantly in the 1990s and beyond.³⁰

What do we hope to learn from an industry specific study? The start of this section mentioned that China's five year plans are in part organized by industry and that China has made notable progress in certain industries. These tangibles hint that perhaps we should look at particular industries to understand China's recent economic history, and the field of evolutionary economics offers a further rationale for undertaking a multi-faceted, longitudinal, industry-specific study.

Evolutionary economics is concerned with how economic structures, processes, and factors interact to mutually change one another over time. In the view of evolutionary economics, organizations, firms, industries, institutions, trade, and other economic loci gradually evolve through small changes in routines, technologies, or processes. Economists from various fields, including evolutionary economics, broadly agree that technological advance is a primary driver of productivity increases, economic growth, and improved living standards around the world. Other factors contributing to economic development are accumulation of physical and human capital, firm and industry organization, resource allocation, and various "institutions," although quantifying each of these components is difficult. Here, "institutions" includes formal institutions such as legal and financial systems, but cultural constructs and norms can also create "small i" institutions, and new industry-specific institutions can emerge which might include new technical standards, new ways of interacting or organizing, new technical societies, new intellectual property issues, and the

³⁰ Steinfeld, *Forging Reform*, pages 24, 254, and 258.

like.³¹ Thus, the term institution can be used to mean different things, but in all these meanings, institutions constitute the “rules of the game” and contribute to economic and technological evolution.³² In evolutionary economics, technological and institutional innovation is seen as an evolutionary process in which different mechanisms, organizational forms, etc. are developed, tested, and selected leading to gradual change. In this way, economic development is seen as “path dependent;” history matters because, through time, a number of tangible economic inputs as well as formal and informal institutions, routine behaviors, and culture all are constantly interacting while new approaches are tested and selected. This leads to institutional and technological learning and ultimately to economic development. In this view, “the qualitative historical record and description matter,” according to Nelson.³³

In light of this, Nelson has proposed that scholars analyze economic evolution through a “bottom up” approach. That is, to understand economic growth, scholars should look at the “activities involved, the forces bearing down on them, and the key institutions,” perhaps by industry, identifying the important “learning by doing” that occurs. Nelson notes that there are significant differences between industries and sectors and that “the birth and death of industries are an essential part of the economic growth story.”³⁴ Thus, like other scholars that

³¹ Nelson, *Technology, Institutions, and Economic Growth*, pages 106-108.

³² Regarding institutions, see <http://money.163.com/special/coase/> for a series of Chinese interviews with Ronald Coase on how his ideas about institutions, laws, property rights, transaction costs, etc., have influenced economists in China. Also, see Douglas North, *Institutions, Institutional Change and Economic Performance* (Cambridge University Press, 1990); Oliver Williamson, *The Economic Institutions of Capitalism* (New York: Free Press, 1985); Ronald Coase, “The New Institutional Economics,” *American Economic Review*, May 1998.

³³ Nelson, *Understanding Technological Change as an Evolutionary Process*, pages 1-3, and *Sources of Economic Growth*, page 6.

³⁴ Nelson, *Technology, Institutions, and Economic Growth*, page 43, and *Understanding Technological Change as an Evolutionary Process*, pages 3-9, and *Technology, Institutions, and Economic Growth*, page 1.

have analyzed changes in particular industries to understand economic growth,³⁵ Nelson seems to suggest an industry-specific approach, as he argues that many economic forces are linked by industry, i.e., university research programs align with particular industries, intellectual property issues vary by industry, professional and technical organizations are industry-specific, government programs target specific industries, etc. A qualitative account of an industry's history would include these factors, and where possible, the standard neoclassical factors, i.e., prices, quantities, etc., would also be analyzed.³⁶

Further, within industries, Nelson argues that the mere accumulation of physical and human capital and access to more advanced technological designs are not enough to ensure advance, especially if an industry or technology is new to a country. "Assimilation" is also necessary; that is, people, organizations, and industries must assimilate to:

"new sets of skills, new ways of organizing economic activity, and familiarity with and competency with new markets. To do [so is] far from a routine matter... the assimilation account stresses learning about, risking to operate, and coming to master technologies and other practices that are new to a country. Controlling a complex technology often involve[s] knowing how to manage a very complex division of labor as much as it involves knowing the relevant physics and chemistry. ...The marshaling of inputs is part of the story, but the emphasis is on ... learning. Accumulationists [in contrasts to 'assimilationists'] seem to believe that the state of technological knowledge at any time is largely codified in blueprints and associated documents. In contrast assimilationists argue that only a small portion of what one needs to know to employ a technology is codified in the form of blueprints; much of it is tacit, and learning is achieved as much by doing and using as by reading and studying."³⁷

³⁵ Amsdem, *Asia's Next Giant*, 1989; Michael Hobday, *Innovation in East Asia* (1995); Linsu Kim, *Imitation to Innovation* (Boston: Harvard Business School Press, 1997), mentioned in Nelson, *Technology, Institutions, and Economic Growth*, pages 54-57.

³⁶ Nelson, *The Sources of Economic Growth*, pages 3-6 and 278 and *Technology, Institutions, and Economic Growth*, pages 2-5 and 154-155.

³⁷ Nelson, *Technology, Institutions, and Economic Growth*, pages 41-43.

In light of this, Nelson proposes that scholars not begin with institutions to see how institutions (either formal or informal) affect activities, but rather he proposes that scholars begin by empirically examining activities within industries and see how activities and interactions foment learning and how this learning gradually changes technologies and institutions. Here, institutions and technologies are not static, but are always evolving through learning.

3. Approach to this Study

This study investigates the key events, trends, influences, and issues in the semiconductor industry in China from the late 1980s to the early 2000s, and the detailed description and analysis of this one industry may suggest how advanced, global industries have developed in contemporary China. For the semiconductor industry, this research addresses how the industry evolved from being isolated and backward in China in the late 1980s to China being an important site for the global semiconductor industry in the early 2000s. The approach is to focus mostly on what *did happen*, while also acknowledging what was *missing* during this period. That is, the semiconductor industry in China was undeveloped in the late 1980s and was still relatively small and lower-tech in the 1990s and early 2000s, as compared to the industry in, say, the U.S. or Japan. To explain the relative status of the industry in China during this time, observers rightly note a number of *missing* factors: access to capital; intellectual property protection; transparent and consistent business environment; openness to foreign investment, trade, and ownership; and finally a dominant role for private (versus state supported) enterprises. Indeed, these were all constraints, and they all emerge in the story of the semiconductor industry in China. However, despite these

constraints, industry revenues in China grew by a multiple of 68 times from 1990 to 2005 (US\$0.56 billion to US\$38.1 billion), by which time China was an important site for the global industry. Thus, in addition to acknowledging all that was missing in China, this study looks closely at what actually *did happen* in China to create this growth. In this way, we can understand the gradual – yet phenomenal – changes in a critical high technology industry.

The research focuses on three periods: 1) the mid to late 1980s, when China's semiconductor industry was centrally planned and state owned but in the midst of significant and complex reforms, 2) the 1990s when the industry faced many difficulties and “learned” in the course of establishing and operating several “key” and “national champion” semiconductor enterprises, all of which had global partners, and 3) the late 1990s and early 2000s when Chinese officials established new policies for the industry, ushering in more rapid development for both Chinese and foreign semiconductor firms in China. During these periods, the study covers the industry's evolving structure and key policies as well as the largest enterprises and projects in China (sources are discussed at the end of the Introduction.) For the large enterprises and projects, the research identifies the goals, activities, lessons learned, outcomes, and resultant changes in the industry, an approach inspired by the works of other business historians and the field of evolutionary economics. In describing and analyzing the industry's history, as much notice is given to challenges and failures as to progress.

Because of China's history of central planning and state ownership in the semiconductor industry and because of extremely high capital requirements in this industry, semiconductor firms in China in the 1990s were not operating in a neoclassical paradigm of for-profit firms competing in a market, balancing supply and demand through price

equilibrium. During that decade, China had a large and growing market for semiconductors, but this market demand was largely supplied by foreign-made, imported semiconductors. Certainly, the global semiconductor industry in the 1990s consisted of for-profit firms in a highly competitive environment. In China, however, the industry was in a period of technological “catching up,” and it had just a few state supported Sino-foreign production enterprises and (Chinese) research and design programs, although the industry was moving toward mixed ownership. Thus, this study covers not only firms but also various actors in the industry including government funded programs, research and design organizations, and university programs. The approach to this study therefore is an evolutionary economics approach (that is, it includes all influences in the industry); the approach is not to quantitatively analyze neoclassical factors, i.e., the output, pricing, productivity, etc., of competitive firms.

This study is ultimately about the development of the globalized “semiconductor industry in China,” as opposed to being about “China’s semiconductor industry.” The research necessarily addresses China’s state-affiliated enterprises, projects, and plans as these were important in the contemporary history of the industry in China. However, unlike some other studies, the primary purpose of this study is not to assess the efficacy of China’s state owned enterprises or state led development in China.³⁸ Rather, this study of the global semiconductor industry in China is a window on how China’s contemporary economy has evolved and in particular how global high technology and capital intensive industries may have developed in China.

³⁸ For example, no attempt is made to compare the actual history with a counterfactual history, such as comparing the economic outcomes of China’s state supported enterprises with (counterfactual) private enterprises in an attempt to judge whether China’s path was economically optimal.

4. Primary Findings in the Semiconductor Industry

In examining how the semiconductor industry developed from the mid 1980s and through the 1990s, we find that immediately on the heels of the “divestiture”³⁹ of China’s centrally planned semiconductor industry (1985-1987) there was a period of about twelve years during which the experiences of individual enterprises resulted in significant industry learning. This learning phase was critical in the industry’s transition from central planning to global integration. Ultimately, lessons learned in enterprises during 1990s led Chinese officials to announce industry-wide policy changes in 2000-2001. Here, “enterprises” refers to state owned enterprises, but also Sino-foreign joint ventures, foreign firms, and Chinese non-state firms. Some of the enterprises’ experiences were based in state supported enterprises (see Chapters Three and Four) while other experiences were predicated on China’s opening to global trade (see Chapters Four and Five.)

For the semiconductor industry, this critical twelve-year period from the late 1980s and through the 1990s was a time of what this study calls “enterprise led development” working in conjunction with state led development. In the 1990s, state led development in this industry consisted of targeted state supports, i.e., one-off state supported technology transfer agreements, research investments, state supported Sino-foreign joint ventures, etc., executed through government-led mechanisms common in China. (However, state led development in the 1990s did not include semiconductor industry-wide policies or production planning.) Notably, the goal of state led development efforts was to foster the emergence of a diverse semiconductor industry value chain in China, including firms of various ownership

³⁹ The “divestiture” largely entailed “releasing” (that is, de-funding) certain state owned factories and institutes, although a national industry structure remained in place. See Chapter Two for more detail.

types. The goal of state led development was not to enable Chinese firms to dominate the industry in China or to attain self-sufficiency in semiconductor production.⁴⁰

Chinese semiconductor officials and enterprise leaders commenced operations for several large enterprises and projects in the 1990s, and these individual enterprises were ultimately sites for enterprise led development. In both start up and operations, these enterprises and their foreign partners met many obstacles, such as slow government approvals, inability to effectively use imported equipment, restrictions on foreign investment, foreign reticence regarding China's intellectual property protection, among other obstacles, as shown in the following chapters. In working through these obstacles, the enterprises underwent significant learning. By tracing the history of the major enterprises and projects, this research identifies clear shifts in:

- Industry structure: toward de-verticalization by industry sector (a global trend)⁴¹
- Enterprise ownership: from state owned, to Sino-foreign joint ventures, to wholly-foreign owned enterprises
- Enterprise organization: toward standard accounting units, linkages between design and production, etc.
- Technologies utilized: from 6 inch to 12 inch wafers, among other technological upgrades
- Markets served: from serving the low end Chinese market toward the low-to-medium global market
- Talent base: from Chinese to Chinese plus global personnel

⁴⁰ Some observers have stated that China sought to be “self-sufficient” in semiconductor production in 1990s. This issue is addressed in Chapter Four.

⁴¹ In the semiconductor industry, de-verticalization primarily meant that different sectors of the semiconductor value chain were increasingly handled by different firms, rather than all being handled “in house” by one firm. In the semiconductor industry, design, manufacturing (called fabrication), and packaging/assembly/testing (P.A.T.) are three key sectors that previously were commonly done within one firm. In the 1990s, however, it was increasingly common to have stand-alone design firms (called design houses), foundries (for fabrication), and stand-alone P.A.T. firms.

Enterprise leaders were closely associated with government officials, and thus officials were well aware of the obstacles faced and lessons learned. Ultimately, Chinese officials announced new semiconductor industry-wide policies in 2000 that benefited both Chinese and foreign firms in China, as a result of lessons learned in the 1990s. Indeed, there was a kind of virtuous cycle between top down (state) programs and bottom up learning in the semiconductor industry during this period from the late 1980s and through the 1990s. The enterprises' experiences in the 1990s were made possible by the top down reforms to the (state owned) industry in the 1980s, and they were directly related to state supports in the 1990s. But ultimately, bottom up learning from the enterprise level in the 1990s influenced future (top down) semiconductor industry-wide policies. Enterprise leaders often had dual roles as government officials, and this enabled bottom up and top down feedback concerning capital needs, ownership structures, and market development in the industry.

Thus, this industry's development in the 1990s in China was not driven by "cowboy science" (i.e., entrepreneurial or technological breakthroughs), nor by coordinated institutional change (e.g., an optimally restructured [state] semiconductor industry, coordinated semiconductor trade policies, or new national research institutions), nor by "market led development," in the sense of new, competitive firms emerging to serve a market.⁴² Rather, this study shows that the industry's development in the 1990s was driven by enterprise led development in conjunction with tactics of state led development.

⁴² Much of the growth in light industries in China from the 1990s has been linked to the globalization of trade. Generally, the notion of "market led development" would suggest that global markets prompted the emergence of manufacturing and assembling firms in China in light industries, due to China's low wage labor pool. Yet, this research suggests that the growing market for semiconductors in China in the 1990s was not sufficient to prompt the emergence of semiconductor producing firms in China. The main semiconductor enterprises in the 1990s in China did seek to supply the market, but given that semiconductor firms are capital intensive and given China's lack of capital markets in the 1990s (among other issues), non-state firms were not able to

Despite advances, the late 1980s to the early 2000s was a difficult period in the industry. This research does not find technological or commercial achievements in the industry in China that global industry personnel would recognize as successes. Indeed, China's progress during the 1990s was "behind the vanguard." That is, enterprises in China did not become technological nor commercial leaders in the global industry but they made improvements in skills, organization, technology, and management that were significant *in China*. Innovation was incremental not step-function, and innovation was organization and process-based, rather than technological. But indeed, the semiconductor industry in China moved from being isolated in the late 1980s to being a global destination in the early 2000s for the fabrication (that is, production) sector and the packaging/assembly/testing (P.A.T.)⁴³ sectors of the industry, both of which are highly technical relative to manufacturing and assembly in many other industries. After 2000, the design sector in China also rapidly advanced. The following figure shows the growth in each sector in the early 2000s.

5. Broader Implications

This research has implications for economic development generally and for China's contemporary economic development, specifically. This section highlights four broad areas of inquiry for which this study's findings are relevant.

1. Demonstrating "Gradual" and "Experimental" Reform in China. Since 1978,

emerge in China in the 1990s to meet China's growing semiconductor market. While some industries in China may have been "market led," the capital and skill intensive semiconductor industry was not, at least in the 1980s and 1990s.

⁴³ This study uses the acronym P.A.T., however, this sector is sometime called S.P.A.&T. (semiconductor packaging, assembly, and testing) or S.A.T. (semiconductor assembly and testing.)

Semiconductor Production Revenues in China, by Sector (RMB100 million), excluding Discrete Devices (Figure 17 in Appendix)

Year	2000	2001	2002	2003	2004	2005
Design	9.8	14.8	21.6	44.9	81.8	124.3
• Percent of industry	5	7	7	13	15	18
Fabrication (manufacturing)	48	27.7	33.6	60.5	180	232.9
• Percent of industry	26	14	14	17	33	33
Packaging, Assembly, Testing (P.A.T.)	128.4	161.1	213.3	246	283.5	344.9
• Percent of industry	69	79	79	70	52	49
Total	186.2	203.6	268.5	3051.4	545.3	702.1

Source: National Bureau of Statistics, 2001-2005, shown in Chen Ling and Xue Lan, "Global Production Networks," *China and the World Economy*, Volume 18, Number 6, 2010, page 114, Table 1.

China's economic reforms have broadly – and correctly – been referred to as “gradual” and “experimental.” This refers to the fact that Chinese officials did not opt for rapid privatization of China's state owned enterprises nor did they enact sweeping policy changes across industries or regions. And yet, how exactly *did* gradual and experimental reforms transpire in China? This study is explicit in detailing how one industry experienced this gradualism and experimentation, in this case through a period of about twelve years of industry learning, through simultaneous enterprise led and state led development. This study reveals the actual events, mechanisms, and processes by which a critical industry in China moved from central planning and state ownership to mixed ownership and global integration. The field of evolutionary economics suggests that, especially for developing countries, technological and economic development is not just a straight-forward matter of technology transfer or studying foreign designs. Rather, industry personnel have to experiment and learn and gradually change through various mechanisms and processes. Industry personnel have to “learn by doing....[and] develop new sets of skills, new ways of organizing economic activity, and familiarity with new markets. To do this [is] far from a routine matter.”⁴⁴ For the semiconductor industry, this research reveals the actual means by which industry learning transpired, and this may suggest how other industries in China have evolved, in particular state dominated or national security-related industries, for which information is not readily available.

This study further suggests that Chinese officials did not overtly coordinate the gradual and experimental reforms across industries. At least for the semiconductor industry,

⁴⁴ On evolutionary economics, see Nelson, *The Sources of Economic Growth*; Nelson (editor), *National Innovation Systems*; and Nelson, *Understanding Technological Change as an Evolutionary Process*. This quote is from Nelson, *Technology, Institutions, and Economic Growth*, pages 41-42 and 54.

Chinese officials' decisions do not appear to have been directly linked to experiments in other industries, in terms of methods or timing, according to available sources.⁴⁵ As just one example, in Chapter Four we see that the origins, methods, and goals of a major state supported semiconductor project (Project 909) are based on the specific needs of the semiconductor industry. The project was not, for example, modeled on similar projects or approaches in other industries. Likewise, there is no evidence that the timing, pace, or sequence of events and changes in the semiconductor industry were directly coordinated with other industries. At a high level, Chinese leaders were surely aware of and influenced by what was happening in other industries across China, but they were not coordinating reforms across industries.⁴⁶

2. The Nature of State Led Development in China. The research also looks in depth at the goals and methods of state led development and national champion enterprises in the semiconductor industry in China and finds surprising differences with state led development, as it is commonly conceived. These insights may suggest how and why Chinese leaders utilized (and continue to utilize) state led development in other industries. State led development is often understood to be the enactment of structured industrial policies, often

⁴⁵ That said, each of China's five year plans prioritize certain industries. Under the five year plans, the semiconductor industry was prioritized along with other critical industries, at least from the sixth five year plan (1981-1985.) Beyond these high level plans, however, actions to reform and develop the semiconductor industry do not appear to have been coordinated with other industries.

⁴⁶ There are, however, three broad caveats to this general finding. First, the timing and mechanisms of the semiconductor industry's "divestiture" in 1985 were generally similar to reforms in other state owned industries in that timeframe (this is discussed further in Chapter Two.) Second, Chinese leaders' attempt to concentrate semiconductor activity by geographic region was an approach that officials used in a number of industries in China. This approach was modeled on "industry clusters" in southern China, Taiwan, Silicon Valley, and elsewhere. In these clusters, close spatial proximity of organizations in similar industries led to synergies in terms of knowledge-sharing, human capital and supply chain optimization, inter-firm alliances, state subsidy allocations, etc. Third, China's changes to its trade policies in the years immediately before and after China's entry to the World Trade Organization in 2000 influenced many industries in China, not just the semiconductor industry.

trade related, that protect domestic “infant” industries and domestic markets to enable domestic enterprises to strengthen their position relative to foreign competitors. This study, however, shows that state led development in the semiconductor industry in China in the 1990s was not practiced through comprehensive, industry-wide policies, but rather it was initially practiced through one-off projects and individual investments. This recalls similar findings from a 1993 study of so-called national innovation systems. In that study, all the low-income countries surveyed used industrial policies to promote industries, but the policies were not centralized, industry-wide policies, but rather they were ad-hoc and as needed.⁴⁷ In the semiconductor industry in China, there was a ten to fifteen year period in which certain key and national champion semiconductor enterprises benefitted from targeted government help, and ultimately these enterprises learned and progressed. Then, then in response to obstacles that these enterprises and their foreign partners had faced over the years, Chinese officials later enacted industry-wide supportive policies. Thus, in this industry, state led development was not a case of knowledgeable officials (first) enacting industry-wide, sage policies and thus enabling the industry to prosper. Rather, officials first learned from enterprises and then enacted helpful policies.

Further, in the semiconductor industry in China, the goals of state led development and national champion enterprises were geared toward technological upgrading and global integration more so than ensuring domestic industry strength or manipulating trade. Again, this aligns with the aforementioned study of national innovation systems, which found that

⁴⁷ Nelson, *The Sources of Economic Growth*, pages 283 and 292-294.

industrial policies were most effective in developing countries when the goals were to advance an industry toward global standards and practices.⁴⁸

Finally, in the semiconductor industry in China, coordinated, industry-wide policies were announced in 2000, but the new policies may or may not fall under the rubric of state led development. That is, the new policies were put in place by the government with the goal of fostering the industry (which conjures state led development), but the new policies were beneficial to both foreign and domestic firms and they lacked many of the domestic-favoring characteristics commonly associated with state led development.

Generally, in examining state policies and programs for the semiconductor industry in the 1980s, 1990s, and early 2000s, we can see significant changes in the industry over time, even though state policies and state supported projects and enterprises had mixed outcomes in their time. If these state led efforts were judged on implementation, global technological standards, or profits, then one would conclude that the state led development efforts of the 1990s were ineffective. Yet, given China's unique context (weak legal system, nearly non-existent capital markets) and the semiconductor industry's high capital requirements, Chinese officials likely believed that using certain state led development tactics was the only option for developing the industry at that time. With a longer-term view, we can see that even the difficulties and failures of the state led projects resulted in industry learning and significant changes in the industry.

3. Economic and Institutional Development as Evolutionary Processes. The semiconductor industry in China the 1990s provides a window on China's evolving "small i" institutions; that is, we see gradual change in certain socially or culturally routinized ways of

⁴⁸ Ibid.

doing things that are common to China's contemporary and modern history. In the 1990s, as Chinese officials and semiconductor industry leaders were attempting to advance the industry, we see these individuals using methods that are not necessarily unique to China but have certainly been common in China. As just a few specific examples, the leaders utilized: five year plans; government "leading groups;" state organized technology transfer agreements; state organized industry delegations for overseas learning trips; state supported projects for large scale manufacturing; government officials as enterprise leaders; among other methods common in China. Interestingly, although these methods recall the days of central planning and state ownership, these "old" methods were used to pursue "new" technologies, organizational structures, and industry relationships for the semiconductor industry. Other methods could have been tried. Nonetheless, Chinese leaders chose methods that were common in China, not only under the C.C.P., but also in the early periods of China's modern history mentioned earlier in the Introduction. The methods mentioned are top down, and this may reflect the importance of hierarchy in Chinese society as well as the belief (or reality) that only a top down approach could marshal the resources necessary for an economic or technological "catch up" program.

In evolutionary economics, Richard Nelson calls this tendency to do things the same way "routinized social technologies." While foreign observers might question the methods utilized in China, Chinese leaders may have seen these methods as obvious or as their only options. Nelson explains that "absent an effective social technology for doing something, it may be very costly to do that thing or doing it may be impossible." Chinese leaders, acting in China's context, likely did not have "effective social technologies" to do things differently, in terms of how they sought to develop the semiconductor industry. However, in the course of

using known methods, enterprise and government leaders in China indeed learned and ultimately changed methods. For example, by the late 1990s, we see Chinese officials asking foreigners to lead projects and allowing an industry association to set industry guidelines. In the terminology of evolutionary economics, these changes to “routine social technologies” constitute innovation, though the innovation was organizational or process-based rather than technological.⁴⁹

Writing on evolutionary economics in 1996, Nelson noted that, in particular, the electronics industries of different nations would necessarily evolve toward global norms of organization, processes, standards, etc., minimizing differences originating from “national policies, history, and culture.” In the highly globalized electronics industry, firms would increasingly be aware of how firms in other nations are organized and inter-firm connections, foreign branch operations, and the like would spur a high degree of standardization.⁵⁰ Indeed, this research shows that the semiconductor industry in China experienced these effects of globalization. For firms in China, foreign partnerships, foreign trade, and the de-verticalization of the semiconductor industry (examined in Chapters Three through Five) led to industry and organizational restructuring, new firm formation, and new managerial approaches in firms operating in China, all of which increasingly approximated global industry standards. These innovations could aptly be described as arising from gradual changes to routine social technologies.

4. Industrial Development and Policy Effects. Finally, this research shows that industrial development can foster institutional and policy development in an emerging

⁴⁹ Nelson, *Technology, Institutions, and Economic Growth*, pages 154-155.

⁵⁰ Nelson, *The Sources of Economic Growth*, pages 295-296.

economy. The semiconductor industry gradually advanced in China's emerging economy of the 1990s despite China's weak legal system and lack of capital markets and despite China's not yet having broad based supportive policies for the semiconductor industry. And, ultimately we see (in Chapter Five) that the semiconductor industry's evolution contributed to an improved institutional and policy environment after 2000, at least for the semiconductor industry. New policies included improved tax and tariff policies, increased commitment to intellectual capital protection, and consistent subsidies for the industry. In this case, robust formal, national institutions were not a necessary precursor to industry development. Generally, strong institutions and supportive policies do foster economic development, but this study suggests that, when such institutions are weak, as is often the case in emerging economies, industry development might still occur and might serve to strengthen institutions and policies.

6. The Global Electronics and Semiconductor Industries: A Brief Background

The electronics industry has arguably been a leading site, if not the leading site, of technological innovation and globalization since the mid 20th century. Business historian Alfred Chandler has compared the revolution in electronics from the mid 20th century with the first and second industrial revolutions in terms of social and technological impacts. Chandler calls the post-World War II period the “electronic era,” due to the rise of computers and consumer electronics, both of which are dependent on semiconductors as their “brains” for memory and processing.⁵¹

⁵¹ Alfred Chandler, *Inventing the Electronic Century* (Cambridge: Harvard University Press, 2005.)

The first semiconductors, invented in the late 1950s, integrated only about twelve transistors on a chip, but semiconductors now integrate billions of electrical components, i.e., transistors, resistors, and capacitors, on a single chip.⁵² To make semiconductors, also called integrated circuits or I.C.s, a producer grows a cylindrical silicon crystal, which is then sliced into thin wafers. A number of chips are patterned onto each wafer through lithography, called masking. Masks are layered, so a chip may have, for example, thirty layers of masking. Larger wafers are more technologically complex to manufacture, but yield better scale economies, that is, a twelve inch wafer can provide 2.4 times as many chips as an eight inch wafer, given its larger surface area. In semiconductor fabrication (that is, production), the production technology is often described by wafer size, so “an eight inch line” produces eight inch wafers. Production technology is also defined by the distance between line etchings on a chip, for example, “0.25 microns,” where smaller line widths are more advanced, as they allow more transistors to fit on a chip. The capital required to establish a semiconductor fabrication facility (called a “fab” or a “foundry”) is extremely high; in 2010, the cost was approximately US\$1billion to US\$4 billion for a single fab.⁵³ After fabrication, chips are packaged/assembled/tested (P.A.T.), which is also a relatively high tech process. This entails encasing the chip to prevent corrosion or other damage. The encasement process is called “packaging” or “assembly.” Electrical contacts are then connected the semiconductor’s packaging, and the final step is testing. In general, semiconductors account for between

⁵² The industry moved from small scale integration (SSI) to medium scale integration (MSI) to large scale integration (LSI) to very large scale integration (VLSI) to ultra large scale integration (ULSI). VLSI indicates at least 1000s of devices on a single chip, and today there are commonly billions of devices on a single chip. Moore’s Law, by Gordon Moore (co-founder of Intel, the world’s largest semiconductor company), says that the number of discrete devices on a chip will double every 18 to 24 months.

⁵³ TSMC of Taiwan, the world’s largest foundry, spent over US\$9 billion in 2010 on a new fab, see Jack Clark “TSMC breaks ground on \$9.3bn ‘Gigafab’,” *ZDNet*, July 20, 2010.

fifteen and twenty-five percent of the value of consumer electronics, computers, and communications products. These semiconductors can be commodity chips or specialty chips. For example, memory chips are commodity chips, so one computer can have chips from multiple suppliers. Specialty chips are for logic processing.

In the early years of the electronics era, large vertically integrated firms such as Fairchild and IBM commercialized new technologies. Their products and services essentially allowed the electronic manipulation, storage, and distribution of information. These products and services thus enabled a new ease of electronic communication between firms, which by the 1980s led to vertical dis-integration and outsourcing in the electronics industry as well as other industries. In the latter half of the 20th century, the semiconductor industry evolved to be a stand-alone industry in its own right, not merely a sector of the broader electronics industry, yet the semiconductor and electronics industries were and remain closely tied.⁵⁴

The rapidly growing electronics and semiconductor industries globalized from as early as the 1960s, when leading firms including Fairchild, Philips, General Instruments, and RCA began to internationally outsource component production and electronic assembly (that is, mounting and connecting semiconductors to circuit boards), which were labor intensive. In his 1998 study of Taiwan, Robert Wade noted that in 1961 foreign semiconductor firms began to outsource labor intensive aspects of semiconductor production to Taiwan, giving Taiwan a role in this valuable industry, and for this reason alone, Wade declared 1961 nothing less than

⁵⁴ Also, there is not one “electronics industry.” There a number of electronics-related industries, some examples include: telecomm, software, hardware, consumer electronics, storage, IT services, and many others. Further, within all the electronics-related industries, there are sectors that operate as discrete industries. That said, for simplicity, this paper uses “the electronics industry” and “the semiconductor industry.”

“a landmark year in the history of East Asia.”⁵⁵ By the 1980s, Japan, South Korea, Taiwan, Hong Kong, and Singapore were all active participants in the global electronics industry. In the semiconductor industry, U.S. firms had led the industry from its origins in the late 1950s, but the industry saw new competitors over the years, first from Japan in the 1970s, then from South Korea in the 1980s, and finally from Taiwan in the 1990s. Today, the largest semiconductor companies in the world are Intel, Samsung, and Texas Instruments.⁵⁶ Of course, semiconductor capability is important for information and defense systems, so governmental support for the industry has been common in most of these countries. The size and growth of the semiconductor industry are striking: global semiconductor revenues were about US\$50 billion in 1990, about US\$200 billion in 2000, and about US\$300 billion in 2010.

7. The Semiconductor Industry in China: An Overview of this Study

The semiconductor industry in contemporary China entered a period of significant

⁵⁵ Robert Wade, *Governing the Market: Economic Theory and the Role of Government in East Asian Industrialization* (Princeton: Princeton University Press, 1990), page 94.

⁵⁶ Texas Instruments' role in the global industry is significant. Texas Instruments (TI) and Fairchild were the earliest producers of semiconductors, and TI was an early and prominent U.S. defense contractor. Texas Instruments was one of the first foreign entrants in both Taiwan and Mainland China's semiconductor industries. Two Taiwanese semiconductor leaders, Morris Chang and Richard Chang (no relation), both worked in the U.S. at Texas Instruments for twenty or more years before returning to Taiwan and starting semiconductor companies there, TSMC and WSMC, respectively. Chang and Chang worked in TI's Semiconductor Group. (I happened to be a student engineer in TI's Defense Systems and Electronics Group for three years during the time that Richard Chang was in the Semiconductor Group.) Morris Chang's TSMC in Taiwan was the first semiconductor company to operate on the industry-changing “foundry model” from 1987; the “foundry model” enables design companies to outsource their production. TSMC's advent of the foundry model de-verticalized the industry, allowing design entrepreneurs to start semiconductor firms without all the capital required for production. At Texas Instruments, Richard Chang built and commenced fabrication facilities around the world, including in Asia. He left TI to start WSMC in Taiwan in 1998, which was quickly bought by TSMC. Richard Chang then founded Mainland China's largest semiconductor company, SMIC, which also operates on the foundry model. These events are discussed further in Chapters Four through Six.

development right on the heels of the industry's growth in Japan, South Korea, and Taiwan. From early in China's reform era, Chinese leaders recognized that electronics was a rapidly evolving, global industry and that improvements in electronics would support China's infrastructure, military, and other industries, while electronics itself was an important consumer industry. Determined to foster the industry, Chinese leaders set out from the early 1980s to reform, develop, and open the industry. The events and changes that followed are described and analyzed in the following chapters.

Chapter Two begins this study by situating the semiconductor industry within China's centrally planned economy of the 1980s and identifying how the industry changed (or not) amid various reforms and new policies and programs from the mid to late 1980s.⁵⁷ That is, Chinese officials sought to restructure and "divest" China's centrally planned electronics and semiconductor industries in the 1980s. Many production and research units were "released" (de-funded) from the national industry from 1985. Around this time, both released and even unreleased enterprises had increasing opportunities to produce for the market rather than only for the central plan. Yet, we learn that by the late 1980s and early 1990s much of the national, hierarchal structure of the semiconductor industry remained in place because Chinese leaders considered the industry a national strategic priority.⁵⁸

In the midst of the industry's divestiture from the mid 1980s, top central officials including Premier Li Peng formed an electronics "leading group" to set new strategies and

⁵⁷ Denis Simon covered China's centrally planned electronics industry and semiconductor industry from 1949 to 1987 in his book *Technological Innovation in China*, published in 1988.

⁵⁸ China's top central leaders were close to the electronics industry and understood its importance. President Jiang Zemin had initially studied and worked as an electrical engineer and later was head of China's Ministry of the Electronics Industry. Premier Li Peng was also an engineer and led major national engineering projects including the Three Gorges Dam and the Shenzhou Manned Space Program.

guidelines for the industry. This was part of a broader push to develop the electronics, computer, and semiconductor industries in China. From these strategies and guidelines and a few high-level “working conferences,” an important strategy emerged. Officials decided to decrease the number of semiconductor enterprises receiving funding from the government for technical upgrades. In the 1980s, officials had imported foreign semiconductor equipment in an effort to upgrade some thirty-three different semiconductor-related facilities, but the effort had proved ineffective. The new approach was to focus effort and investment on just a few semiconductor sites. In particular, officials decided to form two regional “bases” of semiconductor activity,⁵⁹ five “key” enterprises, and to undertake a major semiconductor project called Project 908 which was in large part intended to create a new semiconductor enterprise which would be China’s most advanced.

Chapter Three examines the long and difficult road through Project 908 at the new Huajing semiconductor enterprise, one of China’s five “key” semiconductor enterprises and also a “national champion” enterprise. Project 908 is rarely mentioned in Chinese or foreign sources, and when it is referenced, it is only mentioned briefly and usually with allusions to “failure.” Yet, Project 908 shows in concrete terms how China’s leading state owned semiconductor enterprise, in the midst of reforms to the centrally planned industry, attempted to undertake a capital-intensive, significant technological upgrading through an agreement with U.S.-based AT&T-Lucent. We first see this state owned enterprise making relatively successful technical upgrades and product decisions in the 1980s, and then we see the enterprise managers attempting to execute the much more ambitious Project 908 in the 1990s.

⁵⁹ The “South Base” would cover Shanghai, Jiangsu and Zhejiang, while the “North Base” would cover Beijing, Tianjin, and Shenyang.

Ultimately, a lack of funding due to bureaucratic delays caused Project 908 to be incomplete (actually, to have not even begun) by its planned 1995 endpoint, and thus the perceived “failure” of Huajing and Project 908.

Yet, in struggling to bring Project 908 to an acceptable conclusion in the mid to late 1990s, Huajing’s managers enacted a number of critical changes that essentially served as lessons for the industry in the late 1990s and beyond.⁶⁰ Had this research only examined Huajing on financial or technical results, it would have summarily dismissed the enterprise and Project 908 as failures. However, effectively operationalizing a new enterprise with new technology is complex, and this was especially true in China’s context. Even if Huajing’s early financial and technical results did not demonstrate “success,” Huajing’s path and experiences demonstrate how a Chinese high technology enterprise made significant organizational, managerial, and operational advances. The changes at Huajing in the latter half of the 1990s merit mention here. Huajing managers:

- Re-organized the enterprise by accounting units to hold each unit accountable for its results
- Aligned research units with particular production lines
- Formed part of Huajing into a joint venture with Hong Kong-based but Taiwanese-led CSMC, bringing Taiwanese semiconductor experts to Wuxi to manage the joint venture and provide new sales channels *before* the mainland’s semiconductor industry was officially open to Taiwan
- Adopted the “foundry model” for the joint venture, which was an important new operational trend in the global industry, which de-verticalized the industry by enabling design companies to essentially outsource production to foundries.

⁶⁰ Huajing, now called China Resources Microelectronics, remained one of the two largest Chinese semiconductor enterprise groups by revenue in the late 2000s.

- Restructured Huajing into separate sector-based companies (i.e., a design company, a fabrication company, etc.), as was becoming more common as the global industry de-verticalized
- For financial relief, Huajing joined the larger Huarun enterprise group which was able to alleviate some of Huajing's Project 908-related debt

In Chapter Four, we see lessons from Huajing utilized as other Chinese

semiconductor enterprises form significant global partnerships in the 1990s. These enterprises face obstacles of their own, and like Huajing, their results were not always what would typically be identified as success. Yet their experiences proved valuable both as learning opportunities for the enterprises as well as for shaping post 2000 semiconductor industry policies in China. Chapter Four looks at the establishment of China's "key" semiconductor enterprises, most of which were actually Sino-foreign joint ventures from the outset. It also examines China's largest ever electronics project, Project 909, which was instigated in 1995 when Project 908 appeared to be a failure. Project 909 established a major, new Sino-Japanese semiconductor enterprise called Huahong-NEC, as well as a number of design organizations. Finally, Chapter Four looks at a new Shanghai-based, but wholly foreign owned, enterprise called Semiconductor Manufacturing International Corporation (SMIC.) Despite being foreign owned, SMIC was supported by the Chinese government and considered a "Chinese" enterprise, and even a kind of national champion.

By looking at the history of the key enterprises, Huahong-NEC, and SMIC, we see significant enterprise-based learning in the industry. The semiconductor enterprises and the Chinese officials with whom they coordinated evolved in each of the following areas: political prioritization of the industry, industry and enterprise structure, management and technical skills, foreign partnering for capital, technology, and talent, and awareness of policy-related

obstacles. For example, relative to Huajing, Huahong-NEC and SMIC had improved political prioritization and sponsorship and therefore more timely government funding. Also, from their inception, Huahong-NEC and SMIC were organized with ownership forms different than Huajing's. Huajing was a state owned enterprise that *eventually* formed a part of its organization into a Sino-foreign joint venture. Huahong-NEC, however, was formed from its inception as Sino-foreign joint venture, including partial funding from Japan's NEC. SMIC was founded as a wholly foreign owned enterprises with Taiwanese management and international funding, but also with loans from Chinese state owned banks. Huahong-NEC and SMIC both had a clearer view of the markets they would serve from their inception (relative to Huajing), and both used foreign (Taiwanese and Japanese) managers for production as well as sales. Huajing eventually adopted the foundry model, but SMIC operated on the foundry model from its start, and Huahong-NEC adopted the foundry model in 2002. Both Huahong-NEC and SMIC brought significant technical upgrades to the semiconductor industry in China through various foreign technical partnerships as well as by serving international markets. Finally, these enterprises, along with Huajing, served as training grounds for thousands of Chinese semiconductor personnel, and the existence of each of these large enterprises fostered the emergence of additional jobs throughout the industry chain in China. In all cases, these enterprises and their foreign partners dealt with obstacles based in China's unique policy and institutional environment, i.e, high official import tariffs that had to be negotiated on a one-off basis, concerns about intellectual property protection in China, the need to negotiate with Chinese officials for subsidies and preferences for land, utilities, and taxation. All this enterprise-based learning helped to shape new policies for the industry after 2000, which are addressed in Chapter Five.

Chapter Four also addresses the nature of “national champion” enterprises and state led development in the semiconductor industry in China. Huajing, Huahong-NEC, and SMIC were all considered national champions. By revealing the actual origins, goals, and roles of these national champions, we are able to compare national champion enterprises and state led development in this industry with general notions about state led development in East Asia and in China itself. There are similarities. This was a strategic, capital-intensive industry for which the central government selected and supported specific large enterprises as national champions.

Yet, there were also some surprising aspects of China’s semiconductor national champion enterprises. Chinese officials established Huajing, Huahong-NEC, and SMIC with the primary goal of fostering the development of a diverse semiconductor industry value chain in China, including both domestic and foreign firms. In each case, the hope was that if one advanced enterprise could effectively operate in China’s admittedly imperfect environment, then that enterprise would serve as a beacon to attract other firms throughout the industry chain. Notably, these national champions and key enterprises had a significant degree of foreign ownership and management. These enterprises contrasted with general notions about national champions in several ways. This research suggests that China’s semiconductor national champions were not established to dominate the national industry, to attain self-sufficiency in semiconductor production, to preclude foreign ownership of semiconductor enterprises in China, to create oligopolistic competition in China, nor to dominate and serve protected domestic market segments.

These enterprises introduce a unique definition of “national champion.” These enterprises were not expected to have global leading edge technology (with the exception of

SMIC's production capabilities, which were high) nor were they expected to attain high revenues or profits, at least in the short and medium term. Rather, Chinese officials primarily wanted these large enterprises to utilize more advanced technology, to produce for the global market including the market in China, and to foster the whole industry chain in China.

Chinese officials did not establish these enterprises in the 1990s as part of uniform, industry-wide policies for all firms in the industry. These enterprises were instigated and supported by the state, but each was supported on a one-off basis. The industry thus experienced both "enterprise led" and "state led" development for a period of about 12 years from the late 1980s and through the 1990s. That is, the state supported enterprises in various ways, but then the experiences of individual enterprises provided bottom up feedback to officials and influenced industry-wide policies after 2000. Further research could address whether other high technology industries in China also experienced a mix of enterprise led and state led development in the 1980s and 1990s.

Foreign and Chinese observers have criticized Huajing, Huahong-NEC, and SMIC as inefficient state supported enterprises, yet these were the major enterprises that bridged China's centrally planned era in this industry with the globally integrated era after 2000. The enterprises brought much needed technology and management transfer from abroad and contributed to human resource development at a time when large semiconductor enterprises could not emerge in China due mainly to lack of capital and legal restrictions on foreign investment. Of course, Chapter Four's focus on state supported projects and enterprises does not suggest that the state support and tactics were optimally effective; we have no means to compare actual events with counterfactual scenarios of, for example, less or different state support for the industry.

Chapter Five connects the experiences and trends in the industry through the late 1990s with the era of faster growth after 2000. The chapter begins by considering the growth of the market for semiconductors in China, which was spurred by the global relocation of electronics manufacturing and assembly work to China in the 1990s and 2000s. Due to this broad geographic shift in the electronics industry, global semiconductor firms wanted to establish operations in China to be near their customers. In addition to the global semiconductor firms that entered into major partnerships with Chinese enterprises in the 1990s (covered primarily in Chapter Four), a number of other global semiconductor firms began to establish contracts or facilities in China in the 1990s. These were mostly sales offices, equipment contracts, and low-end manufacturing sites, so they did not contribute substantially to the size of the industry in China, however these activities opened additional dialogue between global firms and Chinese officials in the 1990s.

In light of the increased global integration in the 1990s, Chapter Five addresses two areas of policy that are often cited in connection with the development of the semiconductor industry in Mainland China. First, this study finds that Western (mainly U.S.) export controls on dual use technology to China did not significantly stifle the industry, as Chinese enterprises could purchase semiconductor equipment from non-U.S. sources. Second, this study shows that Taiwan's easing of semiconductor investment restrictions in the Mainland in 2002 augmented industry growth in China, but Taiwan's 2002 policy change was not the major driver of development.

An area of policy that did create a turning point in the industry was the Chinese government's new policies for the semiconductor industry, enacted in 2000. By 2000, Chinese officials were familiar with the constraints that both domestic and foreign semiconductor

enterprises faced in China, and they attempted to address many of these concerns in new policies enacted in 2000 under “Document 18.”⁶¹ Importantly, the new policies applied to firms of any ownership form operating in China. Reflecting the impact of Document 18’s policies, a 2003 study by the U.S. Semiconductor Industry Association said: “With the exception of the auto industry – another Chinese government priority – no comparable [industry] specific measure has been issued by the [Chinese] government, a fact duly noted by national, regional, and local government officials.”⁶² Through Document 18, Chinese officials demonstrated a clear commitment to the semiconductor industry. The new policies were geared toward: easing firm formation; clarifying and decreasing taxation; encouraging foreign investment with preferential policies; opening capital channels including new sources of domestic venture capital and increased access to foreign capital; supportive policies for the high-end design sector of the industry; and a stated commitment to intellectual property protection. Then, China’s entry to the W.T.O. in late 2001 created more impetus for implementing the policies of Document 18, and China’s tenth five year plan (2001-2005) prioritized and provided significant funding for the semiconductor industry.

From 2000-2001, the industry in China entered a period of more rapid growth, building on the foundation developed through the late 1990s and enhanced by new policies. The market for semiconductors continued to grow, and thus global semiconductor firms in the

⁶¹ “18 Hao Wenjian: Guli Ruanjian Chanye he Jichengdianlu Chanye Fazhan de Ruogan Zhengce 18 号文件：鼓励软件产业和集成电路产业发展的若干政策 (Document 18: Some Policies to Encourage the Software and Integrated Circuit Industries).” This document is available from the Chinese Electronics Standardization Institute (*Zhongguo Dianzi Jishu Biaojunhua Yanjiusuo* 中国电子技术标准化研究所) at www.chinasoftware.com.cn/calling_info_detail.asp?id=47.

⁶² U.S. Semiconductor Industry Association, prepared by Dewey Ballantine LLP, by T. Howell, B. Bartlett, W. Noellert, and R. Howe, “China’s Emerging Semiconductor Industry,” 2003, page 45.

fabrication (manufacturing) sector and the lower-end P.A.T. (packaging-assembly-testing) sector sought to locate in China to be near their customers, contributing to the notion of China as “the world’s factory floor.”⁶³ On the other end of the value chain, the high-end semiconductor design sector also flourished in China after 2000 under supportive new policies. New firms relied on China’s relatively small pool of designers that had been nurtured by government programs in the 1990s as well as overseas Chinese and foreign talent. By 2010, design sector revenues in China as a percentage of total industry revenues were only slightly lower than the global average.⁶⁴ Thus, in the early 2000s, the semiconductor industry in China fully integrated with the global semiconductor value chain, from the high-end design sector to the low-end P.A.T. sector. By 2005, the semiconductor industry in China was still generally viewed as “behind” by global industry standards, yet it was far less behind than it had been in 1990.

This study shows that a high technology industry in China was able to advance in the 1990s despite China's still reforming economy, inconsistent policy environment, and immature institutions. Ultimately, the experiences and lessons of individual enterprises (including state supported enterprises and others) contributed to new and effective semiconductor industry-wide policies after 2000. By examining the difficult period of transition from central planning to global integration, this study reveals how a critical high technology industry advanced in contemporary China.

⁶³ Within the semiconductor industry the P.A.T. sector is “low-end,” but relative to other industries, this sector is quite technical.

⁶⁴ In the global semiconductor industry in 2010, the design sector constituted 16.6 percent of revenues. In China, design revenues were 14.5 percent.

Finally, China was not the first country in Asia to become an important global player in the semiconductor industry in the last half of the 20th century. The final chapter (Conclusions) compares the history of the industry in China to its history in Japan, South Korea, and Taiwan.

8. Sources for this Study

The host organization for this research was the Wuxi National Integrated Circuit Base Company (WXICC), one of China's "seven + one" national semiconductor bases (these bases are covered in Chapter Five.) Wuxi, a city about eighty-five miles west of Shanghai in Jiangsu province, was the site of Project 908, and today, Wuxi still has the highest concentration of semiconductor industry activity in China, along with Shanghai. WXICC and China's seven other national semiconductor bases are charged with attracting new semiconductor firms to their respective regions and supporting firms with subsidies (offering incentives on tax, electricity, land, etc.), inter-firm introductions, legal and accounting support, office and lab space, and technical infrastructure for start-up firms.

The Director of WXICC, Chen Tianbao, offered me office space to work with his group, but more importantly he and his staff, in particular Mr. Yang Long, introduced me to semiconductor leaders in Wuxi, Shanghai, Beijing, Shenzhen, and elsewhere in China, thus facilitating a number of interviews with enterprise leaders and national semiconductor officials that, without the WXICC introduction, may not have been possible. The study included over fifty interviews, and a list of all interviewees is included with the Figures at the end of the study. The interview list indicates interviewees' ties to various organizations and projects. Some of the most important interviews included: the top executives and senior

engineers of different companies within the China Resources Microelectronics enterprise group (the group that took over Huajing); the C.E.O. of China's largest state owned package-assembly-test semiconductor enterprise; the General Managers of several firms that spun off from Huajing; the President of China's Semiconductor Industry Association; and others.

While in China, I was also able to interview the C.E.O. and General Manager of two of China's "key" semiconductor enterprises, the Director of the Institute of Microelectronics at the Chinese Academy of Science (the top semiconductor-related institute in China), and two of three of China's leading scholars on the semiconductor industry.

The staff at WXICC also directed me to important written documents, and the bibliography includes a full list of sources. One important written source was a newly available set of records on Project 909 published by the Electronics Industry. This was very helpful because Huahong (the major enterprise of Project 909) was the one enterprise that was not responsive to interview requests. For SMIC, a national champion enterprise covered in this study, there are many available written sources because of its status as a publicly listed, foreign company. Further, during my time in Wuxi, a co-founder and former Chairman of SMIC, Professor Wang Yangyuan, published a lengthy book that, in part, recounted the founding and early experiences of SMIC. The book is mostly about semiconductor technology, but it includes SMIC's role in the industry in China and other important developments in the industry. The C.E.O. of SMIC, Richard Chang, agreed to an interview for this study, but he cancelled on short notice. Because I left China shortly thereafter, we were not able to reschedule. 2009 was a difficult year for Mr. Chang; he resigned later that year. The staff at WXICC also directed me to semiconductor industry reports published by branches of the China Semiconductor Industry Association (CSIA) and CCID. CCID used to

be a research group under the Ministry of the Electronics Industry, and it is now a research and consulting “company” that specializes in Chinese government data. CSIA and CCID are the two official Chinese sources for semiconductor industry data. For Project 908, I had to rely mostly on articles written in the 1990s by Huajing’s General Manager, Su Guangping, or other authors affiliated with Huajing. I found other articles that mentioned Huajing and Project 908, but I did not use articles that were general or repetitive or seemed to be written by people not affiliated with the enterprise. Fortunately, I was able to interview Teng Jingxin and Xu Juyan, two (elder) leading Huajing engineers, and they were able to discuss events, decisions, and outcomes in the history of the enterprise going back to Project 908. Chinese written sources do not say a lot about Huajing and Project 908 likely because of their perceived failure and because of Huajing’s military associations. Indeed, Huajing’s former General Manager during Project 908, Su Guangping, was never mentioned in interviews.

When I was planning this study, Prof. Denis Simon advised me that it would be impossible to get enterprise documents from state owned semiconductor enterprises in China, due to the national sensitivity of the industry. Prof. Simon was correct, and Huajing’s elder Chief Engineer, Teng Jingxin, also made this clear during our first meeting. The relatively younger Huajing C.E.O. (who was Huajing’s General Manager in late 1990s) had a more forthcoming attitude. Generally, the more senior personnel in state affiliated organizations were more reserved, while somewhat younger personnel were more open. Mr. Chen at WXICC and all the Huajing personnel were surprised that a foreigner would be interested in the history of Huajing and Project 908. That said, 2009 seemed to have been an opportune time for this research, especially considering the newly published Project 909 records. More generally, by 2009, the industry had advanced substantially, and there was perhaps less

defensiveness about the 1990s and a cautious willingness to talk about the obstacles and set backs that enterprises encountered during that time on the road to development.

Still, how reliable are the sources? Admittedly, the interviews and available written sources are from Chinese industry leaders and officials, and thus they represent an official Chinese version of the history of this industry. Yet, it does not seem to be a white washed version. Chinese sources consistently refer to the backwardness of the industry, the lack technical skills, the wasted money, the immobility of the system, the difficulty in finding foreign partners, the difficult decisions about what products to make, the low production yields, etc. There is widespread acknowledgement that the industry was beset with problems in the 1990s, but we do not know the financial results. The products and revenues speak for themselves, but for example, in the early years of Huajing and Huahong-NEC (two enterprises covered in Chapters Three and Four), we do not know their results in terms of profits and losses, and losses may have been very substantial.

Finally, because semiconductors are critical to a nation's defense capabilities, we can assume that there were – and are – confidential semiconductor-related activities in China. Beyond Project 908 and Huajing (which were military related), I did not attempt to explore defense-related semiconductor research or activities in China.

Chapter Two

China's State-owned Semiconductor Industry: Historical Structure and Reforms in the 1980s

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In the 1980s, China's state-owned semiconductor industry operated in a unique and dynamic context, as this was the era when Chinese officials were reforming China's centrally planned economy. Because of the complexity of the era, this chapter identifies the structure and key reforms to China's semiconductor industry in the 1980s and how these reforms led to new strategic priorities for the industry in the 1990s. In the 1980s, China's over 30 semiconductor enterprises were all state-owned.⁶⁵ Thus, the state-owned semiconductor industry was the arena in which all Chinese semiconductor officials and professionals were working prior to the 1990s, and many personnel continued to work in these enterprises -- or restructured versions of these enterprises -- in the 1990s and beyond. For this reason, the origins of China's contemporary semiconductor-related policies, strategic priorities, enterprises, and talent pool are found in China's state-owned industry of the 1980s. Further, many of the challenges that the industry faced in the 1990s and beyond (see Chapters Three through Five) were legacies of China's centrally planned economy. Thus, this chapter examines: the development of China's semiconductor industry prior to 1978 (Section 2.2); the structure of China's centrally planned electronics and semiconductor industries in the 1980s (Section 2.3); the various reform policies that affected the industry in the 1980s (Section 2.4); and finally an introduction to the major state-led semiconductor projects of the 1990s (Section 2.5), which bridged the centrally planned era with the post-2000, globally-integrated era.

In the 1980s, China's semiconductor industry was indeed a state-owned industry, but in the 1990s, the industry began to have a mix of ownership forms including state-ownership, Sino-foreign joint ventures, foreign firms, and new domestic private firms. In this dissertation,

⁶⁵ In the 1980s, because Chinese semiconductor enterprises were relatively low-tech, most of the demand for semiconductors in China was actually met by imported semiconductors.

the phrase “*China’s* semiconductor industry” refers to Chinese owned semiconductor enterprises, which in the 1980s were state-owned. In the 1990s and beyond, China’s semiconductor industry still had state-owned enterprises, but the number of firms with other ownership forms was increasing.⁶⁶ This dissertation uses the phrase “the semiconductor industry *in China*” to refer to all semiconductor-related firms operating in China. From the 1990s and forward, the semiconductor industry in China included Sino-foreign joint ventures and foreign firms, as well as Chinese firms, both state-owned and private.

Reforms to China’s state-owned semiconductor industry in the 1980s were important in the industry’s history, but it is important to note at the outset that these reforms were not the primary driver of the industry’s development in the 1990s and beyond. Industry reforms in the 1980s were certainly necessary. They freed up and re-directed resources, and they were critical in creating a more open environment in the industry. However, later chapters will show that other forces were equally or more important for the technological advances and global integration of the semiconductor industry in China. These factors included: vertical dis-integration in the global semiconductor industry, Chinese enterprises’ foreign partnering and adoption of foreign technology and management practices, China’s growing talent pool, and new Chinese laws and policies encouraging private business and foreign trade, including new policies specific to the semiconductor industry. Nonetheless, to understand the context of the semiconductor industry in China in the 1990s and beyond, we must first look at the industry’s organization and reforms in the 1980s.

From 1978, China entered its era of “reform and opening” and pursued the “four modernizations,” which included the modernization of agriculture, industry, the military, and

⁶⁶ For more on the new ownership forms, see Section 2.42.

science & technology. China's economic reform and opening was complex because of the broad and deep scope of China's centrally planned economy. Reforms had to address the most trenchant problems of the centrally planned economy: hierarchal and bureaucratic industry structures; lack of appropriate pricing mechanisms within supply chains; inefficient use of resources by state-owned enterprises in which management lacked incentives for profit and innovation; the organizational separation of research and production; and rigid career paths for individuals, among other problems.⁶⁷ Because of the scope and complexity of reforming industries across China, Chinese leaders began economic reforms "gradually," to use Barry Naughton's term,⁶⁸ often experimenting with new methods in one area before attempting broad-based implementation and allowing "out-of-plan" economic activity to emerge alongside the planned economy.⁶⁹

In the semiconductor industry, officials indeed took what could be generally characterized as a gradual and experimental approach, allowing out-of-plan trade to emerge while the state sector was being reformed. That said, to understand the actual events, this chapter examines three areas of reform that affected the semiconductor industry. These include overall industrial reform (Section 2.41), reforms to the science & technology (S&T)

⁶⁷ For more on the problems of centrally planned economies, also called command economies, see: Andrew Walder, *The Waning of the Communist State* (Berkeley: University of California Press, 1995); Harry Harding, *Organizing China* (Stanford: Stanford University Press, 1985); Peter Evans, *Embedded Autonomy* (Princeton: Princeton University Press, 1995); Janos Kornai, *The Socialist System* (Princeton: Princeton University Press, 1992); Nicholas Lardy, *China's Unfinished Revolution* (Washington DC: Brookings Institute, 1998); Barry Naughton, *Growing Out of the Plan* (Cambridge: Cambridge University Press, 1995); Thomas Rawski, "Enterprise Reform in Chinese Industry," *Journal of Economic Perspectives*, 8-2, 1994.

⁶⁸ Naughton, *Growing Out of the Plan*.

⁶⁹ Industry reforms continue today, in 2012. The Chinese government still controls banking, energy, telecommunications, and other key industries. As of 2012, about 150 state-owned enterprises report directly to China's central government through the State Council's State-Owned Assets Supervision and Administration Commission, but these enterprises also have thousands of subsidiary enterprises. Further, China's many provincial and municipal governments own enterprises, and enterprises can be *partially* state-owned, with the government as a shareholder.

system (Section 2.42), and reforms to the electronics industry, including new strategies specific to the semiconductor industry (Section 2.43).⁷⁰

The reforms, however, did not result in immediate, tangible changes to China's state-owned industries and enterprises. Yu Zhongyu, the President of China's Semiconductor Industry Association, explained that "1978 to 1989 was really a period of just identifying methods [of reform and new practices] and identifying resources, and we met many obstacles."⁷¹ In the 1980s, industry hierarchies with their many layers of bureaucracy remained largely in place and state ownership of enterprises continued across industries. Reforms in the 1980s largely sought to change the *environment* in which state-owned enterprises operated. For example, new policies changed the funding mechanisms for state-owned electronics enterprises and encouraged these enterprises to seek revenue through China's new "technology markets," discussed in Section 2.4. In the literature on China's economic reforms, one sees terms such as "restructuring," "decentralization," and "divestiture," and a reader might assume that this means that China's state-owned enterprises were "restructured" in the contemporary, Western sense of the term. In today's advanced economies, if a firm is restructured, this usually means that the firm's ownership, organizational structure, and operations are changed in clearly defined, tangible ways within a fairly rapid timeframe. This was not the experience of most state-owned enterprises in China in the 1980s. For example, although the central Ministry of the Electronics Industry "divested" its many electronics enterprises in 1985, the organizational structure of the national

⁷⁰ In China's centrally-planned economy, the semiconductor industry was embedded in the electronics industry, but internationally, the semiconductor industry is recognized as a specific industry.

⁷¹ Interview with Yu Zhongyu, July 2, 2009, at China Semiconductor Industry Association (CSIA) headquarters in Beijing. Yu is the President of the CSIA.

electronics industry remained largely in place into the 1990s.⁷²

That said, reforms did result in certain changes to the centrally planned electronics and semiconductor industries in the 1980s and 1990s. Identifying precise organizational changes, however, is difficult because of China's generally closed posture in terms of revealing internal political and economic structures. Further, the semiconductor industry was, and still is, considered a sensitive, national-security-related industry. Most of the Chinese sources from the 1980s and 1990s on the semiconductor industry are entirely technical. Industry articles focus on the progression of semiconductor technology, not on organizational or political structures in China's domestic semiconductor industry. The authors of technical articles likely wrote less about the industry's structure because of the sensitivities mentioned above, but it is also possible that, like their counterparts in more advanced economies, these semiconductor industry professionals were mostly concerned with learning and applying rapidly evolving semiconductor technologies. With the passage of time, however, key Chinese semiconductor industry leaders have written about the period, discussing the most important changes in this critical high technology industry.⁷³ These authors emphasize new and constructive developments such as the acquisition of new technology, improved production outcomes, new foreign partnerships, etc. They rarely address the reforms to the "old" industry structure, such as when and how particular factories were "released," but.

⁷² The national electronics industry remained in place, but some electronics factories were indeed "released" from the national industry structure during the 1980s. See more in section 2.43.

⁷³ These sources are cited throughout this and other chapters. These authors include current and former officials from leading production enterprises such as Huahong (Hu Qili) and SMIC (Wang Yangyuan) as well as from the Institute of Microelectronics of the Chinese Academy of Science (Ye Tianchun) and the China Semiconductor Industry Association (Yu Zhongyu).

through their written accounts as well as interviews in 2008 and 2009, we can discern the major structural shifts and new priorities that emerged in the 1980s

The best source on the *organization* of China's semiconductor industry until 1987 is Denis Simon's 1988 book, *Technological Innovation in China: The Case of the Shanghai Semiconductor Industry*. Simon addresses both organizational structure and policy-making in the electronics and semiconductor industries in the midst of China's 1980s economic reforms, as well as technological advances and production outcomes. Late in his book, Simon essentially concludes that innovation in China's semiconductor industry in the 1980s was not really about *technological innovation*; rather, the industry was still so hampered by bureaucracy that the real need was for *organizational innovation*. Chinese enterprises might have begun to "catch up" technologically in the 1980s, but they were not yet capable of true technological innovation, at least in the high technology semiconductor industry. Simon's study has much to say about electronics-oriented and semiconductor-oriented governmental committees, the policy-making process, and policies until 1987, all of which aimed to technologically upgrade China's semiconductor industry. Yet, despite intentions, by the late 1980s, China's semiconductor industry was still enmeshed in its bureaucracy and woefully behind global technical standards.⁷⁴

As for the geographic locus of innovation in China's semiconductor industry, Simon was partially correct in identifying Shanghai. In the 1980s, Shanghai was home to more *electronics* organizations than any other area in China, and after 2000, Shanghai and the larger Changjiang Triangle were indeed home to more *semiconductor* enterprises than any

⁷⁴ Denis Simon, *Technological Innovation in China: The Case of the Shanghai Semiconductor Industry* (Massachusetts: Ballinger Publishing, 1988).

other region in China. That said, in the 1970s, 1980s and early 1990s, the city of Wuxi, also located in the Changjiang Triangle about 85 miles west of Shanghai,⁷⁵ was home to China's most advanced semiconductor enterprise and was the largest recipient of the central government's semiconductor investments, as detailed in Chapter Three. At the time of Simon's research, however, information about Wuxi's leading role in the industry was likely not publicly available, due to the strategic and security-related nature of the industry.

Today, with some twenty-five years of hindsight, we can identify the actual outcomes and important trends in China's semiconductor industry from the late 1970s through the early 2000s. One important trend, covered in Section 2.4, is that industry officials narrowed and deepened state-led semiconductor efforts, for example, they shifted from attempting to simultaneously upgrade equipment in more than 30 state-owned semiconductor enterprises in the late 1970s and early 1980s to deciding in 1989 to attempt to create just five "key" semiconductor enterprises, one of which would be a highly-advanced semiconductor enterprise. This enterprise was called Huajing, and it originated in Wuxi's #742 Factory, a state owned enterprise. Officials hoped that if Huajing could operate successfully in China's still-reforming environment, then Huajing would serve as a kind of beacon to attract foreign firms as well as spur the emergence of new domestic semiconductor firms. This chapter addresses reforms to the state owned sector in the 1980s but also this "narrowing" trend and other important changes in China's state-owned semiconductor industry.

⁷⁵ The Changjiang Triangle refers to Shanghai, southern Jiangsu province and northern Zhejiang province, along the Yangtze River.

2.2 The Early Foundations of China's Semiconductor Industry, 1956-1978

Prior to Reform and Opening in 1978, China's domestic semiconductor industry was at a very low technological level by global standards.⁷⁶ There may have been over 40 factories engaged in semiconductor-related manufacturing in the early 1970s, but these factories were mostly producing simple diodes and transistors, which are the “discrete devices” used in many electronic products and which are the building blocks of semiconductors. Only a few factories were making actual semiconductors, and under China's planned economy, these factories were producing only low levels of output. “Cost was high and efficiency was low, but price was high,”⁷⁷ according to a Chinese engineer who worked at several of these factories in the early 1970s. Of course, in the 1960s and 1970s, even leading Western firms such as Texas Instruments and Fairchild had only recently begun to mass-produce semiconductors.

Despite the generally low level of China's semiconductor industry in the early 1970s, the years between 1956 and 1978 were formative. In 1956, a group of leading scientists was organized by China's State Council -- China's highest state body⁷⁸ -- to develop

⁷⁶ Semiconductors (半导体) are also called integrated circuits (IC or 集成电路), and they are the core of the field of microelectronics (微电子). These terms will be used repeatedly in this and other chapters.

⁷⁷ Yu Xiekang 于燮康 (General Manager of Jiangsu Changjiang Electronics Technology, called JCET, and former General Manager of Huajing), “*Gongtong de Lixiang, Gongtong de Fendou, Gongtong de Shouhuo—Jiangsusheng Jichengdianlu Chanye Kechixu Fazhan de Licheng yu Tansuo* 共同的理想, 共同的奋斗, 共同的收获 --- 江苏省集成电路产业可持续发展的历程与探索 (Common Ideal, Common Striving, Common Achievement – The History of Sustainable Development in the Jiangsu Province IC Industry),” *Baodaoti Hangye 半导体行业 (Semiconductor Industry)*, December 7, 2008.

⁷⁸ The State Council has been and remains China's highest state body. In 2012, there were 65 organizations reporting directly to the State Council. These included ministries, commissions, institutes, offices and other organizations. The Chinese government has a website with a complete listing of organizations under the State Council. See <http://english.gov.cn/links/statecouncil.htm>.

a plan for China's overall scientific and technological development. The outcome was a document called "Outline for Science and Technology Development, 1956-1967". According to Wang Yangyuan, this document identified semiconductor technology as a "key priority" for China's future.⁷⁹ Following this, in the late 1950s, the Applied Physics Institute of the Chinese Academy of Science⁸⁰ held a seminar for overseas returned scholars to discuss semiconductor theory and manufacturing. Following this seminar, five major universities began offering a major called "Semiconductors and Physics." These universities included: Peking University, Fudan University, Jilin University, Xiamen University, and Nanjing University. Soon, other semiconductor-related educational and degree programs were established. As early as 1957, Peking University's first class of Semiconductor and Physics majors graduated.⁸¹

The policy emphasis and the university programs outlined above created a foundation of technical knowledge for the industry from 1956 to 1965, but progress was interrupted by the chaos of China's Cultural Revolution from 1965 to 1975. During the Cultural Revolution, industry slowed, many universities were closed, and the Chinese Communist Party disparaged and purged "elites," including scientific elites. Thus, semiconductor industry personnel were stymied in their studies and research. In interviews with Fudan University alumni who

⁷⁹ Wang Yangyuan and Wang Yongwen 王阳元, 王永文, *Wo Guo Jichengdianlu Chanye Fazhan Zhilu: cong Xiaofei Daguo Zouxian Chanye Qiangguo* 我国集成电路产业发展之路：从消费大国走向产业强国 (*China's IC Industry Development Path: From a Big, Consuming Nation to a Strong, Industrial Nation*), Kexue Chubanshe Science Press 科学出版社 (Science Press), 2008, page 291. Wang Yangyuan is an industry elder and founder and Chairman of SMIC, a major semiconductor enterprise in China.

⁸⁰ Headquartered in Beijing, the Chinese Academy of Science (CAS) is China's most prominent national-level scientific academy. CAS has institutes and branches throughout China.

⁸¹ Several of the 1957 class from Peking University are still active leaders in the industry today, e.g., Yu Zhongyu as President of CSIA, Wang Yangyuan as Chairman of SMIC, and Xu Juyan, CAS Academician, Honorary Chief Engineer at CRM and CETC 58. Each of these individuals were interviewed for this study. Wang and Wang, *Wo Guo Jichengdianlu Chanye*, page 291.

studied semiconductors-related majors during this period, the alumni stated that they had not really studied from about 1966, but rather they were made to either work in factories or undertake so-called political study. Each of these men expressed great frustration at China's ten-year retreat from scientific and technological progress, and each had been eager to return to university in the late 1970s to continue their studies, as the field of semiconductors was widely recognized as critical at that time.⁸²

Despite an overall slow-down during the Cultural Revolution, China's state-owned and centrally planned semiconductor industry made some technological advances between 1965 and 1978, both in knowledge and small-scale production. In the early 1970s, Chinese semiconductor organizations began to import foreign equipment to expand and upgrade production. However, funds were limited and equipment acquisition was price-based and piecemeal, with the result that Chinese personnel often could not implement, use and maintain the imported production equipment. Nonetheless, in this period under central planning, knowledge was shared among factories and research institutes. Yu Xiekang, who was formerly a General Manager of Huajing and who is now an executive at one of China's largest semiconductor enterprises,⁸³ described the work environment in the 1970s as follows:

⁸² Interviews with four Fudan University alumni, May 30, June 4 and June 8, 2009, in Shanghai. These four men finished their educations in semiconductor-related fields in the late 1970s after the Cultural Revolution. Each initially entered a state research institute. One eventually became a professor at a Fudan University institute and later formed a technology company with foreigners. Another spent his career in the state semiconductor industry and is currently Director of the Shanghai IC Industry Association. Another went from an institute to a state-owned enterprise and later started two technology companies. The fourth migrated to New Zealand in the mid 1980s and returned to China in the early 2000s, where he now has his own industrial consulting company, serving Chinese and foreign companies. Despite no longer working in state-owned semiconductor enterprises or institutes, these men still closely follow the events and politics of China's largest semiconductor enterprises.

⁸³ Yu is with Jiangsu Changjiang Electronics Technology (JCET), which does packaging/assembly/testing (P.A.T.) of semiconductors. The three major sectors of the semiconductor industry value chain are: design, fabrication (manufacturing), and P.A.T.

“I graduated in 1968..., so I have seen the whole Jiangsu semiconductor industry begin and grow and [become] strong... Although conditions were really bad [in the early 1970s], the spirit of coordination between companies was very good, and technology was shared freely. I myself participated in the R&D for 3DA93, [which we] learned from the Shanghai #5 Component Factory. I also participated in making the 3DK2 transistor and in R&D for the 3DK7, which I learned from the Chengdu #970 Factory. At the same time, the #742 Factory [later called Huajing] trained people from the Nanjing Industrial Academy, Chengdu Telecomm and Engineering Academy, Xinjiang Semiconductor Factory, Gansu #871 Factory, Wuxi Transistor Company, Jiangyin Transistor Company, Changshu Transistor Company, etc. At that time, [many supplies were] made by ourselves at #742 Factory...[and] were also designed by ourselves. I ate and lived in the factory. I was not only a technical person but also a task person, so I had to do everything.”⁸⁴

After the Cultural Revolution, China’s pool of semiconductor talent grew each year. In the late 1970s, China established comprehensive research universities, including 88 “key” universities each of which offered electronics-related programs. Also in the 1980s, new policies enabled Chinese students to study abroad, and many students pursued engineering and science degrees at foreign institutions. These educational opportunities in China and abroad created a growing cohort of electronics professionals, and by 1985, China’s semiconductor enterprises employed approximately 5,000 technical staff.⁸⁵

2.3 China’s Centrally Planned Semiconductor Industry in the 1980s

In the early 1980s, industry officials continued to try to develop China’s semiconductor knowledge base and production. According to the China Semiconductor

⁸⁴ Yu Xiekang 于燮康 (General Manager of JCET, former General Manager of Huajing), “*Gongtong de Lixiang, Gongtong de Fendou, Gongtong de Shouhuo—Jiangsusheng Jichengdianlu Chanye Kechixu Fazhan de Licheng yu Tansuo* 共同的理想, 共同的奋斗, 共同的收获 --- 江苏省集成电路产业可持续发展的历程与探索 (Common Ideal, Common Striving, Common Achieve – History of Sustainable Development in the Jiangsu IC Industry),” *Baodaoti Hangye 半导体行业 (Semiconductor Industry)*, December 7, 2008.

⁸⁵ Yu Zhongyu, “China’s IC Industry, the Status Quo and Future,” a presentation delivered at Stanford University, 2005. Chapter Five will further discuss the growth in China’s semiconductor talent pool.

Industry Association, in the early 1980s, China had 33 semiconductor enterprises, which were in the process of being updated through imported equipment, because China did not yet have the capability to self-produce such equipment.⁸⁶ See Figure One for a list of China's key semiconductor facilities in the mid 1980s.⁸⁷ With funds from the central government, these enterprises spent RMB 1.3 billion to import 24 production lines. Most of these lines were outdated 3 inch lines, but a few were 4 inch lines.⁸⁸ As in the early 1970s, equipment was purchased piecemeal and second-hand, and Chinese personnel did not know how to use or maintain the equipment, nor did they know what products to produce. Thus, this RMB 1.3 billion investment was widely dispersed across enterprises, and ultimately only a few of the production lines were functional.⁸⁹

⁸⁶ Former engineers gave examples of the factories' need to import production lines in the 1980s. In one case, Chinese engineers claim to have "tricked" Philips (a leading equipment company based in the Netherlands) into selling them a production line at half price, claiming that they could make it themselves, when in fact they could not. In another case, a Chinese research institute offered to give production equipment to a factory at no cost, but the factory responded by saying that they had already applied for permission to import equipment, and they would rather have the far-more-expensive imported equipment. Interviews, June 4 and June 8, 2009, Shanghai.

⁸⁷ In his 1988 study, Denis Simon identified 13 key semiconductor production facilities and 7 key research institutes. In the 2000s, Chinese sources identified 33 to 40 semiconductor facilities from the 1980s, and these sources include all the key facilities identified by Simon, see Simon, *Innovation*, 67.

⁸⁸ In the semiconductor industry, a production line's size in inches, e.g., "a 3 inch line" refers to the diameter of the silicon wafer, from which semiconductors are cut. Larger diameter wafers provide more semiconductors per wafer and thus better economies of scale, but they are more expensive and complex to manufacture (manufacturing is called "fabricating" in the semiconductor industry). Thus, an 8 inch line is more technologically advanced than a 6 inch line. Semiconductor process technology is also commonly measured by the micron level, abbreviated as μm , which is one-millionth of a meter. The microns (or nanos), e.g., "5 μm ," refers to the width of the line etchings on a semiconductor. In the case of microns and nanos, smaller represents more advanced technology.

⁸⁹ Sources: China Semiconductor Industry Association (CSIA), "Zhongguo Jichengdianlu Chanye de Huigu yu Zhanwang 中国集成电路产业的回顾与展望 (Review and Prospects of China's IC Industry)," a document provided by WXICC in January of 2009. Also, Wang and Wang, *Wo Guo Jichengdianlu Chanye*, page 291-293. Also, Yu Xiekang 于燮康 (General Manager of JCET, former General Manager of Huajing), "*Shenhua he Wanshan Jichengdianlu Chanye Zhengce, Tuijin Wo Guo Jichengdianlu Chanye Chixu Wending Fazhan 深化和完善集成电路产业政策, 推进我国集成电路产业持续稳定发展* (Deepen and Perfect Policies for IC Industry, Promote the Sustainable Development of China's IC Industry)," *Bandaoti Hangye 半导体行业 (Semiconductor Industry)*, August, 2008. Yu Xiekang said that of the many enterprises receiving new production lines, "only one and a half lines were really functioning and 10 or more lines barely survived."

Figure 1: China's Largest Semiconductor Production Facilities in the 1980s

Facility	Location
Jiangnan Semiconductor Factory	Jiangsu, Wuxi
Tianguang Electronics Factory	Gansu, Qinan
Dongguang 878 Factory	Beijing
Changzhou Semiconductor Factory	Beijing
Beijing Semiconductor #2	Zhejiang, Shaoxing
Shaoxing Electronics Factory	Shanghai
Shanghai #5 Components Factory	Shanghai
Shanghai #14 Radio Factory	Shanghai
Shanghai #19 Radio Factory	Shanghai
CAS Factory #109	Beijing
Lishan Microelectronics Corporation	Xian
Tianjin Semiconductor Factory	Tianjin

Source: From Denis Simon, *Technological Innovation in China*, page 67.

Industry observers often suggest that export controls on semiconductor equipment by Western countries hindered or blocked China's technological progress during the Cold War era, but export controls likely did not hinder the development of China's semiconductor industry. During that time, the NATO organization CoCom (the COordinating COMmittee for Multilateral Export Controls, established in 1949) indeed limited high technology and dual use technology exports to China, the Soviet Union, and other Warsaw Pact countries. The role of CoCom was to set acceptable "technical specifications for dual-use items that were being considered for export" to China and Warsaw Pact countries.⁹⁰ Several Chinese semiconductor industry leaders with broad knowledge of the industry mentioned that CoCom restrictions did not really affect China's ability to import production equipment in 1980s and 1990s, discussing specific cases where the foreign equipment they sought was available for import. Although CoCom would have blocked cutting-edge semiconductor technology exports to China in the 1970s and 1980s, Chinese semiconductor leaders usually were not seeking production equipment that rose to the level of being export-controlled.⁹¹ The technical knowledge of semiconductor production in China was such that, even when Chinese organizations imported *outdated* equipment, the technicians and production staff often were not able to use and maintain the equipment. Thus, according to these interviews, CoCom restrictions had little real effect on China's efforts to upgrade technology in the 1980s and earlier. The semiconductor production technology that Chinese enterprises sought in the

⁹⁰ Hanns-D. Jacobsen, "CoCom - The Coordinating Committee on Multilateral Export Controls (1st Draft)," The Economics of the Cold War, a conference at the Hamburg Institute for Social Research, September 2-4, 2009.

⁹¹ These interviewees included: Teng Jingxin, Chief Engineer of Huarun, and Wang Guoping, CEO of Huarun, July 16, 2009, Wuxi, Huarun headquarters; Yu Zhongyu, President of China Semiconductor Industry Association, July 2, 2009, CSIA headquarters in Beijing; Yu Xiekang, General Manager of Jiangsu Changjiang Electronics Technology, June 2, 2009, JCET headquarters.

1970s and 1980s was available for purchase, if not from the United States, then from equipment suppliers in Europe, such as ASML in the Netherlands. And, if a CoCom country wanted to sell a restricted item to China, they sometimes were able to sell to a “neutral” Chinese university research institute rather than a Chinese enterprise.⁹² As will be discussed in Chapter Three, Wuxi’s #742 Factory got China’s first full 3 inch semiconductor production line from Toshiba of Japan, a CoCom member country, during China’s 6th five year plan (1981-1985). By 1986, Huajing was China’s most advanced semiconductor enterprise, based on the 5 micron technology that Huajing had gotten from Japan. However, 5 micron technology had been in use in the US and Japan since the early 1970s and thus was not considered leading edge technology by CoCom.⁹³ Similarly, Simon (1988) wrote that from 1981 to 1985 “China’s electronics industry imported over 1,000 items of technology; one-third of the country’s major electronics factories [were] at least partially renovated thru [foreign importation]” from Japan and other countries, although these importations and renovations were limited by funding, approvals, and technical knowledge.⁹⁴ When writing about or discussing the era, Chinese semiconductor industry leaders frequently mention the CoCom export controls, but the equipment that they actually needed and sought was not at a high-enough technological level to be prohibited and was indeed available.⁹⁵ According to

⁹² Interview with Joseph Chen, ASML (a leading global semiconductor equipment company), Wuxi, June 29, 2009.

⁹³ Writing in 1987-88, Denis Simon said “claims have been made that the manufacturing technologies for ICs in the 5 micron range have been mastered during the 6th five year plan...” These claims were likely about Huajing, then called #742 Factory and considered a sensitive site in the industry due to its military ties. See Simon, *Innovation*, 66.

⁹⁴ Simon, *Innovation*, 129-130.

⁹⁵ In a 1985 Rand report based on interviews with Chinese electronics enterprise managers, Jonathan Pollack summarized the situation by writing “Despite frequent complaints from Chinese officials and end users and from some American businessmen on the inhibiting effects of the U.S. export licensing process, modern

interviews with Chinese semiconductor industry leaders, the main obstacles to foreign equipment acquisition in the 1970s and 1980s was China's shortage of foreign exchange and the cumbersome process of getting government approval to import equipment.⁹⁶ Figure Two compares China's technological level with global leading levels from the 1970s.

Along with these technological limitations, China's semiconductor industry was also beset with structural limitations in the 1980s. In his 1988 study, Denis Simon used information from China's Ministry of the Electronics Industry and the *Chinese Electronics Yearbook* (1986) to develop a useful summary chart of the structure of China's national civilian electronics industry in 1987.⁹⁷ Simon shows a vast national bureaucracy, organized into a vertical hierarchy. Figure Three is based on the chart that Simon developed (Simon, *Technological Innovation*, Figure 3.1, page 54), with additions. As Figure Three shows, a number of ministries – in addition to the Ministry of the Electronics Industry – had electronics-related institutes and factories.⁹⁸ Further, each ministry oversaw a number of bureaus, each of which had both institutes and factories. Simon notes that in 1985 the

electronics items from the US, Japan, and Western Europe (including advanced microcomputers) are widely, if unevenly, prevalent in Chinese laboratories and factories. The intensely competitive nature of the semiconductor and computer industry – and the easy proximity of Hong Kong to enterprising Chinese factory and laboratory personnel – virtually guarantees a steady flow of these products to China, regardless of U.S. Policy.” Pollack, *The Chinese Electronics Industry*.

⁹⁶ Interview with Yu Zhongyu, President of China Semiconductor Industry Association, July 2, 2009, CSIA headquarters in Beijing. Wang and Wang, *Wo Guo Jichengdianlu Chanye 我国集成电路产业 (China's IC Industry)*, 341-342. Wang and Wang cite the meager investment in China's semiconductor industry as RMB 880 million from 1986 to 1990, RMB 11 billion from 1991 to 1995, and RMB 14 billion from 1996 to 2000, for a 15 year total of approximately US\$3.2 billion, which they describes as less than Intel's annual investment in the early 2000s. For details on the complex approval process for foreign equipment importation, see Simon, *Innovation*, 130-133.

⁹⁷ Ibid., pages 52-55, chart on page 54.

⁹⁸ In 1988, the Ministry of the Electronics Industry was merged with the State Machine Building Commission to form the Ministry of Machine Building and Electronics Industry.

Figure 2: Gap Between China and Global Leading Technology (year attained)

	Wafer Size in Inches (larger is more advanced)	
Year	Global	China
1970	2	1.5
1975	4	1.5
1980	5	2
1985	6	3-4
1990	6-8	3-4
1995	8	6
2000	12	6-8
2005	12	12
2010	12-18	12

< Shougang-NEC

< Huahong-NEC and CSMC-Huajing

< SMIC

	Small Scale Integration	Medium Scale Integration	Large Scale Integration	Very Large Scale Integration	Ultra Large Scale Integration
Global	1958	1964	1966	1976	1986
China*	1965	1972	1972	1986	1999

The years indicated for China seem optimistic. They may reflect technological understanding more than actual production capabilities.

Source: Zhu Yiwei 朱贻伟, *Zhongguo Jichengdianlu Chanye Fazhan Lunshu Wenji 中国集成电路产业发展: (China's IC Industry Development: Collected Works)*, Beijing: Xinshidai 新时代出版社 (New Times Press), 2006, page 69.

Ministry of the Electronics Industry alone was overseeing some “2600 factories...along with over 130 research institutes and 6 dedicated universities.”⁹⁹

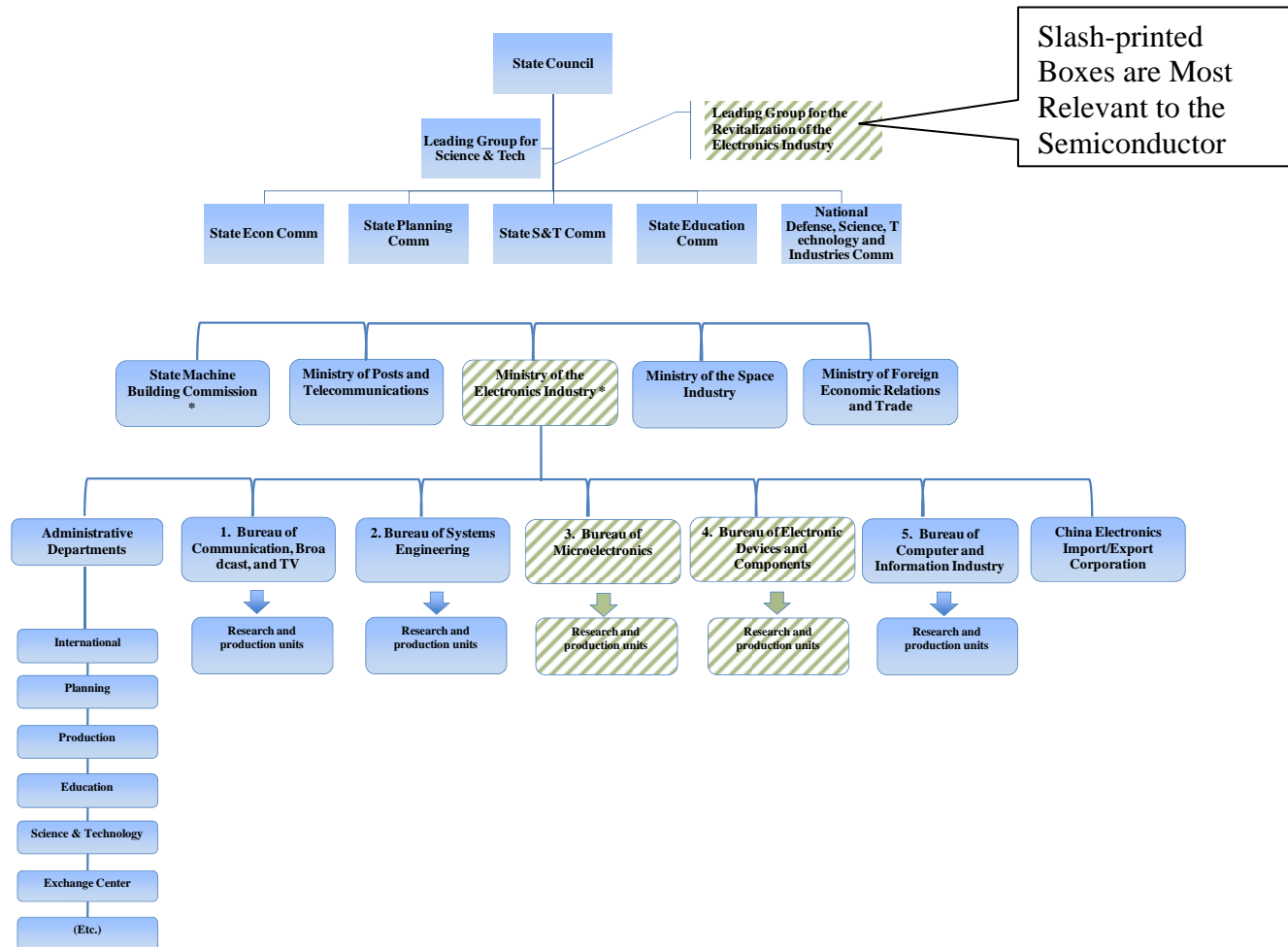
As for the semiconductor industry, apart from the larger electronics industry shown in Figure Three, according to the China Semiconductor Industry Association, there were about 5,000 technical staff and 40,000 total staff in China’s 33 semiconductor enterprises in 1985,¹⁰⁰ many of which likely worked under the Bureau of Microelectronics, shown under the Ministry of the Electronics Industry in Figure Three. Extending the vertical hierarchy represented in Figure Three, each semiconductor enterprise had additional associated units. For example, in 1989, Huajing had a total of 72 associated units, consisting of three groups: 1) core units, meaning research institutes, factories and educational units, 2) close units, meaning units that supported or supplied Huajing, and 3) independent units, meaning units that were not officially part of Huajing but cooperated or supported Huajing in some way.¹⁰¹ In this way, the national industry structure was even larger than Figure Three suggests. Of course, China’s 1980s electronics research and production capacity also included military-oriented organizations. Military-oriented electronics facilities were organized and located separately from civilian electronics. Barry Naughton has shown that many military-related facilities were located in China’s remote “Third Front” areas, away from China’s

⁹⁹ Simon, *Innovation*, 52. Simon also has charts and Figures showing the complexity of Shanghai’s municipal electronics industry and its electronics research and development system in the mid 1980s. See pages 100 and 105 of his book, Figures 4.2 and 4.3, respectively. As a municipality, Shanghai had its own set of industrial bureaus outside of the bureaus that were under the national-level industrial ministries.

¹⁰⁰ Yu Zhongyu, “China’s IC Industry, the Status Quo and Future,” a presentation delivered at Stanford University, 2005.

¹⁰¹ Interview Yu Xiekang, June 2, 2009, at JCET headquarters. Yu Xiekang was General Manager of JCET and an official of the China Semiconductor Industry Association (CSIA) in 2009. JCET is a large, state-affiliated ATP enterprise in Jiangsu. Yu Xiekang was also General Manager of Huajing from 1987.

Figure 3: China's Electronics Industry, Circa 1986



** Simon notes that in 1985, the Ministry of the Electronics Industry oversaw some 2600 production units and 130 research institutes.

* In 1988, the State Machine Building Commission and the Ministry of the Electronics Industry merged to form the Ministry of Machine Building and Electronics Industry.

Source: Denis Simon, *Technological Innovation*, page 54, from China's Ministry of the Electronics Industry, Beijing, July 1987.

eastern seaboard.¹⁰² China's 3rd Front included outlying provinces such as Sichuan, Guizhou, and Yunnan. According to Naughton, from 1964 to 1971, Chinese officials established important industrial and military enterprises in these areas in order that China's facilities would be geographically dispersed and thus safer from foreign attacks that might target the eastern part of the country.¹⁰³ Further, China's many military-related electronics facilities were not part of the Ministry of the Electronics Industry. Rather, from 1982, China's National Defense Science, Technology and Industries Commission oversaw military work. Until the late 1980s, military electronics and civilian electronics remained largely separate, with the exception that, at times, civilian organizations, such as CAS institutes, would support military-related projects.¹⁰⁴ However, by the mid to late 1980s, military-oriented electronics factories attempted to shift part of their production to civilian electronics in order to serve the growing market for electronics.¹⁰⁵ (Section 2.43 under *Implementation of Reforms* addresses state-owned enterprises' shift from producing only for central and local plans to also producing for China's growing electronics market.) Both military and civilian semiconductor facilities sought to supply the semiconductors and discrete electronic components, e.g., diodes, transistors, and switches, that were required for electronic products.

¹⁰² See Barry Naughton, "The Third Front: Defense Industrialization in the Chinese Interior," *The China Quarterly*, September, 1988. Naughton argues that industrial and military development of the Third Front "dominated" China's industrialization between 1964 and 1971. For more on China's military, see Richard Bitzinger, "Arms to Go: Chinese Arms Sales to the Third World," *International Security*, Volume 17, Number 2, pages 84-111; Litai Xue and John Lewis, *China Builds the Bomb* (Stanford: Stanford University Press, 1988); and various works by James Mulvenon, Robert Ross, and David Shambaugh.

¹⁰³ Ibid.

¹⁰⁴ Simon, *Innovation*, 39.

¹⁰⁵ For more on China's military industry and its reforms, see works by Tai Ming-cheung, James Mulvenon, David Shambaugh, and David Lampton.

Despite China's many research institutes and civilian and military electronics factories and despite the push to import more modern equipment, by the mid to late 1980s, China's electronics industry was not advancing as hoped and as needed. Industry officials recognized that there were too many projects and not enough capital. Further, investments by the central government in enterprises became debts, e.g., if the Ministry of the Electronics Industry provided funds to an enterprise to procure foreign equipment, then the enterprise would later have to repay the Ministry. China's semiconductor enterprises did not have independent ability to source capital, nor did they have the capacity to develop their products or their human resources.¹⁰⁶ Further, Simon's study detailed the many bureaucratic and decision-making obstacles within the national industry. This research and Simon's research both show several overriding problems in China's state-owned semiconductor industry in the 1980s: the complex and bureaucratic national industry structure, limited funds for capital intensive semiconductor equipment, and the level of skills and knowledge among Chinese production personnel. Thus, as in many other industries in China, Chinese officials pursued distinct reforms and strategic projects for the semiconductor industry, with the goal of strengthening this critical high-technology industry.

¹⁰⁶ At that time, state-owned enterprises did not have access to capital outside of their ministry or the state-owned banks. At that time in China, capital was not available through private channels, as China's banking and financial system had been nationalized in the 1950s. Yu Xiekang 于燮康 (General Manager of JCET, former General Manager of Huajing), "Shenhua he Wanshan Jichengdianlu Chanye Zhengce, Tuijin Wo Guo Jichengdianlu Chanye Chixu Wending Fazhan 深化和完善集成电路产业政策, 推进我国集成电路产业持续稳定发展 (Deepen and Perfect Policies for IC Industry, Promote the Sustainable Development of China's IC Industry), *Bandaoti Hangye 半导体行业 (Semiconductor Industry)*, August, 2008.

2.4 New Policies Affecting China's Semiconductor Industry from the mid 1980s

After reform and opening in 1978, but mainly from the mid 1980s, Chinese central government officials pursued a number of new policies and reforms that directly or indirectly supported the semiconductor industry. Most of these reforms flowed from China's "four modernizations." In the mid 1980s, while government officials remained committed to maintaining control of China's military-related electronics organizations, officials also sought to reform the centrally planned and state-owned civilian electronics industry.

Chinese officials were well aware that developed countries had been rapidly innovating while also commercializing electronic technology throughout the 1970s and 1980s. Through the 1960s, the main uses globally for semiconductors had been military equipment and mainframe computers, but in the 1970s and early 1980s, a wave of new consumer applications that required semiconductors emerged including calculators, video games, and the Mac and IBM personal computers. From the mid-1980s, the speed and memory of computers continuously improved. For example, Intel's 386, 486, and 586 "chips" (i.e., integrated circuits) were ever-advancing versions of Intel's microprocessors, which served as the central processing units (CPUs) of computers.¹⁰⁷

As semiconductor technology quickly evolved in the 1980s, Chinese policy makers pursued a number of new policies to help China's semiconductor industry "catch up" technologically with the global industry. These policies are addressed as follows: Section 2.41, general industrial reform policies; Section 2.42, science and technology (S&T) reform policies; and Section 2.43, electronics and semiconductor industry reform policies. The

¹⁰⁷ From the mid 1980s to the mid 1990s, the 386, 486 and 585 improved personal computers. Then, from the mid 1990s, Microsoft's "Windows" software improved the user-interface of personal computers. Also in the mid 1990s, computer users benefited from networked and wireless technology.

important point to bear in mind, however, is that although these new policies were indeed important, the policies were not always immediately and fully implemented. As we will see in Chapters Three through Five, many of the problems plaguing China's centrally planned economy continued to affect the electronics and semiconductor industries long after the 1980s.

2.41 An Overview of China's Industrial Reform Policies and Intentions

Prior to 1978, China's government planning authorities had control over most of China's industrial resources in terms of investment, production, pricing and consumption. The central planning authority set production targets for enterprises and provided the enterprises with the inputs to achieve their targets. Prices were also set by central planning authorities and did not reflect a "market value." Under this system, China's central government, as well as China's provincial, municipal and local governments, controlled thousands of enterprises, both large to small.

From 1978, Chinese leaders had reformed China's agricultural sector and had allowed the growth of the non-state sector with notable success. Following this, in the 1980s, the Chinese government announced its intention to reform China's vast industrial sector. However, progress in reforming the industrial sector was limited in the following years, and thus in 1984, China's 12th Central Committee issued its "Central Committee Decision on Reform of the Economic System."¹⁰⁸ This "decision" sought to fundamentally reform China's centrally planned economy, across industries. According to Barry Naughton and

¹⁰⁸ Also, in 1982, China's State Council formed a new group called the "State Commission for Restructuring the Economic System"; Premier Zhao Ziyang was Chairman.

other scholars,¹⁰⁹ key elements of the 1984 decision included: price reform to allow prices to reflect supply and demand; reducing the scope of central planning, although not abolishing central planning; allowing enterprise managers to have more decision-making control in terms of investment, resources, personnel, profits, and trade; and developing a new taxation system wherein enterprises would pay a portion of their profits in taxes. In addition, the 1984 decision encouraged trade including foreign trade, regional specialization, rather than regional self-sufficiency, and the growth of collective and private enterprises, alongside the state-owned enterprises.

The challenges to carrying out such fundamental change across China's major industries were many. There were political as well as operational challenges. Some officials continued to believe strongly in government control of economic resources, while other officials simply did not want to give up their base of power. Obviously, to implement such broad-based reforms across industries, many new systems had to be developed and old systems had to be reformed, including such key economic levers as pricing. At the enterprise level, managers' experience and skills were based in the existing centrally planned system, and thus their ability to implement new practices was limited.¹¹⁰ Further, China did not have a functioning legal system nor capital markets to support and protect industries and enterprises, as is available in advanced economies. Nonetheless, the 1984 decision

¹⁰⁹ For more, Gregory Chow, "Development of a More Market-Oriented Economy in China, Econometric Research Program," *Research Memorandum Number 326*, Princeton University's Econometric Research Program, August 1986; Naughton, *Growing Out of the Plan*; Dwight Perkins, *China: Asia's Next Economic Giant?* (Washington: University of Washington Press, 1990); Justin Yifu Lin, "Fiscal Decentralization and Economic Growth in China," *Economic Development and Cultural Change*, October 2000.

¹¹⁰ Ibid.

summarized above reveals that officials at the highest levels of China's government hoped to implement broad and deep industrial reforms in the latter half of the 1980s.

2.42 Reform Policies for the Science and Technology (S&T) System

Under China's centrally planned economy, in addition to a hierarchical national structure for each industry, there was also a national science and technology "system." This system mainly consisted of five different types of organizations. These included: 1) the Chinese Academy of Science (CAS) and its institutes and branches throughout China, 2) research institutes under the State Council's various industrial ministries, 3) university research institutes, 4) military-related research institutes, and 5) provincial and municipal research institutes. Semiconductor-related research was conducted in each of these types of organizations. As part of China's four modernizations, Chinese officials sought to reform the S&T system to ensure that science and technology supported China's overall economic growth and technological progress.¹¹¹

2.42a Problems in China's S&T System

In his research on China's S&T system in the 1980s,¹¹² Tony Saich argued that China's S&T system was beset with a number of problems. These included insufficient funding, little to no individual financial incentive, and bureaucratic and rigid organizations that did not foster individual mobility and knowledge sharing.

¹¹¹ For China's early reforms in science and technology, see Richard Suttmeier, *Science, Technology, and China's Drive for Modernization* (Stanford, CA: Hoover Institution Press, 1980).

¹¹² Tony Saich, *China's Science Policy in the 80s* (Atlantic Highlands, New Jersey: Humanities Press International, 1989).

Another major problem with the vertical structure of China's industries as well as its S&T system was the separation of research organizations from production organizations. Scientists and production personnel largely worked in their own vertical silos, and thus scientists and production staff did not readily communicate their problems, findings, or goals to one another.¹¹³ Saich identifies this separation of research and production based on the structure of China's S&T system and based on Chinese reform proposals, which explicitly sought to forge closer links between research and production.¹¹⁴ In China's S&T system, scientists could gain advanced knowledge and possibly produce a prototype of a new technology product, but their goal was to serve their research organization. Their tendency was to concentrate on "basic" research, which advances scientific knowledge without necessarily applying that knowledge to enhance products. The goal of many scientists was not to design products for mass production, nor to design products to meet a market demand. Chinese scientists focused less on "applied" research, which is directed toward functional innovations such as consumer, industrial or military applications. Like elsewhere in the world, basic research was -- and is -- considered more prestigious in China. Meanwhile in China's factories, factory managers sought to meet their production quota from the central plan, not to innovate or improve their products. Industry managers around the world and across industries have long known that close working relationships and proximity between research and production personnel are invaluable. Typically, a group of engineers works directly with the

¹¹³ Ibid., page 24. Saich cites a document called the "Decision of the Central Committee of the Chinese Communist Party on Reform of the Science and Technology Management System (*Zhonggong Zhongyang guanyu Kexue Jishu Tizhi Gaige Jueding* 中共中央关于科学技术体制改革的决定)," from the People's Daily (*Renmin Ribao* 人民日报), March 20, 1985, pages 1 and 3.

¹¹⁴ Ibid.

production team for a product or product line. These relationships enable scientists and engineers to coordinate with production personnel in making ongoing, incremental improvements to product designs and production processes.

This cross-fertilization, however, was often missing in China's planned economy, and indeed was largely missing in China's electronics and semiconductor industries.¹¹⁵ This was the drawback of China's S&T system that most tangibly affected China's ability to produce semiconductors,¹¹⁶ but reforms to the S&T system were critical for the semiconductor industry for two other important reasons. China's research institutes were far behind the global industry in applied research and design for semiconductors, and semiconductor research was conducted in widely dispersed organizations throughout the S&T system and thus there was a belief that knowledge was not being effectively shared.¹¹⁷

2.42b New S&T Policies

In March of 1978, Beijing hosted a "National Science Conference," and at this conference, electronics was named a key national priority. According to Denis Simon, there was "special emphasis on semiconductors and computers... [and shortly thereafter] the 'National Development Plan for Science and Technology (1978-1985)' set very ambitious

¹¹⁵ Ibid., pages 34-35, Chapter Two, pages 148-151. Also, Simon, *Innovation*, pages 32 and 39-41. As an example, Chapter Three will show that Huajing joined with Institute 1424 to gain research support as well as coordination between research and production.

¹¹⁶ Tony Saich, *China's Science Policy in the 80s* (Atlantic Highlands, New Jersey: Humanities Press International, 1989), pages 34-35, Chapter Two, pages 148-151.

¹¹⁷ Jiang Chenqi 蒋臣琦, "Pinbo Chuangye, Fazhan Pandeng: 24 Suo Chengli Ershi Zhounian Huigu yu Zhanwang 拼搏创业, 发展攀登: 24 所成立 20 周年回顾与展望 (A Difficult Business, the Development Climb: Institute 24's 20th Anniversary Review and Prospect)," *Weidianzi Xue 微电子学 (Microelectronics)*, March, 1990. The author, Jiang Chenqi, was one of the first staff members at Institute 24.

goals for electronics...[including] a massive influx of foreign technology.”¹¹⁸ The State Council eventually established a Special Leading Group for Science and Technology in January 1983; this leading group was led by Premier Zhao Ziyang¹¹⁹ and had representatives from State Science and Technology, State Planning, and State Economic Commissions. The State Council occasionally establishes such “leading groups” (*lingdao xiaozu* 领导小组); these are special groups of high level officials that can coordinate across China’s many ministries and other government organizations. Leading groups can consider problems, make policy recommendations to the State Council, and coordinate policy implementation across various governmental organizations. To implement the ambitious goals of S&T reform, Saich and Simon argue that the Special Leading Group for Science and Technology was necessary in order to forge working relationships and decision-making for S&T across the highest organs of government.¹²⁰ The group aimed to reform the S&T system while also coordinating these reforms with the needs of the economy.¹²¹ In March of 1985, this leading group published a document with more detailed plans for reforming the S&T sector. This document was called “The Decision of the Central Committee of the CCP on the Reform of the

¹¹⁸ Simon, *Innovation*, 59.

¹¹⁹ Zhao’s participation signals the importance of this work at the highest levels of government; Zhao was Premier of China from 1980 to 1987 and General Secretary of the CCP from 1987 to 1989.

¹²⁰ Saich, *China’s Science Policy*, page 22 and Chapter One. Simon, *Innovation*, pages 29-32.

¹²¹ Tony Saich, “Reform of China’s Science and Technology Organizational System,” *Science and Technology in Post Mao China*, (Massachusetts: Harvard University Press, 1989); Simon, *Innovation*, 1988, pages 28-32. According to these accounts, in the early 1980s, both the Chinese Academy of Science (CAS) and China’s State Science and Technology Commission (SSTC, established in the late 1950s) – China’s two top bodies for science and technology -- proved unable to make headway with reforms. The two groups had been in conflict for decades. Also, from the era of the Cultural Revolution (1965-1975), political elites had been suspicious of technical elites. Finally, in the mid 1980s, technically-qualified personnel were (re)appointed to S&T organizations and scientists were re-installed to lead CAS.

Scientific and Technological System.”¹²² Major priorities of this decision were to: reform the funding mechanisms for S&T; develop markets for trade in technology and intellectual property; and increase the professional mobility of science personnel.¹²³

Funding changes had the most immediate impact on the structure of the S&T system.¹²⁴ The plan was not to immediately decrease *overall* S&T funding, yet the plan entailed “releasing” many of the existing institutes in the coming years. For institutes that were ultimately released, funding was reduced over time, perhaps initially reduced by half and later all funding would cease. Even in the retained institutes, funding was often reduced.¹²⁵ For these organizations, their funding would no longer be allocated through central government grants, but rather the institutes would have to place competitive bids to try to win funding for specific projects. The plan also called for allocating funds for new state-sponsored S&T initiatives. These included: major S&T projects and programs across industries,¹²⁶ a national science foundation, and various “sites” such as technology parks and incubators.

¹²² Ibid., pages 36 and 54. Saich’s source is the *Renmin Ribao* 人民日报 (Peoples Daily), March 20, 1985, pages 1 and 3. The document is called the “*Zhonggong Zhongyang guanyu Kexue Jishu Tizhi Gaige Jueding* 中共中央关于科学技术体制改革的决定”.

¹²³ Ibid.

¹²⁴ Ibid. Also interviews with former research staff: Xu Guochang, June 17, 2009, Shanghai IC Industry Association; Prof. Yang, Fudan University, June 8, 2009; Yin Guohai, Huarun-Anst, June 19, 2009.

¹²⁵ Interview with Fudan alumni group, May 30, 2009, in Shanghai.

¹²⁶ Important programs also included: The 863 program (a.k.a. The National High Technology R&D Program), established in March of 1986 and the TORCH program, established in August, 1988. In the 863 program, an expert committee in Beijing established research priorities in a number of high technology fields. Organizations could apply (compete) for funding from the 863 Program. If awarded funding, the expert committee would check project milestones. The purpose of the TORCH program was to commercialize, industrialize and internationalize high technology, mainly through small and medium size enterprises in China. Working with a US organization, TORCH program leaders organized many overseas delegations and eventually developed “policies, laws and regulations,...financing policies and sources,...and domestic and overseas information channels.” Most concretely, the Torch program was responsible for the establishment of

In addition to the programs above, research personnel -- whether still with an institute or recently released -- were encouraged to seek additional funding or income by pursuing customers, contracts, and partnerships with other “enterprises and [in] the market”¹²⁷ on their own. That said, the market for technology products was only then being developed: from 1984 the government sponsored “technology fairs” to enable research institutes and production enterprises to begin to trade with one another using such mechanisms as contracts, joint ventures, one-time sales, and other transactions.¹²⁸

2.42c S&T Outcomes

In the second half of the 1980s, the actual outcomes of these reforms of the S&T system were mixed for the semiconductor industry. In the microelectronics field, basic research may have suffered because there was little demand and funding for it from central-level ministries, but markets for applied technology, e.g., consumer electronics, began to flourish.¹²⁹ Institutes still received some funding and projects for basic research from the government, but institute personnel increasingly had to seek funding and projects in China’s emerging technology market. Yet, when an institute got a contract or project with a factory, it was often for applied, derivative research. Basic research slowed relative to applied research because factory requests were low-tech, as factories sought to produce low-end consumer

many industrial parks, incubation centers, and innovation parks for returned scholars. See Shi Dinghuan, Executive Director of Torch, “Torch Program,” *The 21st Public Conference Journal* (The Texas Lyceum), November 2006.

¹²⁷ Simon, *Innovation*, 32-33. Also interviews with former research staff: Xu Guochang, June 17, 2009, Shanghai IC Industry Association; Prof. Yang, Fudan University, June 8, 2009; Yin Guohai, Huarun-Anst, June 19, 2009.

¹²⁸ Ibid.

¹²⁹ These technology markets were supported by China’s 1985 Patent Law, but most transactions at that time did not make use of patent protections.

electronic goods.¹³⁰ Further, market-based contracts with factories could be risky because, in some cases, research personnel did not get paid unless a factory had success with a product.¹³¹ In 1987-88, Denis Simon found a “rapid expansion” of China’s new technology markets. Simon noted hundreds of research contracts, technology service organizations, consulting contracts, etc., although Simon’s findings only reflected conditions in Shanghai.¹³²

A related outcome of the new S&T policies was that some scientists, either while still working for an institute or after departing, were able to form entirely new organizations outside of the planned economy. These new enterprises were referred to as private companies (*minban gongsi* 民办公司), non-governmental enterprises (*minying qiye* 民营企业), S&T enterprises (*keji qiye* 科技企业) or privately-owned and operated S&T enterprises (*minyou minban keji qiye* 民有民办科技企业). Such enterprises were newly allowed under government policies that aimed to promote high technology industries and high technology zones. Although these firms were privately or collectively owned, they could sometimes get start-up loans from state-owned banks or other state-owned organizations.¹³³ At that time, other sources of capital, such as private banks, private equity or venture capital, were not yet available in China, as China’s banking and financial system had been nationalized since the

¹³⁰ Interview with Li Weide, June 4, 2009, Shanghai. Li was formerly a semiconductor scientist with a state institute.

¹³¹ Interview with Fudan alumni group, May 30, 2009, Shanghai.

¹³² Simon, *Innovation*, page 148.

¹³³ For more on these new S&T firms, see Adam Segal, *Digital Dragon: High Technology Enterprises in China* (Ithaca: Cornell University Press, 2003.)

1950s. The intention was for these new technology enterprises to directly support China's economic needs by being active in China's new markets for technology.¹³⁴

A famous example of institute staff forming a successful, so-called private company occurred at the Beijing Software Institute. Scientists in the institute formed a company in 1984 with the English name Legend Computer Group Corporation (later called Lenovo), and Legend became successful in China's software and computer markets. Later Legend bought the Beijing Software Institute, and the institute became Legend's internal research unit. In his 2000 book, *China's Leap into the Information Age*, Lu Qiwen details the history of China's four most prominent computer companies of the 1990s: Legend (established 1984), Stone (established 1984), Founder (established 1986) and Great Wall (established 1986). In each of these four cases, research staff left their state-owned research institute to form a new, (ostensibly) non-governmental computer company.¹³⁵ Despite these success stories, however, Simon concluded that most new S&T organizations in the mid to late 1980s were "far from" effectively balancing quality, customer needs, competition, and profits when determining which new products to produce,¹³⁶ due to their lack of experience with market-based decision-

¹³⁴ For more on the policies around new science and technology enterprises in the 1980s, see Richard Suttmeier, "Laying Corporate Foundations for China's High Tech Future," *The China Business Review*, July-August, 1988, pages 22-26. Also, Tony Saich, *China's Science Policy*, 1989. Also, Lu, *China's Leap*, 2000.

¹³⁵ Qiwen Lu, *China's Leap into the Information Age* (New York: Oxford University Press, 2000). "Non-governmental" and "privately-owned" (*minying* 民营 and *minyou minban* 民有民办) are somewhat misleading terms for the four enterprises covered in Lu's book. According to Lu, Stone was initially established as a collectively-owned township and village enterprise. Legend initially formed as a state-owned, but non-government-run enterprise (*guoyou minying qiye* 国有民营企业). Founder, originally established as the New Technology Development Company of Beijing University, was state-owned by Beijing University, but it operated autonomously and was not compelled to follow the regulations for state-owned enterprises regarding wages, benefits, etc. Lu shows that the ownership structure of each of these enterprises evolved over the years.

¹³⁶ Simon, *Innovation*, 146-149. From the late 1990s, Chinese semiconductor technical staff began to have more success with forming new semiconductor design companies, discussed in Chapter Five.

making. Nonetheless, in the mid to late 1980s, new market-oriented S&T enterprises were emerging, and these enterprises sought to meet the technology needs of China's reforming industries.

2.43 Reform Policies for the Electronics and Semiconductor Industries

2.43a Electronics Industry Reform

From early in the reform era, officials sought to reform China's electronics industry, recognizing that electronics was a rapidly evolving global industry and that improvements in electronics would support China's infrastructure, military, and other industries, while electronics was itself an important consumer and civilian industry. Ultimately, a newly formed electronics leading group issued key strategies and guidelines for the electronics industry in 1985 and 1986, and the Ministry of the Electronics Industry¹³⁷ "divested" its enterprises in 1985. Despite the divestiture, the Ministry of the Electronics Industry's new strategies and guidelines for the industry issued in 1985 and 1986 included ongoing roles for the Ministry as well as centrally-led investment and projects for the industry.

In 1982, the State Council funded a permanent leading group called the Leading Group for Electronics, Computers, and LSI (*dianzi jisuanji he daguimo jichengdianlu lingdao*

¹³⁷ In 1988, the Ministry of the Electronics Industry merged with the State Machine-Building Commission to form the Ministry of Machine Building and Electronics Industry. Later, this ministry was again called the Ministry of the Electronics Industry. Then, in 1998, the Ministry of the Electronics Industry was subsumed under the Ministry of Information Industry (MII). In 2008, the MII was subsumed under the new Ministry of Industry and Information Technology (*gongye he xinxihua bu* 工业和信息化部).

xiaozu 电子计算机和大规模集成电路领导小组),¹³⁸ in order to determine plans and priorities for the electronics industry and to cut through the overlap and rivalries common to China's industries.¹³⁹ Headed initially by top central government officials including Vice-Premier Wan Li and later by Premier Li Peng, the group consisted of three tiers of officials and experts. The leading group was charged with creating a plan to develop China's semiconductor industry starting from that period of the 6th five year plan (1981-1985).¹⁴⁰ In 1984, the group's name was changed to the "State Council Leading Group for the Revitalization of Electronics [Industry]" (*guowuyuan dianzi zhenxing lingdao xiaozu* 国务院电子振兴领导小组).¹⁴¹ The following year, the leading group published a document called "The Strategy for the Development of China's Electronics and Information Industries" which had strategies for 1986, the start of the 7th five year plan, and forward. According to Simon, the document was followed in 1986 by the Ministry of the Electronics Industry's 7th five year plan for the electronics industry which echoed the 1985 document but included more detailed goals, measures and guidelines. Simon summarized the 1985 strategies as follows.

¹³⁸ LSI refers to large-scale integration, versus medium or small-scale integration, for integrated circuits, i.e., semiconductors. The formation of the leading group is covered in Wang and Wang, *Wo Guo Jichengdianlu Chanye*, page 331.

¹³⁹ Simon, *Innovation*, 56-57 and 138. Simon details the structure and participation of this leading group, showing that it included members from all China's key commissions and ministries as well as subject matter experts, such as leading engineers and scientists working in the various subfields of electronics.

¹⁴⁰ China Semiconductor Industry Association (CSIA), "Zhongguo Jichengdianlu Chanye de Huigu yu Zhanwang 中国集成电路产业的回顾与展望 (Review and Prospects of China's IC Industry)," document provided by WXICC in January of 2009.

¹⁴¹ Wang and Wang, *Wo Guo Jichengdianlu Chanye*, page 331.

Note that numbers 4 through 6 below indicate ongoing central involvement in industry planning.¹⁴² Each of these strategies indeed came to fruition in the electronics and semiconductor industries in the 1980s and 1990s (*italics added*).

1. Increase electronic *applications* including, for example, Chinese character programs and microcomputers.
2. Use *foreign technology* to advance China's technology, including engaging in *joint ventures* with foreign firms.
3. Create an integrated electronics supply chain -- *equipment to final products* -- with emphasis on quality mass production and large-scale integrated circuits.
4. Allow *markets and competition* to play a greater role in the industry while relying on unified, *national-level plans* for projects that required very large investments.
5. Coordinate the development of the electronics, communications and telecommunications industries.
6. Design a system to allocate *central funding through competitive bids* (versus grants) and leverage *foreign capital*.

In terms of the existing industry structure, in late 1985, the Ministry of the Electronics Industry officially divested its enterprises and “relinquished control over the day-to-day management.”¹⁴³ This resulted in the central government and the ministry having less direct control. Around this same time, enterprises were encouraged to engage in the newly emerging technology markets, as discussed in Section 2.42 under *New S&T Policies* and *S&T Outcomes*. Then, in early 1987, the Ministry of the Electronics Industry undertook another major reform that effectively separated industry planning and policy-making from enterprise management. Under this reform, the Ministry of the Electronics Industry established five

¹⁴² Simon, *Innovation*, 62-65.

¹⁴³ Ibid, page 152.

product-related bureaus to set macro-level policies. Each bureau was responsible for a number of research institutes and factories, but the bureaus would not directly manage the activities of their units, see Figure Three.¹⁴⁴ The Leading Group for the Revitalization of the Electronics Industry, its proposed strategies, and the Ministry of the Electronics Industry's divestiture all had direct effects on the semiconductor industry

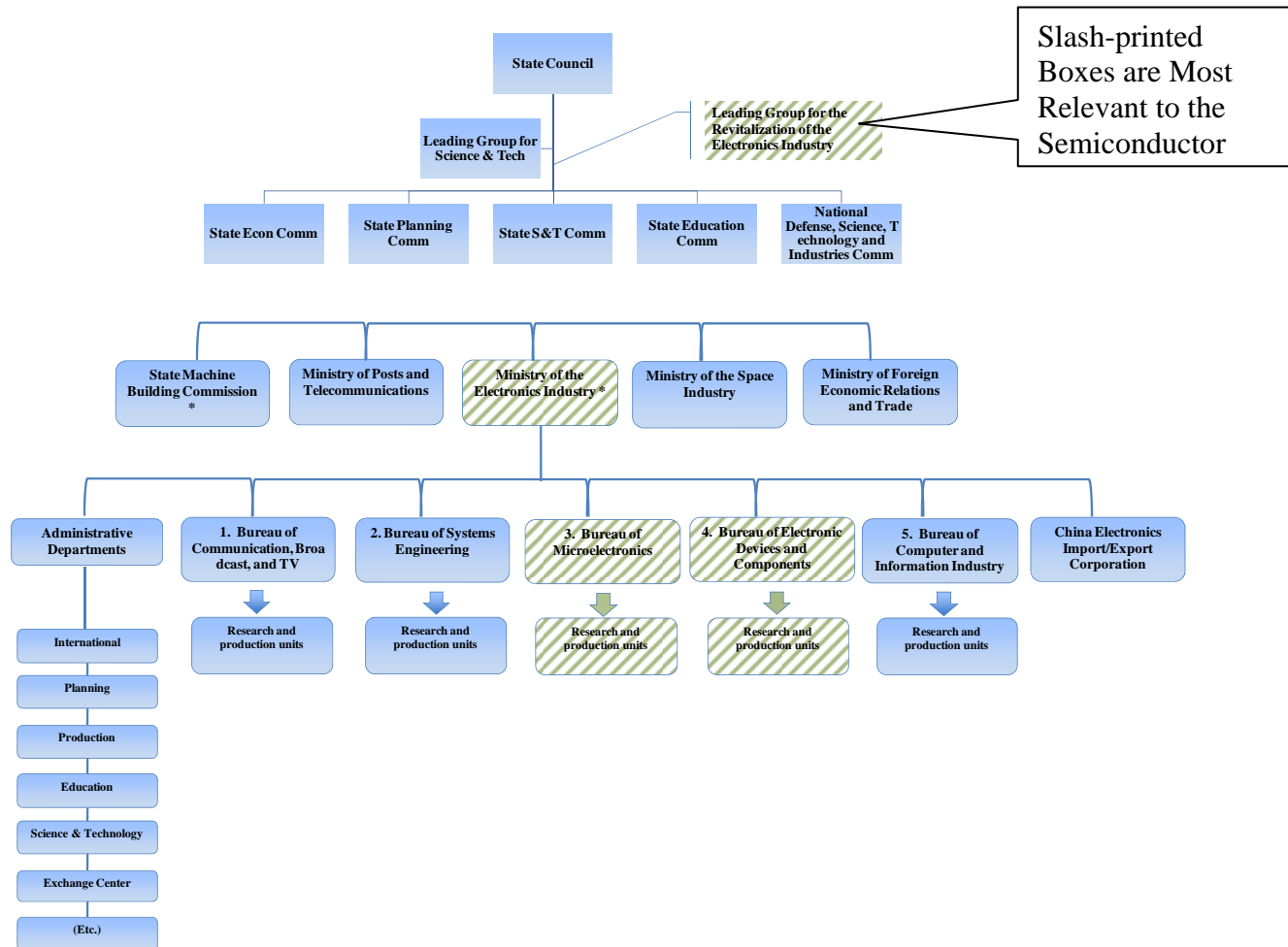
2.43b Semiconductor Industry Reform

From its formation in 1982, State Council Leading Group for the Revitalization of Electronics [Industry] discussed strategies and reforms specific to the semiconductor industry. Wang Yangyuan recalls a policy called “Control Fragmentation and Control Chaos” (*zhi san, zhi luan* 治散, 治乱). This strategy referred to the prevailing sense among semiconductor industry leaders that the industry was “fragmented” due to having too many organizations and “chaotic” because the organizations were not effectively coordinating nor technologically upgrading. The “Control Fragmentation and Control Chaos” strategy was discussed while semiconductor investment funds for upgraded equipment were being dispersed to 33 different factories with few results. In the ensuing years, the leading group would propose and fund semiconductor strategies and projects that were increasingly focused on technologically upgrading just a few enterprises or sites, rather than dispersing funds across thirty plus enterprises. As a start, in 1983 the leading group proposed the policy of “Build Two Bases (North and South) and One Point” (*jianli nan bei liang ge jidi he yi ge dian* 建立南北两个基地和一个点).¹⁴⁵

¹⁴⁴ Ibid., 52-55, 152. The bureaus were: 1) communication, broadcast, and television, 2) microelectronics, 3) systems engineering, 4) electronic devices and components, and 5) computer and information industry.

¹⁴⁵ China Semiconductor Industry Association (CSIA), “Zhongguo Jichengdianlu Chanye de Huigu yu Zhanwang 中国集成电路产业的回顾与展望 (Review and Prospects of China's IC Industry),” document provided by WXICC in January of 2009.

Figure 3: China's Electronics Industry, Circa 1986



** Simon notes that in 1985, the Ministry of the Electronics Industry oversaw some 2600 production units and 130 research institutes.

* In 1988, the State Machine Building Commission and the Ministry of the Electronics Industry merged to form the Ministry of Machine Building and Electronics Industry.

Source: Denis Simon, *Technological Innovation*, page 54, from China's Ministry of the Electronics Industry, Beijing, July 1987.

The South Base would cover Shanghai, Jiangsu and Zhejiang, while the North Base would cover Beijing, Tianjin, and Shenyang. The Point was to be the city of Xian, which would be devoted to aerospace-related work. The idea was that the bases would be concentrated geographic areas wherein enterprises could more effectively share human and material resources and could develop semiconductor industry chains, i.e., supply chains, thus ultimately upgrading the whole industry's capabilities.

Indeed, the leading group's 1985 document, "The Strategy for the Development of China's Electronics and Information Industries," prioritized the semiconductor industry due to its importance in military products, computers, and infrastructure. The group also put special emphasis on increasing China's production of consumer-oriented electronic products. This emphasis furthered the need for electrical components and semiconductors, which are needed to produce consumer electronics products such as radios and televisions. In the mid 1980s, however, China's components and semiconductors were low quality relative to imported semiconductors. Thus, the leading group was doubly committed to improving the production quality of Chinese components and semiconductors,¹⁴⁶ as semiconductors were needed for the military and infrastructure but also for consumer products.

From 1985, the leading group held two conferences specifically for defining strategies for China's semiconductor industry. The first conference was held in November of 1986 in Xiamen. One major outcome of this conference was the official agreement on the "2 Bases, 1 Point" strategy discussed above. Industry leaders were increasingly aware of the benefits of industry spatial concentration, such as was occurring in Silicon Valley in the United States but also in Japan and Taiwan. The old view was that spatial concentration of industrial activity

¹⁴⁶ Simon, *Innovation*, 63-66.

was dangerous for China's national security. More generally, Chinese officials were emphasizing the development of China's east coast, so the 2 Bases, 1 Point strategy aligned with the new acceptance of industry spatial concentration as well as the priority on east coast development.¹⁴⁷ The other significant outcome of this first conference was the "5-3-1" strategy which suggested that many of China's state-owned semiconductor enterprises should be using 5 micron technology, a few leading enterprises should begin using 3 micron technology, and a "technical attack" should be launched to pursue 1 micron technology.¹⁴⁸

Shortly thereafter, in 1986, the State Council also adopted four preferential policies specifically for the semiconductor industry, which according to Yu Xiekang,¹⁴⁹ stimulated the industry until the early 1990s. These included: 1) the government would extract less capital from enterprises, 2) imported equipment would be exempt from tariffs for major, approved projects, 3) enterprises would be exempt from value-added tax, and 4) enterprises would pay only half of their income tax. However, general industry tax reforms in the early 1990s overrode and essentially de-activated these semiconductor-friendly tax policies.

In 1989, the leading group held a second strategic conference in Wuxi. The outcome of this conference was a multi-pronged strategy for 1989-1995, which included: 1) accelerate the establishment of the 2 Bases, 2) achieve scale production, and 3) enhance R&D and

¹⁴⁷ Simon, *Innovation*, 133-134. Simon mentions that officials discussed developing *four* semiconductor industry bases in China, but it seems that the ultimate decision was to develop two bases.

¹⁴⁸ Wang and Wang, *Wo Guo Jichengdianlu Chanye*, page 292 and 331. Also, Yu Zhongyu, "China's IC Industry, the Status Quo and Future," a presentation delivered at Stanford University, 2005.

¹⁴⁹ Yu Xiekang 于燮康 (General Manager of JCET, former General Manager of Huajing), "*Shenhua he Wanshan Jichengdianlu Chanye Zhengce, Tuijin Wo Guo Jichengdianlu Chanye Chixu Wending Fazhan* 深化和完善集成电路产业政策, 推进我国集成电路产业持续稳定发展 (Deepen and Perfect Policies for IC Industry, Promote the Sustainable Development of China's IC Industry)," *Bandaoti Hangye* 半导体行业 (Semiconductor Industry), August, 2008.

develop special-purpose semiconductors. Perhaps most importantly, the conference also resulted in the agreement to allocate RMB 5 billion (about US\$600 million) for the 2 Bases and for five “key” semiconductor enterprises, to augment their capabilities with foreign equipment.¹⁵⁰ The goal was for the five key enterprises to produce high enough quality components and semiconductors to meet more than 60 percent of China’s domestic sales volume by 1995. The key semiconductor enterprises were formed in 1988 and 1989 from existing factories and institutes; in some cases several existing factories were combined into a new key enterprise. Each of these five enterprises had significant scale, and all still exist today in 2012. (See Chapter Four for more details on these key enterprises.) Figure Four shows the five key enterprises and their capabilities.¹⁵¹

Finally, in October of 1990, as an outgrowth of the second strategy conference in Wuxi, the Ministry of Machine Building and Electronics Industry¹⁵² together with the State Planning Commission held a symposium in Beijing with leading semiconductor experts. Ultimately, this group sent a report to China’s Central Party Committee advocating Project 908, which sought to establish China’s first world-class I.D.M. at Wuxi’s #742 Factory, soon to be renamed Huajing.¹⁵³ Huajing would in effect be the site for launching the

¹⁵⁰ Yu Zhongyu, “China’s IC Industry, the Status Quo and Future,” a presentation delivered at Stanford University, 2005.

¹⁵¹ Interview with Zhou Weiping, July 15, 2009, at ASMC headquarters in Shanghai. Zhou is CEO of ASMC and a former General Manager of Shanghai Belling. Also, Chen Ling, “Chanye Xingcheng Jieduan 产业形成阶段 (The Industry’s Formative Stage),” Qinghua University paper, circa 2005. Chen notes that RMB 2.5 billion was spent by 1995, citing the *China Electronics Industry Yearbook*, 1996, page 125.

¹⁵² In 1988, the Ministry of the Electronics Industry was merged with the State Machine Building Commission to form the Ministry of Machine Building and Electronics Industry.

¹⁵³ China Semiconductor Industry Association (CSIA), “Zhongguo Jichengdianlu Chanye de Huigu yu Zhanwang 中国集成电路产业的回顾与展望 (Review and Prospects of China’s IC Industry),” a document provided by WXICC in January of 2009. Also, interview with Mao Chenglie, May 19, 2009, at ETEK

“technical attack” for 1 micron technology, per the 5-3-1 strategy.

2.43c Implementation of Reforms

*“There was a peaceful transformation of the industry, not a war. Just reform the structure piece by piece. Some pieces were closed, some went with a (Sino-foreign) joint venture, and some went private. The emphasis was on transforming from government orientation to market orientation, following the ideas of Deng Xiaoping and Jiang Zemin.”*¹⁵⁴

Xu Guochang,
Director of the Shanghai IC Industry Association, recalling the 1980s.

The electronics industry moved away from central planning and toward increased market activity in the same timeframe as other industries in China. Barry Naughton’s *Growing Out of the Plan* (1995) shows that, from 1979, China’s State Council increasingly allowed certain industries and enterprises to produce for China’s emerging markets after meeting their assigned -- and declining -- production quotas per central and local plans. During this time, Chinese authorities allowed “dual-track pricing” in a number of industries. Under dual-track pricing, prices for inputs and outputs under the plan were set by the planning authorities, and prices for inputs and outputs in the still-developing markets could fluctuate,¹⁵⁵ with market prices usually being higher than “plan” prices. That said, at that time, China’s new market prices were not like the market prices of fully developed market economies, due to non-market input pricing and other (non-market) economic policies and practices.¹⁵⁶

headquarters in Wuxi. ETEK was founded by a former Vice General Manager at Huajing and other former Huajing personnel.

¹⁵⁴ Interview with Xu Guochang, June 17, 2009, at the Shanghai IC Industry Association.

¹⁵⁵ Qimao Fan, “State-owned Enterprise Reform in China: Incentives and Environment” in *China’s Economic Reforms*, editors Qimao Fan and Peter Nolan (New York: St. Martin’s Press, 1994), pages 140-145. Until 1985, market prices were only allowed to fluctuate within a given range.

¹⁵⁶ Ibid, page 143. Also, Naughton, *Growing Out of the Plan*, pages 220-227.

Figure 4: China's Five Key Semiconductor Enterprises

Five Key Enterprises	Founded	Prior Enterprises Joining	Initial Joint Venture Foreign Partner	Location	Estimates of Initial Investment circa 1990*	Production in 1995	Staff in 2000*	Products and Market*
Huajing/CSMC (Project 908)	1989	#742 Factory (Wuxi) and Institute 24 (Sichuan)	CSMC of Hong Kong, with Taiwan Mgmt	Jiangsu, Wuxi		2, 3, 5 micron 4 inch line: 140,000 units/yr 5 inch line: 130,000 units/yr	1600 tech staff plus other employees	discrete devices, bipolar and CMOS ICs, primarily for TVs and audio equip, per IEEE 1995
Huayue	1988	#871 Factory (Gansu and Shaoxing branch)	[Lacked a foreign partner as of 1995]	Zhejiang, Shaoxing		3, 5 micron 3 inch line: 120,000 units/yr 4 inch line: 60,000 units/yr		a candidate for Project 908 in 1990; analog devices and bipolar ICs for TVs and phones
Shanghai Belling (China's first Sino-foreign microelectronics joint venture)	1988	#14 Factory (Shanghai) and Shanghai Electronics and Operation Instruments Holding Company	Shanghai Bell Telephone Equipment Mfg Co, which was a joint venture with Alcatel Bell of Belgium	Shanghai	US\$82.4 m	2.4, 5 micron 4 inch line: 120,000 units/yr	500+ employees, of which 200 are tech staff	ICs for Shanghai Bell Telephone, the first switch-maker to use locally made circuits, per IEEE 1995
ASMC (Advanced Semiconductor Manufacturing Corporation); Chinese name Shanghai Xianjin, formerly known as Shanghai-Philips.	1988	#5 and #7 and #19 Factories (Shanghai)	Philips of the Netherlands (Also Nortel of Canada from approx 1995-2000)	Shanghai		3 micron 5 inch line: 120,000 units/yr	450+ employees	began as a foundry; Philips transferred older tech and producing for export
Shougang-NEC	1991	Beijing Shougang Gongtie (Capital Steel)	NEC (Nippon Electric Company) of Japan	Beijing	US\$240 m	1.2, 1.5 micron 6 inch line: 36,000 units/yr	800+ employees	color TVs, air conditioners, VCDs, IC cards, clocks, palm PCs

This chart is compiled from the following sources:

1) Interview with Zhou Weiping, July 15, 2009, at ASMC headquarters in Shanghai. Zhou is C.E.O. of ASMC and a former General Manager of Shanghai Belling.

2) Zhu Yiwei 朱贻伟, Zhongguo Jichengdianlu Chanye Fazhan Lunshu Wenji 中国集成电路产业发展: (China's IC Industry Development: Collected Works), Beijing: Xinshidai 新时代出版社 (New Times Press), 2006, pages 162 and 164.

3) Wang Yangyuan and Wang Yongwen 王阳元 and 王永文, Wo Guo Jichengdianlu Chanye Fazhan Zhilu: cong Xiaofei Daguo Zouxian Chanye Qiangguo 我国集成电路产业发展之路: 从消费大国走向产业强国 (China's Integrated Circuit Industry Development Path: From a Big, Consuming Nation to a Strong, Industrial Nation), Kexue Chubanshe 科学出版社 (Science Press), 2008, page 294.

4) iSupply, "Semiconductor Wafer Manufacturing in China: A Panacea or a Global Investment Trap?," Q3, 2002, page 11.

5) Michael Pecht, Weifeng Liu and David Hodges, "Chapter Two: Electronics Manufacturing Update," Office of Naval Research and U.S. Department of Commerce, 2000-2001.

Nonetheless, according to Qimao Fan's research in the late 1980s, dual-track pricing "brought about a substantial reduction in the scope of central planning and expansion in the role of market mechanisms," and the timing of this national trend away from central planning and toward market activity accords with changes in the electronics industry.

After the Ministry of the Electronics Industry's divestment in 1985, enterprise managers in the electronics industry were entrusted with day-to-day management, and research suggests that managers were making more decisions for out-of-plan production. As Chapter Three will detail, managers at Wuxi's 742 Factory, an officially favored site, faced new decisions about which products to produce in the 1980s, as they sought to meet China's growing market for consumer electronics products. In 1986, the managers at Wuxi's #742 Factory were "serving the market (*zai wei shichang fuwu de guocheng zhong* 在为市场服务的过程中)...by "fully organizing and using all aspects of information (*chongfen de cuoqu zuzhi he liyong cong ge fangmian xinxi qingbao* 充分地措取, 组织和利用从各方面信息情报)"...to decide what to produce for the..."competitive market (*shichang jingzheng* 市场竞争)".¹⁵⁷ Also, interviews with electronics enterprise managers by Jonathan Pollack in 1984 and 1985 suggest that enterprises had the discretion to produce for the market, after meeting plan quotas, although electronics enterprises varied widely in their ability and willingness to

¹⁵⁷ Zheng Shilong, Lu Zhixin and Tian Jingying 郑世隆, 陆志信 和田婧瑛, "'Huajing Jingshen': Ji Guoying Jiangnan Wuxiandian Qicaichang 华晶精神: 记国营江南无线电器材厂 (The Spirit of Huajing: Jiangnan State-owned Radio Equipment Factory)," *Liaowang 瞭望 (Outlook)*, Period 22, 1986.

enter the market.¹⁵⁸ Similarly, Simon (1988) interviewed a source at a leading Shanghai semiconductor factory in 1985, and this interviewee explained that in 1984 about half of the factory's work was "received...from the Ministry of the Electronics Industry, the State S&T Commission, and the Shanghai Bureau for Electronics and Instrumentation." However, the source said that by 1985, about ninety percent of this factory's work was "self-initiated."¹⁵⁹ Thus by the mid to late 1980s, electronics enterprises seem to have indeed been making production decisions outside the dictates of central and local planning authorities, with the more advanced and favored factories being more likely to produce for the market.¹⁶⁰

The transition away from central planning was gradual, but it presented a number of difficulties for the both "retained" and the "released" factories. Retained factories attempted to adopt China's new and evolving "contract management responsibility system" (CMRS), which had been implemented in state-owned enterprises across industries since the early 1980s. By late 1988, some version of the CMRS covered about seventy percent of China's state-owned enterprises.¹⁶¹ The intention of this system was to remove central-level ministry officials from daily enterprise management and to make enterprises more market oriented and responsible for their profits and losses. Enterprises could keep their profits, but they had to

¹⁵⁸ Pollack, *The Chinese Electronics Industry*, pages 40-53. Pollack categorized factories by their level of technology, productivity and market-orientation. He identified five categories: 1) the "dinosaurs," with very low productivity, 2) the "whatever-ists" which conservatively follow "whatever" policy makers say, 3) the "incremental-ists" that cautiously adopt new practices and technology, 4) the "favored few" showcase factories with more resources, newer organizations, and younger managers, and 5) the "entrepreneurs," favored factories that were also quickly creating and seizing new technical and market opportunities.

¹⁵⁹ Simon, *Innovation*, 148.

¹⁶⁰ Central planning was being phased out, but local authorities also had input to production decisions through "guidance planning," which ostensibly did not entail compulsory production targets. See Barry Naughton, *Growing Out of the Plan*, page 221.

¹⁶¹ Derong Chen, *Chinese Firms Between Hierarchy and Market: the Contract Management Responsibility System in China* (Basingstoke: Macmillan, 1995). The system was originally called the "economic responsibility system." Fan, "State-owned Enterprise Reform," pages 149-150.

remit a portion of profits to the state as tax. Under the CMRS, an enterprise would negotiate and sign a contract with its central ministry (or municipal ministry, etc.); the contract would specify how much profit (i.e., revenue or tax) the enterprise would remit as well as other enterprise performance measures, such as dividends paid, total wage costs, and technological upgrades. However, according to DeRong Chen and Barry Naughton,¹⁶² China's CMRS had serious structural problems, and it was ultimately phased out in 1995. Under the CMRS, the government's central-level ministries still owned the enterprises, but at the same time, the government was the tax collector and regulator of these enterprises. If an enterprise's profit was lower than anticipated, then the government might not hold the enterprise accountable for its contracted tax bill or the enterprise might re-negotiate its contract. This system, thus, was in contrast to a uniform, non-negotiable, modern income tax system.¹⁶³ As a result of the CMRS, enterprises still had so-called soft budgets, and government revenues were lower than expected under the often re-negotiated contracts. Perhaps most importantly, although enterprises adopted the CMRS, China's hierarchal and complex industry structures remained in place.¹⁶⁴

For retained semiconductor enterprises, the intention of the CRMS was ostensibly to devolve control from the central to the enterprise level, but Simon (1988) suggests that in the

¹⁶² For more on CMRS and other enterprise reform measures, see Chen, *Chinese Firms*, and Naughton, *Growing Out of the Plan*.

¹⁶³ In the mid 1980s, in addition to the CMRS, the government also began collecting revenue from state-owned enterprises through a new income tax system. This system evolved during the 1980s. See Nicholas Lardy, *China's Unfinished Economic Revolution* (Washington, D.C.: Brookings Institution Press), pages 22-24 and 183-184; Fan, "State-owned Enterprise Reform," pages 145-149; and Justin Yifu Lin, Fang Cai, and Zhou Li, *The China Miracle: Development Strategy and Economic Reform* (Hong Kong: Chinese University Press, 1996), pages 138-144.

¹⁶⁴ For more on this system, see Derong Chen, *Chinese Firms Between Hierarchy and Market: the Contract Management Responsibility System in China* (Basingstoke: Macmillan, 1995).

semiconductor industry in the 1980s “dual leadership” (*shuangzhong lingdao* 双重领导) of factories by central and local officials was still in play.¹⁶⁵ The adage of “your old boss is still your boss” remained relevant; individuals still sought to retain their professional relationships and networks for organizational and political reasons. Enterprise managers were stymied in their decision-making and progress by multiple and unclear lines of authority. The problem of *tiao-tiao, kuai-kuai* (条条块块) remained; *tiao* referred to the vertical authority of the central ministries, and *kuai* referred to the horizontal authority of provincial or local officials. At the time, Simon reported that “It is often difficult for Chinese as well as foreigners to know who has authority or responsibility for making various decisions about setting priorities, sourcing and pricing inputs, managing particular projects, or initiating relationships between R&D units and potential end-users.” From his study of electronics enterprises in Shanghai in the mid 1980s, Simon noted that only about half of the enterprises were making any decisions locally, and, of these enterprises, only about half of their decisions were made locally.¹⁶⁶ Finally, the effort to place enterprise management at the enterprise level was likely stymied in part because enterprise managers genuinely did not understand new practices and expectations, including the CMRS.¹⁶⁷ Certainly, the CMRS was not a cure-all for the low productivity and lack of market orientation of state-owned enterprises.¹⁶⁸

¹⁶⁵ Simon, *Innovation*, 55.

¹⁶⁶ Ibid., 56 and 153-154.

¹⁶⁷ Ibid., 52-53 and 154.

¹⁶⁸ Pollack, *The Chinese Electronics Industry*. In 1984/5 before CMRS was widely implemented, Jonathan Pollack interviewed electronics enterprise managers in China, and -- not surprisingly -- he found Chinese managers to still have attitudes and practices that reflected of a central planning environment. For example, he cites one interview in which an enterprise manager explained that his factory met its annual “quota” by October. When Pollack reminded the interviewee that his factory no longer had production quotas, the

Factories that were released faced their own difficulties. Ministries and commissions released a number of their electronics and semiconductor factories over a period of years in the 1980s and into the 1990s. While in the process of being released, factories often operated in an ambiguous zone because release was usually gradual, e.g., funding would be reduced over time, and releasing could affect part but not all of an enterprise. For example, at Shanghai's #14 Factory, an important electronics component factory, part of the organization was merged into the new Shanghai Belling, one of China's new "key" semiconductor enterprises (see Section 2.43 under *Semiconductor Industry Reform*). Meanwhile, another part of Shanghai's #14 Factory was fully released.¹⁶⁹ In addition, both officials and enterprise managers had reasons to resist the process of releasing. Some managers and officials did not want to lose their best personnel to outside organizations, and some feared the influence of newly released, roving technical personnel. After all, the loss of technical personnel might diminish an organization's ability to achieve its goals, and technical personnel working in new organizations might in some way hinder the state's goals.¹⁷⁰

Although the Ministry of the Electronics Industry's divested its enterprises in 1985, even into the 1990s after divestiture and other reforms were well underway, the national electronics and semiconductor industry structures remained in place under the Ministry of

manager replied that he meant to say "orders." Yet, after having fulfilled his orders in October, the manager had no plans to use the remainder of the year for more production nor to experiment with new products. Pollack generally found many electronics enterprise managers at that time to be attuned to the industry hierarchy, uninformed about their cost structure (and thus cost/price differentials), risk averse, and lacking a sense of urgency.

¹⁶⁹ Interview with Professor Yang, June 8, 2009, Shanghai. Prof. Yang worked in a Fudan University semiconductor-related research institute and later started a technology company with foreign partners.

¹⁷⁰ Simon, *Innovation*, 36-37.

Machine Building and Electronics Industry.¹⁷¹ Why? As this chapter has shown, Chinese officials viewed the semiconductor industry as a high-tech national imperative, and their plans for the semiconductor industry demonstrate that they believed that continued oversight, planning and careful use of resources was the best path, at least at that time, to quickly upgrade the industry's technical capabilities. None of the stated plans for the semiconductor industry rebuked state ownership and state planning. Officials opted to release many institutes and factories, but they retained much of the national industry structure and sought to upgrade the industry's technological capability through plans such as 5-3-1 Strategy discussed above, Project 908 (detailed in Chapter Three), and *New Industry Guidance Mechanisms* discussed below.

The national industry hierarchy continued to influence both retained and released semiconductor enterprises in the 1990s. For example, in the 1990s, managers of retained enterprises had to get multiple permissions for actions such as establishing foreign partnerships,¹⁷² and in Chapters Three and Four, we will see that even the highest priority state sponsored semiconductor project of China's eighth five year plan encountered funding delays, permission and approval delays and other problems that were endemic to China's state-owned enterprises.¹⁷³ On the positive side, however, in the 1990s, the Chinese

¹⁷¹ The Ministry of Machine Building and Electronics Industry was formed in 1988 as the result of a merger between the Ministry of the Electronics Industry and the State Machine Building Commission.

¹⁷² Interview with Yu Xiekang, June 2, 2009, JCET headquarters in Jiangsu province. Yu talked about Huajing's experience trying to develop a partnership with Intel to no avail, due to permission delays and disputes. Also, see Zhong Fu 中福, "Huajing Xingban Hezi Gongsi Jinjun Nanfang Shichang 华晶兴办合资公司进军南方市 (Huajing Establishes a Joint Venture to Expand into the Southern Market)," *Weidianzi Jishu 微电子技术 (Microelectronics Technology)*, May, 1994. This article says that Huajing did establish several joint ventures in southern China in the early 1990s to make and distribute semiconductor products with Hong Kong entities. These joint ventures served both the domestic and foreign markets.

¹⁷³ For more on the managerial problems in China's state-owned enterprises across industries, see Ed Steinfeld,

government was able to provide funding to establish China's five key semiconductor enterprises, providing the high level of capital to build and operate semiconductor facilities. And capital costs were indeed high: from 1980 to 1990, the cost to build a semiconductor fabrication facility¹⁷⁴ increased fourfold, and this rate of cost increase continued between 1990 and 2000.¹⁷⁵ In the 1980s and into the 1990s, China's emerging private and non-governmental semiconductor-related enterprises did not have access to this level of capital.¹⁷⁶ Finally, the national industry hierarchy continued to influence even nominally released enterprises. These enterprises operated in China's still-reforming economy, and thus faced various government dictates such as what portion of their production could be exported versus sold in the domestic market.¹⁷⁷

Further, the wave of releasing had little real effect on semiconductor professionals' career options in the 1980s. For new college graduates, the state assigned jobs through the early 1980s, and by the mid 1980s, the state still assigned jobs for many graduates, although graduates could try to find jobs on their own by using their relationships (*guanxi* 关系), usually with their university professors or family. In the electronics and semiconductor industries, it was not until the 1990s that new graduates largely found jobs on their own, most

Forging Reform in China (Cambridge: Cambridge University Press, 1998); Naughton, *Growing Out of the Plan*; Lin, Cai, and Li, *The China Miracle*; Pollack, *The Chinese Electronics Industry*.

¹⁷⁴ A "fab" is a fabrication facility, also called a foundry, which is a manufacturing facility for semiconductors.

¹⁷⁵ KLA Tencor Corporation for the US-Taiwan Business Council, "Addressing the Rising Challenges of Semiconductor Manufacturing," presented at the Taiwan-China Semiconductor Industry Outlook Conference, see www.us-taiwan.org.

¹⁷⁶ As noted in Section 2.42 under *S&T Outcomes*, China nationalized its banking and finance system in the 1950s, and thus in the 1980s, new private and non-governmental enterprises in China did not have formal, private financial institutions and markets from which to seek investment capital.

¹⁷⁷ Interview with Yu Zhongyu, July 2, 2009, at China Semiconductor Industry Association (CSIA) headquarters in Beijing. Yu is the President of the CSIA.

relying on *guanxi*. Networks of alumni from China's leading science and engineering universities could be found in both state-owned enterprises and in the new so-called private and non-governmental enterprises, (defined in Section 2.42 under *S&T Outcomes*), due to the prevalent use of *guanxi* for job placements. For example, in semiconductor enterprises in and around Wuxi, many personnel are alumni of the University of Electronic Science and Technology in Chengdu (*dianzi keji daxue* 电子科技大学)¹⁷⁸ or Southeast University (*dongnan daxue* 东南大学) in Nanjing.¹⁷⁹ In the 1990s, most new graduates still sought jobs with state-owned enterprises, although increasingly new graduates could also find positions in Sino-foreign joint ventures and in the new private and non-governmental enterprises.

A main goal of releasing institutes was to free up mid-career scientific staff to join production enterprises and thus to bridge the historical gap between research and production. For scientists and engineers who were released and thus had to involuntarily change jobs, important destinations were China's new key state-owned semiconductor enterprises,¹⁸⁰ Sino-foreign joint ventures, and the new private and non-governmental enterprises. However, for these job seekers, there was little financial benefit in changing jobs in the 1980s and even into the 1990s, as the pay was usually the same across different types of organizations. Only from perhaps the late 1990s could science and engineering personnel find meaningful pay

¹⁷⁸ The University of Electronic Science and Technology in Chengdu offers degrees in all the key disciplines in electronic and information sciences. It was formerly called the Chengdu Institute of Telecommunication Engineering (*chengdu dianxun gongcheng xueyuan* 成都电讯工程学院).

¹⁷⁹ Southeast University is currently a comprehensive university with leading engineering and science programs. It was called the Nanjing Institute of Technology from 1952 until it was renamed Southeast University in 1988.

¹⁸⁰ The five key enterprises were Huajing, Huayue, Shanghai Belling, ASMC-Philips, and Shougang-NEC; see Section 2.43 under *Semiconductor Industry Reforms*. The establishment of these enterprises is detailed in Chapter Four.

differentials between different organizations and between the growing number of ownership categories available by the late 1990s, e.g., state-owned, joint venture, multi-national company, Chinese private, etc.¹⁸¹

The implementation of reforms to China's state-owned semiconductor industry was indeed, as Xu Guochang put it, "piece by piece...from government orientation to market orientation."¹⁸² This section covered key aspects of implementation, i.e., the transition from central planning to market activity, new management practices for state-owned enterprises (such as the CMRS), the continued role of the national industry structure, and gradual changes in semiconductor professionals career patterns. In each of these areas, this section has shown that, despite changes, aspects of the centrally planned, state-owned industry continued. Thus, the following section examines the particular new state-sponsored mechanisms that officials devised to guide the semiconductor industry's ongoing technological upgrading.

New Industry Guidance Mechanisms

While reforming the centrally planned semiconductor industry, officials at the Ministry of the Electronics Industry established several new mechanisms to support and guide the industry. Importantly, almost all of these mechanisms aimed to advance specific semiconductor-related technologies. The following outline highlights the new industry guidance methods, all of which remained in place as of 2009, except for two (noted below), which had by 2009 been restructured or disbanded.

¹⁸¹ The rise of these ownership categories is covered in more detail in Chapters Five.

¹⁸² Interview with Xu Guochang, Director of the Shanghai IC Industry Association, June 17, 2009, Shanghai.

- Circa 1980: the Ministry of the Electronics Industry set up the Office of 5 Micron Technology Promotion to assist the whole industry in adopting 5 micron process technology.¹⁸³ (Restructured by 2009.)
- 1984: Shanghai officials identified the Caohejing area as a site for high technology zone that would center on microelectronics. In the mid 1980s, there was some dispute whether this zone was to be funded by Shanghai or the central government,¹⁸⁴ and meanwhile the Ministry of the Electronics Industry was investing in Wuxi's #742 Factory. Nonetheless, from 1995, the Caohejing High Technology Park would be the site for Project 909 and SMIC (see Section 2.5.)¹⁸⁵
- From 1985: National Engineering Research Centers were established with over 70 established by 1995. Of those, RMB 1.7 billion was invested in 34 centers that focused on microelectronics, software, telecommunications, automation, and other electronic technologies.¹⁸⁶ These centers were under the Chinese Academy of Science.
- 1986: The State Council decided to provide funds each year to the Ministry of the Electronics Industry in order for the Ministry to establish the Electronic Industry Development Fund (*dianzi fazhan zhuan yong zijin* 电子发展专用资金). In its first 20 years, the fund awarded almost RMB 4 billion to improve existing enterprises' R&D capabilities in targeted technologies.¹⁸⁷
- 1986: The 863 I.C. Specialist Project was established as part of the broader, national 863 Program, a.k.a. The National High Technology R&D Program, which is still in place today. In the 863 Program, expert committees in Beijing establish research priorities, and organizations apply (compete) for funding from the 863 Program to pursue advances in specific technological area, such as SoC.¹⁸⁸ If awarded funding, the expert committee periodically checks project milestones.¹⁸⁹ The 863 Program is under the Ministry of Science and Technology.

¹⁸³ Yu Xiekang 于燮康 (General Manager of JCET, former General Manager of Huajing), “*Shenhua he Wanshan Jichengdianlu Chanye Zhengce, Tuijin Wo Guo Jichengdianlu Chanye Chixu Wending Fazhan* 深化和完善集成电路产业政策, 推进我国集成电路产业持续稳定发展 (Deepen and Perfect Policies for IC Industry, Promote the Sustainable Development of China's IC Industry), *Bandaoti Hangye* 半导体行业 (Semiconductor Industry), August, 2008

¹⁸⁴ Simon, *Innovation*, 136-138.

¹⁸⁵ In 1985, Jiang Zemin, future President of the PRC (1993 to 2003) and Minister of the Electronics Industry from 1983, was appointed as mayor of Shanghai.

¹⁸⁶ Wang and Wang, *Wo Guo Jichengdianlu Chanye*, page 332.

¹⁸⁷ *Ibid.*, 333.

¹⁸⁸ SoC is “system on a chip,” which refers to an important technological advance in integrated circuits. In SoC, all the components of a computer are integrated onto a single chip.

¹⁸⁹ Wang and Wang, *Wo Guo Jichengdianlu Chanye*, page 333.

- From 1985-1995: Central-level I.C.C.A.D. and I.C.C.A.T. specialist committees were established as part of the national science and technology R&D program to guide semiconductor-related R&D programs and projects. From 1990, these committees introduced a new “rolling” mechanism for project proposals, investment, and testing. In this system, every four months, new projects are proposed and potentially funded. The progress of funded projects is checked at regular intervals.¹⁹⁰
- Late 1980s: the Ministry of the Electronics Industry established the “Import Check Office” to ensure that semiconductor products that could be made with acceptable quality in China were not being imported.¹⁹¹ (Restructured by 2009.)

Also, in 1990, a new national organization was formed that would play a leading role in supporting the semiconductor industry in the years to come. In December of 1990, Chinese semiconductor industry leaders established the China Semiconductor Industry Association (CSIA). A few industry leaders had been talking about forming some kind of industry leadership group since 1987, and by 1989 they formed an association.¹⁹² Once officially recognized in late 1990, the CSIA sought to function similarly to existing semiconductor industry associations in other countries, such as the SIA in the United States and TSIA in Taiwan. The CSIA would also serve in China as an important national organization to guide, support, and unify existing and emerging actors in the semiconductor industry. The CSIA’s leadership consisted of senior industry executives and industry (government) officials. From

¹⁹⁰ Ibid., 331-332.

¹⁹¹ Yu Xiekang 于燮康 (General Manager of JCET, former General Manager of Huajing), “*Gongtong de Lixiang, Gongtong de Fendou, Gongtong de Shouhuo—Jiangsusheng Jichengdianlu Chanye Kechixu Fazhan de Licheng yu Tansuo* 共同的理想，共同的奋斗，共同的收获 --- 江苏省集成电路产业可持续发展的历程与探索 (Common Ideal, Common Striving, Common Achievement – The History of Sustainable Development in the Jiangsu Province IC Industry),” *Baodaoti Hangye 半导体行业 (Semiconductor Industry)*, December 7, 2008.

¹⁹² Yu Xiekang interview. According to Yu, the original group that sought to form an association consisted of individuals from several groups including: 中国电子器件总公司 (China Electronic Device Company), 微电子发展研究中心 (Microelectronics Industry Development Research Center), 集成电路联合组成半导体情报 (IC Coalition of Semiconductor Intelligence).

its inception, the CSIA sought to recruit voluntary membership from semiconductor organizations in China, regardless of ownership type.¹⁹³ According to the CSIA, the organization's role was (and still is) to:

- Help government officials to formulate policies and to communicate policies to enterprises
- “Build bridges” between enterprises and government
- Regularly collect and publish industry data and statistics
- Sponsor conferences, seminars, and exhibitions
- Provide advisory services to semiconductor enterprises
- Promote global integration
- Protect and advise member firms on legal matters including intellectual property and trade issues

Indeed, by the 2000s, the CSIA was taking the lead in all these areas, and was the most common Chinese source, along with CCID,¹⁹⁴ for semiconductor industry data. Semiconductor industry conferences, exhibits, and the like were sponsored and run by CSIA branches. For example, at conferences, the Ministry of Information Industries (formerly called the Ministry of the Electronics Industry) would typically be one of several sponsoring organizations, but the CSIA seemed to take the lead role in organizing such activities. Many top executives in the industry have served in leadership roles in the CSIA, as the CSIA formed numerous branch organizations and committees, giving industry leaders many opportunities to participate. CSIA sub-organizations included the “Semiconductor Integrated Circuit Design Branch,” “Semiconductor Supporting Sector Branch,” “Intellectual Property

¹⁹³ CSIA, “History of the CSIA,” a paper provided by Yu Zhongyu (President of the CSIA) at the CSIA headquarters on July 2, 2009. The date of the paper's origin is not shown.

¹⁹⁴ CCID was established in 1986 as the information research group for the Ministry of Electronics Industry. From 2002 known as CCID Consulting, CCID Consulting is a publicly listed research and consulting firm. For more information see www.statchina.com.

and Product Innovation Working Committee,” and the “Environment, Safety, and Health Working Committee,” among others.¹⁹⁵

From the mid 1980s, each of the new mechanisms outlined above began to significantly augment the national industry hierarchy in terms of setting priorities and policies, channeling funding, and generally supporting technological as well as commercial advances in the industry. While these mechanisms show the state’s ongoing role in technologically upgrading industry, it is interesting to note that none of the newly defined guidance mechanisms in the mid to late 1980s sought to guide trade or further state ownership of new enterprises.

Decision Making: Top Down or Bottom Up?

A key component of central planning and state-owned industries is the seeming top-down, centralized nature of decision making. However, even under central planning, local enterprise managers supplied central planning authorities with estimates of their input needs and output capabilities, and central and local economic plans were based on this bottom-up input. As China’s electronics and semiconductor industries were reformed in the 1980s, input and decision-making at the enterprise level became ever more apparent and influential. Reflecting on the reforms of China’s semiconductor industry presented thus far, this section highlights processes that -- while still centralized -- made use of input from the enterprise level.

In the 1980s the Ministry of the Electronics Industry made funds available to 33 enterprises to import foreign equipment. During this period, funding was allocated when

¹⁹⁵ For more on the history and current activities of CSIA, see www.csia.net.cn.

enterprise managers themselves made requests for funds in order to import equipment that they themselves identified. Funds were not distributed to all factories nor were funds distributed equally, rather the distribution of funding was based on enterprise-level initiative. Through the allocation of this funding, certain enterprises began to emerge as more capable and favored.¹⁹⁶

Further, as several of the new industry guidance mechanisms outlined above suggest, enterprise level managers and scientists began to make requests to central level committees to get funding to pursue particular technical projects. The national 863 Project, the Electronic Industry Development Fund, and the I.C.C.A.D. and I.C.C.A.T. specialist committees were all central organizations that published catalogs or lists of desired projects. However, expert committees developed these catalogs, and the expert committees were made up of technical experts from around the country, not central officials.¹⁹⁷ In addition to these mechanisms, enterprises could also appeal to their respective ministry, bureau or commission to seek funds and approval for self-initiated projects. Writing in 1988, Simon found that “Over the last several years, the locus of project initiation has increasingly shifted from the central to the local level” and “the market has come to play a more critical role in stimulating locally

¹⁹⁶ For more on these dynamics, see the interviews in Pollack’s *The Chinese Electronics Industry*. Also, see Simon page 130-133. Zheng Shilong, Lu Zhixin and Tian Jingying 郑世隆, 陆志信 和田婧瑛, ““Huajing Jingshen”: Ji Guoying Jiangnan Wuxiandian Qicaichang 华晶精神: 记国营江南无线电器材厂 (The Spirit of Huajing: Jiangnan State-owned Radio Equipment Factory),” *Liaowang 瞭望 (Outlook)*, Period 22, 1986. Also, as a later example from around 1999, according several interviewees, when state-owned enterprise Huajing was going through its restructuring (see Chapter Three), central government officials gave more power over Huajing to Jiangsu provincial officials. However, Jiangsu officials “did not know what to do,” so they asked Wuxi city officials for help with decision making. When Wuxi officials also “did not know what to do,” they asked Huajing’s managers to make decisions.

¹⁹⁷ Interview with Prof. Yang, June 8, 2009, Shanghai. Prof. Yang worked in a Fudan University (semiconductor) research institute and later started a technology company with foreign partners.

initiated projects,”¹⁹⁸ in addition to central strategies and priorities. For example, one researcher who worked at a state-owned institute in the 1980s explained that his institute had its own expert committee of eleven individuals (including himself), and this group would approve projects. This expert committee reported to the Shanghai Science and Technology Commission, which occasionally checked their progress on projects but otherwise “did not really interfere.”¹⁹⁹

Perhaps an even more important example of input and decision making coming from lower levels is found in the State Council Leading Group for the Revitalization of Electronics (*guowuyuan dianzi zhenxing lingdao xiaozu* 国务院电子振兴领导小组), which was introduced early in Section 2.33. Recall, this group originated in 1982 and was led by Vice Premier Wan Li and later Premier Li Peng. According to Simon (1988), this leading group consisted of three tiers. The first tier had officials from five of China’s top ministries and commissions, while the second tier had fifteen members from leading electronics-related organizations. The third and lowest tier consisted of twenty permanent members divided into four specialties (integrated circuits, software, etc.), with a ten to fifteen person advisory group (in effect, a fourth tier) for each specialty. The advisory groups were made up of technical experts from all over China, and it was these “lowest” groups who actually developed the policy recommendations.²⁰⁰

¹⁹⁸ Simon, *Innovation*, 124.

¹⁹⁹ Interview with Li Weide, June 4, 2009, Shanghai. Li was formerly a semiconductor scientist with a state institute.

²⁰⁰ Simon, *Innovation*, 56-58.

This Section 2.43 has assessed the extensive reforms to China's centrally planned electronics and semiconductor industries, including new industry guidance mechanisms and shifts in the loci of decision-making. At the end of the 1980s, the national industry structure remained in place, but semiconductor industry officials began to use the new semiconductor industry strategies and the new guidance mechanisms to promote technological advances in the industry.

2.5 1990s: Major State-sponsored Projects (908, 909, and SMIC) and Global Integration

In the 1970s through most of the 1990s, the global semiconductor industry was characterized by vertical integration, that is, the growing demand for semiconductors was met by integrated device manufacturers (I.D.M.s) such as Texas Instruments of the United States, Toshiba of Japan, and Samsung of Korea. I.D.M.s do design, fabrication (production), and packaging/assembly/testing (P.A.T.), which are the three major steps in the creation of semiconductors.²⁰¹ As China pursued reforms to its state-owned semiconductor industry in the 1980s, Chinese officials hoped to establish a successful, high technology I.D.M. in China.²⁰²

Section 2.43, *Semiconductor Industry Reforms*, noted that the final major semiconductor reform proposal coming out of the 1980s was a report by semiconductor experts to the Central Party Committee in 1990. The report advocated that the central

²⁰¹ The major exception to the I.D.M. norm was the advent in 1987 of the "foundry model" by the Taiwan Semiconductor Manufacturing Corporation (TSMC). China's adoption of the foundry model is covered in Chapters Three and Four.

²⁰² Here is an example of how semiconductor I.D.M.s and other types of technologies companies work together. In the case of a personal computer, IBM designs a computer, buying the semiconductors for the computer from Intel, which is a semiconductor I.D.M. IBM buys software for the computer from Microsoft, a software company.

government sponsor Project 908, which sought to establish China's first world-class I.D.M. at Wuxi's #742 Factory, recently renamed Huajing.²⁰³ Huajing would launch China's "technical attack" for 1micron technology, per the 5-3-1 strategy. Ultimately, from the early 1990s through the early 2000s, the central Chinese government sponsored three major semiconductor projects in succession, beginning with Project 908 in Wuxi, followed by Project 909 and SMIC. In each project, the government sponsored a particular enterprise with the goal of establishing a successful semiconductor enterprise in China that matched global technological standards for semiconductor production. These projects are detailed in Chapters Three and Four. Officials believed that establishing even one enterprise that was effectively using sophisticated production technologies would foster human resource development in China and spur the growth of other sectors in the semiconductor value chain, such as materials suppliers and equipment manufacturers. Officials believed that such an enterprise would also allow global semiconductor executives to be confident about establishing advanced operations in China. According to Yu Zhongyu,²⁰⁴ the enterprises that were part of these three projects (Huajing, Huahong of Project 909, and SMIC) were not meant to be "models" for future Chinese enterprises nor were they part of a grand, long-term plan to build a better state-led industry. Rather they were just to be symbols or examples that advanced technologies and organizations could actually operate in China, despite China's less than ideal environment, including a weak legal system and evolving trade policies. China's

²⁰³ China Semiconductor Industry Association (CSIA), "Zhongguo Jichengdianlu Chanye de Huigu yu Zhanwang 中国集成电路产业的回顾与展望 (Review and Prospects of China's IC Industry)," a document provided by WXICC in January of 2009.

²⁰⁴ Interview with Yu Zhongyu, July 2, 2009 at CSIA headquarters in Beijing. Yu is President of China Semiconductor Industry Association.

market, i.e., the *demand*, for semiconductors was growing rapidly with the growth of China's whole economy, and hopefully these enterprises would be able to partially *supply* this market, rather than having to rely almost entirely on imported semiconductors.

The major semiconductor projects were also motivated by national defense. In the Gulf War in 1991, the Chinese government saw the gap between Western defense technology, particularly in precision-guided weapons, and China's capabilities. The technology for such weapons was fundamentally at the level of the chip. That said, the actual goals and technology of the projects were still far behind Western leading-edge technology, so the projects were not a direct or immediate attempt to catch-up in defense technology.

Historical Ramifications of Projects 908, 909, and SMIC

Despite the high hopes for these projects, industry personnel, both Chinese and foreign, point to their ineffectiveness, often commenting on wasted resources and lack of results. If Project 908 is mentioned in written sources at all, it is mentioned only briefly and disparagingly. Authors describe Project 908 as a loss-making, delayed, troubled project, saying other projects should “seek to avoid” its path.²⁰⁵ As one former Huajing employee

²⁰⁵ Gao Gaifang, "Project 908 Finale: Huarun's Fat Hand Grabs Wuxi's Huajing (908 gongcheng zhongjie pian: huarun fei zhang juequ wuxi huajing 908 工程终结篇: 华润肥掌攫取无锡华晶)," *21st Century Business Herald*, September 4, 2003, wrote that Project 908 was a “deformed, malnourished child (*shi yingyang buliang de jixinger* 是营养不良的畸形儿)” and that the next big project, Project 909, sought to “avoid following Huajing's path (*bimian zou huajing de lu* 避免走华晶的路),” noting that Huajing “in desperation had leased part of their equipment to Hong Kong CSMC semiconductor company (*huajing jiang bufen shebei zu gei xianggang shanghua bandaoti gongsi* 华晶将部分设备租给香港上华半导体公司).” In the article “Zaibao Huajing: Wuxi Gongye San Da Chongzu Jiedu zhi Yi 再造华晶: 无锡工业三大重组解读之一 (Recycling Huajing: Three Interpretations of Wuxi's Industrial Reorganization),” *Wuxi Ribao* 无锡日报 (*Wuxi Daily*), October 9, 2002, the author said Huajing “tasted bitterness (*changjing le qizhong de kuse* 尝尽

explained “In the 1990s, ...Huajing was the product of the planned economy [and]...it failed.”²⁰⁶ As for Project 909 and SMIC, Project 909 is often faulted for its long path to profitability, and SMIC was charged with intellectual property and trade secret theft as well as being suspected of inefficient operations and opaque business-government relationships.

Yet, these projects and enterprises were the bridge between China’s former centrally planned, isolated, and technologically outdated semiconductor industry of the 1980s and China’s post-2000, globally linked industry. These projects were sites for organizational and technological learning and change, despite operating in China’s not-entirely-open market and operating in China’s relatively un-reformed institutional environment of the 1990s. Today, after significant change and growth in the industry, the three enterprises associated with these projects remain three of China’s five largest semiconductor enterprises. Further, many

了其中的苦涩)” ...and that Huajing “got into trouble (*xianru le kunjing* 陷入了困境)” ...and had “huge losses (*ju kui* 巨亏).” In the article “The Nation’s Capital Investment, the Case of the Chip Industry: Huajing’s Silent Ending (*guojia ziben touru xinpianye de ge'an: huajing de wuyan jieju* 国家资本投入芯片业的个案: 华晶的无言结局), 21st Century Business Herald, May 23, 2003, the author explained the outcome of Project 908 by writing that after “this line was built, all the contracted products were outdated, and none could be put into production (*zhe tiao xian jiancheng, suoyoude hetong chanpin dou guoshi le, meiyou yi yang neng touru shengchan* 这条线建成, 所有的合同产品都过时了, 没有一样能投入生产).” The author was referring to the long approval and implementation timeline for Project 908, noting that, by the time the line was ready to run, 6 inch technology was no longer leading edge technology, although the author was apparently incorrect to write that “none could be put into production.” Wen Yi, “The Pain of China’s Chip Manufacturing (*zhongguo de xinpiian zhizao zhi tong* 中国的芯片制造之痛),” EEWORLD (*dianzi gongcheng shijie* 电子工程世界), September 9, 2008, begins with “Mention Project 908 and it will cause people to feel even more the pain of China’s chip industry. This project was meant to bring an end to the difficulties of China’s chip industry from 1965 to 1990, but its result is that everyone is hopeless (*tiji gongcheng, rang ren gengduo de gandao de shi zhongguo bandaoti chanye de tong. zhe xiang zhongguo weile dapo 1965 nian dao 1990 nian yilai zhongguo xinpiian chanye kunjing de guojiaji gongcheng, qi jieguo que shi suoyou ren bu xiwang de* 提及工程, 让人更多的感到的是中国半导体产业的痛。这项中国为了打破 1965 年到 1990 年以来中国芯片产业困境的国家级工程, 其结果却是所有人不希望的.)”

²⁰⁶ Interview with Mao Chenglie, May 19, 2009, at ETEK headquarters in Wuxi. ETEK was founded by a former Vice General Manager at Huajing and other former Huajing personnel.

engineers and managers of the post 2000 era got their early technical and managerial training in these enterprises. Chinese semiconductor personnel call Huajing the “Huangpo Military Academy,” in reference to the military academy where so many Chinese military officers were trained in the early 20th century. Indeed, Huajing served as a training ground for many semiconductor personnel in China. A group of Fudan engineering alumni educated in the 1960s and 1970s expressed that “Project 908 and 909 not only educated a lot of talent, but they made factories that are still going today!”²⁰⁷ In the 1990s and into the 2000s, many of China’s leading semiconductor personnel worked in one or more of Huajing, Huahong-NEC, and SMIC.

The history of these projects and other government policies from the 1990s reverberate today. Much of the structure of China’s 1980s state-owned electronics and semiconductor industries had been dismantled by the late 2000s, but government investment, policies, and some government ownership was still in play in the semiconductor industry in China by 2010. Many interviewees commented that China’s former industry structure and government policies are still in the minds of semiconductor personnel, certainly of anyone who began his or her career prior to 2000. When industry executives have problems or need capital, even by the late 2000s, they often still sought assistance from the government, and this applied to executives in firms of all ownership types.²⁰⁸ Indeed, central and local annual funding and operating plans for the semiconductor industry remained in place as of 2009.²⁰⁹

²⁰⁷ Interview with Fudan alumni group, May 30, 2009 in Shanghai.

²⁰⁸ Almost all company executives interviewed for this study either talked about attempts to get government funding or expressed frustration at the lack of government funding in the post 2000 era.

²⁰⁹ Interview with Xu Juyan, July 22, 2009, at CETC 58 in Wuxi. Xu Juyan was former Chief Engineer of Institute 58, and in 2009 he was a senior advisor to CRM and Institute 58, among other roles. Also, interview

As one example, research organizations still get funding through the 863 and 973 Programs, as they did in the 1990s.²¹⁰

With hindsight, Project 908's Huajing, Project 909's Huahong-NEC, and SMIC suggest that Chinese officials sought increased openness and decreased state-ownership with each of these three new projects. The initial ownership forms of the participating enterprises were:

- 1) State-Owned Enterprise: Project 908, Huajing, initiated in 1990-1992
- 2) Joint Venture: Project 909, Huahong-NEC, initiated in 1995-1997
- 3) Wholly Foreign Owned: SMIC (Semiconductor Manufacturing International Company), initiated in 2000-2002

In terms of ownership, Project 908 was based in China's state-owned enterprise, Huajing, while Project 909 primary enterprise was a joint venture between China's state-owned Huahong and Japan's NEC. Finally, SMIC was headquartered in Shanghai as a wholly foreign owned enterprise, but it was registered in the Cayman Islands. While these different ownership forms may reflect the industry's gradual opening, industry leaders including Yu Zhongyu and Dr. Ye Tianchun of China's Microelectronics Institute say that there was no original master plan to have three chronological projects of these varying ownership types. Indeed, Yu said, "From the beginning with Huajing, we invited foreign investors, but they

with Yu Zhongyu, July 2, 2009 at CSIA headquarters in Beijing. Yu is President of China Semiconductor Industry Association.

²¹⁰ Interviews with Yu Zhongyu (CSIA), July 2, 2009, and Dr. Ye Tianchun (CAS), July 3, 2009. For the 863 and 973 Programs, the government develops a roadmap of favored technologies and products, based on input from industry and research personnel. Then, organizations make technology or project specific applications to vie for state funding. However, according to Yu and Ye, the "roadmap-application-funding" process is faulty because the application-approval process is too slow to enable funding recipients to keep pace with changes in the market and technological advances.

said ‘No, we can’t make money in China.’”²¹¹ Originally, Chinese leaders only planned Project 908. Their hope was that Project 908 would achieve the necessary technological advances. When that project did not attain the expected results by the mid 1990s, Project 909 was instigated. Later, when Project 909 did not achieve its expected financial results in a timely manner, Chinese officials supported the establishment of SMIC in China, offering favorable preferences and eventually bank loans. Foreign observers might view the shift from state owned enterprise to joint venture to wholly foreign owned enterprise as evidence of planned, gradual opening, but Chinese industry people describe this sequence of events as contingent. Dr. Ye summarized by saying, “There was no plan [for 909 to follow 908, etc.] It was a complicated time.”²¹²

To identify the methods and challenges of moving from state ownership and central planning to global integration, this study details the travails (and lessons) of China first major state-sponsored project, Project 908 (Chapter Three), other major state supported enterprises and their global partners (Chapter Four), and global forces in the semiconductor industry in China (Chapter Five.) Chinese industry leaders seem to agree with Dr. Ye Tianchun’s statement that, despite the challenges, “Huajing and Project 908 in the late 1980s and 1990s were the foundation of the post-2000 industry,”²¹³ despite the perceived failures. In Huajing’s history, we see a state-owned enterprise undertake a long-term, high-profile, but very challenging project in the 1990s, and finally we see Huajing’s growth and critical

²¹¹ Interview with Yu Zhongyu, July 2, 2009 at CSIA headquarters in Beijing. Yu is President of China Semiconductor Industry Association.

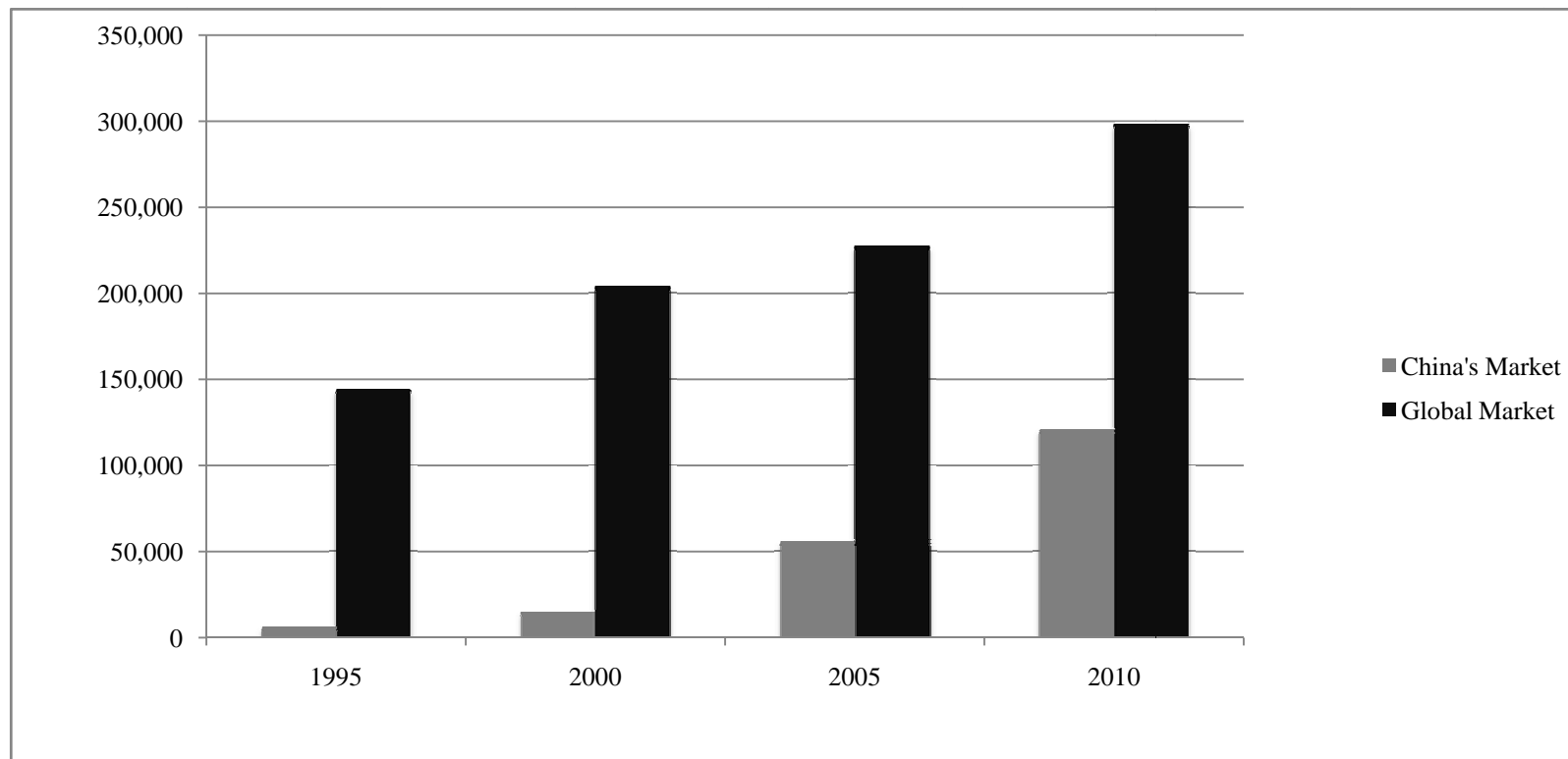
²¹² Interview with Ye Tianchun, July 3, 2009, at the CAS Institute of Microelectronics in Beijing. Ye is the Director of the Microelectronics Institute and a top advisor on national semiconductor industry policies.

²¹³ Ibid.

organizational changes in the late 1990s, a period that broadly marked the takeoff of the semiconductor industry in China. Leaders of the latter two projects, Project 909 (a Sino-Japanese joint venture) and SMIC (a wholly foreign owned enterprise), benefited from lessons learned during Project 908, and they also benefitted from a further re-formed environment and an enlarged market for semiconductors in China. In this post 2000 period, Huajing (now called Huarun), Huahong (home of Project 909), and SMIC remain active, along with China's other "key" semiconductor enterprises including: Huayue, Shanghai Belling, ASMC, and Shougang-NEC, most of which formed as joint ventures with global partners. Alongside these major state-sponsored enterprises, Chapter Five traces the emergence and challenges of other semiconductor organizations, both foreign and domestic, operating in China in the 1990s and into the 2000s. To indicate the takeoff of this industry, from 1995 to 2005 the semiconductor market in China as a share of the global market grew from two percent to twenty-five percent, and semiconductor production in China as a share of global production grew from less than one percent to seven percent, and (see Figures Ten and Nineteen.)²¹⁴

²¹⁴ PricewaterhouseCoopers, "China's Impact on the Semiconductor Industry, 2006 Update," 2006, pages 7 and 19, data from CCID, CSIA and company information. In the post 2000 period, the largest semiconductor manufacturers in China were split about evenly between Chinese and foreign firms, including a number of Chinese-foreign joint ventures, per PricewaterhouseCoopers, "China's Impact on the Semiconductor Industry," 2004, page 23, data from CCID and CSIA and company information.

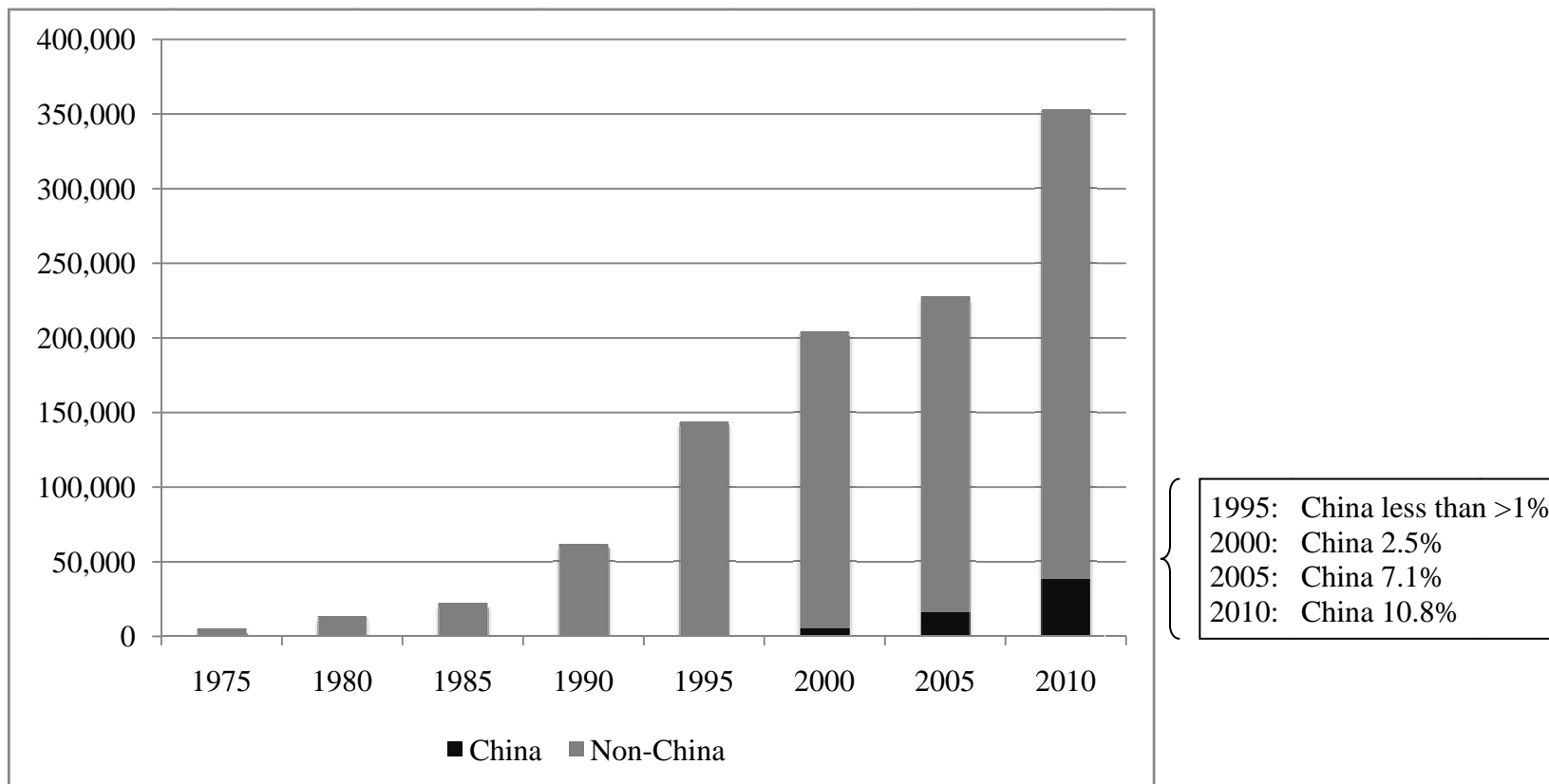
Figure 10: Semiconductor Market: China and Global, in US\$ Billions



Sources:

- 1) PWC, "China's Impact on the Semiconductor Industry, 2004, 2006, 2011 and 2012," data sources include China Semiconductor Industry Association, CCID, and PwC analysis.
- 2) Wang Yangyuan and Wang Yongwen 王阳元 and 王永文, *Wo Guo Jichengdianlu Chanye Fazhan Zhilu: cong Xiaofei Daguo Zouxian Chanye Qiangguo 我国集成电路产业发展之路：从消费大国走向产业强国* (China's Integrated Circuit Industry Development Path: From a Big, Consuming Nation to a Strong, Industrial Nation), Kexue Chubanshe 科学出版社 (Science Press), 2008, page 123, per CSIA

Figure 19: Total Semiconductor Industry Production Revenues, US\$ Billions, Global vs. China



Sources:

1) PwC, "China's Impact on the Semiconductor Industry, 2004, 2006, and 2012," data sources include China Semiconductor Industry Association, CCID, and PwC analysis.

2) Wang Yangyuan and Wang Yongwen 王阳元 and 王永文, *Wo Guo Jichengdianlu Chanye Fazhan Zhilu: cong Xiaofei Daguo Zouxian Chanye Qiangguo 我国集成电路产业发展之路：从消费大国走向产业强国* (China's Integrated Circuit Industry Development Path: From a Big, Consuming Nation to a Strong, Industrial Nation), Kexue Chubanshe 科学出版社 (Science Press), 2008, page 123, per CSIA.

3) Author's analysis

Chapter Three

Huajing and Project 908: The Origins of China's Contemporary Semiconductor Industry

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Wuxi, 85 miles west of Shanghai

From 1990 to 1998, the Chinese state-owned semiconductor enterprise Huajing, based in Jiangsu Wuxi, undertook a major modernization program called Project 908. This singular and influential project would ultimately introduce new technology and organizational changes in both Huajing and China's larger semiconductor industry. Prior to the 1990s and Project 908, the industry remained largely enmeshed in its pre-reform structures, discussed in Chapter Two, although semiconductor-related enterprises were in the process of upgrading their capabilities, in large part through attempting to use imported equipment.²¹⁵ Despite its founding role in China's contemporary semiconductor industry, Project 908 suffered delays and financial and technical challenges. Both Chinese and foreign sources refer to the project only briefly, if at all, usually labeling it a failure. Perhaps because of the lack of documentation and discussion, written references to the project have conflicting information.²¹⁶ This chapter attempts to construct a narrative of the project as well as analyze the project's key obstacles through interviews and selected industry articles from the era.²¹⁷ Despite Project 908's many problems, the project prompted precedent-setting enterprise and industry changes.

Today, the former Huajing (now called Huarun, 华润, English name China Resources Microelectronics or CRM) is integrated with the global semiconductor industry and is China's

²¹⁵ Simon 129. For example, Simon writes "between 1983 and 1985, Shanghai signed 168 contracts [for foreign electronics equipment] valued at RMB144 million... While this equipment has made a substantial contribution...it tends to be seriously underutilized."

²¹⁶ Secondary references to Project 908 have conflicting information about what technology was sought and the timing and financing of the project.

²¹⁷ Most of the selected articles are written by industry personnel with direct knowledge of events, such as Huajing managers or staff, or they are articles containing interviews with key industry personnel. There are other articles from the period, but they are either technical in nature or their content is vague or repetitive.

second largest domestic semiconductor enterprise group.²¹⁸ Former Huajing employees work in a spectrum of semiconductor and semiconductor-related firms in China and abroad. In effect, the history of Huajing and Project 908 shows the connections between the pre-reform industry and the early 21st century industry, and it shows the often difficult process of reforming, upgrading, and globalizing a formerly state-led, high-tech industry.

3.1 Huajing's Origins and Wuxi as the “Cradle” of China's Semiconductor Industry

Huajing's history as an industry leader extends deep into the pre-reform era. The organization was founded on September 1, 1960 in Wuxi as the local Jiangnan Radio Equipment Factory (江南无锡电器材厂). At that time, the radio factory had less than 300 employees, and its products, based on Soviet diodes, were for military use. On December 24, 1962, the factory was upgraded and renamed the 742 Factory, becoming a state-owned enterprise under central control. Then, on December 20, 1968, the 742 Factory merged with the Wuxi Radio Industry School (无锡电工业学校).²¹⁹

Despite being a state-owned enterprise in a relatively isolated and centrally-planned economy, in the early 1970s, the 742 Factory's managers faced several competitive and strategic choices. The 742 Factory's Director, Wang Hongjin, was struck by the increasing

²¹⁸ CRM is an enterprise group in that it encompasses several companies, each of which focus on a particular sector of the semiconductor value chain. CRM's companies include: Semico (design), Huajing (discreet devices), CSMC (I.C. foundry), and Anst (P.A.T.). CRM's parent, China Resources, is one of China's largest enterprise groups and is a member of China's national team of 100 plus large enterprise groups. For more on China's large enterprise groups, see Chapter Four, Section 4.42.

²¹⁹ Zheng Shilong, Lu Zhixin and Tian Jingying 郑世隆, 陆志信 和田婧瑛, ““Huajing Jingshen”: Ji Guoying Jiangnan Wuxiandian Qicaichang 华晶精神: 记国营江南无线电器材厂 (The Spirit of Huajing: Jiangnan State-owned Radio Equipment Factory),” *Liaowang 瞭望 (Outlook)*, Period 22, 1986.

interest among industry leaders in integrated circuits, due to advances in the global electronics industry and in particular advances in consumer-oriented electronics. (An integrated circuit, also called an IC, is a semiconductor). Yet Wang was afraid that the 742 Factory might fail if it tried to compete with other Chinese enterprises in producing integrated circuits, due to the 742 Factory's lack of experience with high volume production of ICs. With this in mind, he ordered the factory to "give up producing circuits" and to focus instead on discrete devices,²²⁰ which soon were in very high demand in China's expanding electronics market. In this same period, the 742 Factory was extending beyond military production to also begin making civilian products such as radios and recorders.²²¹

The 742 Factory's decision to provide the relatively simple, high volume discrete devices proved successful and ultimately led central officials to select the factory for more advanced operations. In 1982, the 742 Factory was chosen as the site for an important new military project, called the 742 Jiangnan Project,²²² and indeed, the 742 Factory was named one of China's so-called "key" enterprises from 1981-1995 under China's 6th, 7th, and 8th five year plans, under the control of the Ministry of Machine Building and Electronics Industry (Chapter Four covers China's "key" semiconductor enterprises in more detail.) During this time, the 742 Factory was also selected for two projects that resulted in it being China's first

²²⁰ Discrete devices are the simple components, such as transistors, diodes, resistors and capacitors, which are used in integrated circuits.

²²¹ Zheng Shilong, Lu Zhixin and Tian Jingying 郑世隆, 陆志信 和 田婧瑛, "'Huajing Jingshen': Ji Guoying Jiangnan Wuxiandian Qicaichang 华晶精神: 记国营江南无线电器材厂 (The Spirit of Huajing: Jiangnan State-owned Radio Equipment Factory)," *Liaowang 瞭望 (Outlook)*, Period 22, 1986.

²²² The 742 Jiangnan (military) Project was mentioned by Chinese industry elders as evidence of Wuxi's and Huajing's importance. The project is also mentioned in an exhibit in the Wuxi Museum's technology section (Wuxi Museum, in Taihu Square, Qingyang Road, Nanchang District, Wuxi) and in the Wuxi New District's business development office.

Figure 2: Gap Between China and Global Leading Technology (year attained)

	Wafer Size in Inches (larger is more advanced)	
Year	Global	China
1970	2	1.5
1975	4	1.5
1980	5	2
1985	6	3-4
1990	6-8	3-4
1995	8	6
2000	12	6-8
2005	12	12
2010	12-18	12

< Shougang-NEC

< Huahong-NEC and CSMC-Huajing

< SMIC

	Small Scale Integration	Medium Scale Integration	Large Scale Integration	Very Large Scale Integration	Ultra Large Scale Integration
Global	1958	1964	1966	1976	1986
China*	1965	1972	1972	1986	1999

The years indicated for China seem optimistic. They may reflect technological understanding more than actual production capabilities.

Source: Zhu Yiwei 朱贻伟, *Zhongguo Jichengdianlu Chanye Fazhan Lunshu Wenji 中国集成电路产业发展: (China's IC Industry Development: Collected Works)*, Beijing: Xinshidai 新时代出版社 (New Times Press), 2006, page 69.

true producer of integrated circuits. These projects were named Project 65 and Project 75, for being part of China's 6th and 7th five year plans (1981-1990). The 742 Factory's work on Projects 65 and 75 then led to its selection for Project 908,²²³ so named because the project was approved in August of 1990.

In undertaking Project 65, the 742 Factory ultimately spent RMB270 million²²⁴ to import a 3 inch, 5 μ m bipolar²²⁵ production line as well as a 4 inch line from Toshiba.²²⁶ At that time, the line represented China's highest technology and most comprehensive semiconductor capability. Figure Two (previous page) compares China technological level in the semiconductor industry with global leading technology, from the 1970s. In 1980 and 1981, the 742 Factory had sent staff to Toshiba in Japan to learn bipolar linear integrated circuit design and manufacturing technology. The line that the 742 Factory later imported from Toshiba was a comprehensive and brand-new line for television circuits. Its installation was completed in 1982. Importantly, the import agreement with Toshiba included supporting

²²³ Interview with Wang Guoping, July 16, 2009, at CRM headquarters. Wang was the CEO of CRM in 2008 and had been the General Manager of Huajing in the late 1990s. Wang discussed projects 65 and 75.

²²⁴ Document on Institute 24 and industry milestones provided by Wuxi National IC Design Base Company, accessed on July 14, 2009. The document did not have a title or author listed.

²²⁵ This type of production line could produce bipolar transistors. In semiconductor industry history, bipolar transistors were the first mass produced transistors. A transistor is a discrete device used to amplify or redirect electronic signals and/or power. Note: some English language sources say that Huajing imported "two used lines from the United States" during this period. These sources may be repeating Michael Pecht's assertion about production lines being imported from the United States. (Pecht has written several books on the electronics industry.) I, however, did not find any mention of complete production lines from the United States in Chinese sources; possibly the equipment was from Japan, not the United States.

²²⁶ Interview with Wang Guoping, July 16, 2009, at CRM headquarters. Wang was the CEO of CRM in 2008 and had been the General Manager of Huajing in the late 1990s. In the semiconductor industry, a production line's size in inches, e.g., "a 3 inch line," refers to the diameter of the silicon wafer, from which semiconductors are cut. Larger diameter wafers provide more semiconductors per wafer (so better economies of scale), but they are more expensive and complex to manufacture (manufacturing is called "fabricating" in the semiconductor industry). Thus, an 8 inch line is more technologically advanced than a 6 inch line. Semiconductor process technology is also commonly measured by the micron level, abbreviated as μ m, which is one-millionth of a meter. The microns (or nanos), e.g. "5 μ m," refer to the width of the line etchings on a semiconductor. In the case of microns and nanos, smaller represents more advanced technology.

equipment, tools and software, as well as ongoing training for the 742 Factory's staff.²²⁷

Indeed, in 1985, Teng Jingxin (later Huajing's Chief Engineer) traveled to Japan for training to better understand bipolar production. This technology transfer project was the first time that a Chinese *semiconductor* enterprise imported overseas production technology. By 1984, the line was in production, and that year it produced 30 million units, surpassing the 742 Factory's original 1984 production goal of over 26 million units.²²⁸

According to an article written in 1986, the 742 Factory managers later decided to use the new equipment to meet the growing domestic demand for *color* television circuits.²²⁹ But shortly after this big decision, the 742 Factory had to switch production back to circuits for black and white televisions, due to a mismatch in China's supply of cathode ray tubes for color televisions. This mismatch may have occurred because the increasing production of consumer electronics among state enterprises was not yet fully accounted for in the central plan in terms of inputs and production quotas. This switch allowed the 742 Factory to avoid a huge build-up of inventory and to become a major supplier for the many factories then producing black and white televisions. Once again, the 742 Factory was following a strategy of producing a simpler product but one that was in high demand.²³⁰

²²⁷ Chen Ling of Qinghua University, "Chanye Xingcheng Jieduan 产业形成阶段 (The Industry's Formative Stage)," unpublished paper, circa 2005. After returning from the 1981 Toshiba trip, Teng Jingxin was named Director of Huajing's New Products Research Office.

²²⁸ Document on Institute 24 and industry milestones provided by Wuxi National IC Design Base Company, accessed on July 14, 2009. The document did not have a title or author listed.

²²⁹ The managers at the 742 Factory opted to "abandon the original P-24 and change to produce the TA circuit" for color televisions, see Zheng Shilong, Lu Zhixin and Tian Jingying 郑世隆, 陆志信 和田婧瑛, "'Huajing Jingshen': Ji Guoying Jiangnan Wuxiandian Qicaichang 华晶精神: 记国营江南无线电器材厂 (The Spirit of Huajing: Jiangnan State-owned Radio Equipment Factory)," *Liaowang 瞭望 (Outlook)*, Period 22, 1986.

²³⁰ Ibid.

Despite the new equipment and training, production yields²³¹ at the factory were still low at just over 80 percent, inhibiting high volume production of integrated circuits (I.C.s). To combat this, the 742 Factory established a “best sales yield,” which was a quality standard higher than the standard set by the ministry. In effect, the “best sales yield” meant that only products that could be sold would be counted in the yield, so the 742 Factory managers measured output not only on production but on marketable yield. When the 742 Factory began this program, nearly two million integrated circuits were abandoned based on quality. By 1985, however, the factory had fulfilled contracts for 72 million integrated circuits for black and white televisions, up from 30 million units in 1984. In producing these circuits, the 742 Factory paid a fee to five other factories in the Wuxi area for sub-processing, thus creating “supplement factories, which are like little dragons under the guidance of the leading dragon.”²³² In October of 1985, the 742 Factory went on to pass the national exam for color linear I.C. production and began operations for color television circuits. By 1986, the 742 Factory was considered China’s leading electronics-semiconductor enterprise, having effectively put ICs into mass production while developing the capabilities of neighboring enterprises in Wuxi.²³³

Nonetheless, entering the period of China’s 7th five year plan (1986-1990), the 742 Factory’s technology was still significantly behind global levels. To upgrade, the factory undertook a re-organization that brought advanced R&D capabilities closer to the 742 Factory’s production operations. At that time, most research institutes in China were not

²³¹ “Production yield” refers to the percentage of units produced that meet quality standards and are usable.

²³² Ibid.

²³³ Ibid.

directly affiliated with factories, hindering applied research and production engineering at production sites. However, in 1986-1987, the 742 Factory joined with Research Institute 24 of Sichuan's Yongchuan area in order to leverage the institute's renowned technical knowledge.²³⁴ Institute 24, established in 1970 under the Ministry of Machine Building and Electronics Industry, specialized in memory, linear circuits and micro-processing circuits at the medium scale integration (MSI) and large scale integration (LSI) levels.²³⁵ At that time Institute 24 was called China's "sole comprehensive center studying semiconductors."²³⁶ According to Yin Guohai,²³⁷ it was the first organization in China to do all the processes of an integrated device manufacturer (an I.D.M.) An I.D.M. performs the main three steps in the semiconductor value chain:

Design > Fabrication (manufacturing)²³⁸ > Packaging/Assembly/Testing (called P.A.T.)

By the end of 1985, Institute 24 had shared its technological advances with over 20 factories in 13 provinces, and according to an industry article from 1990, with Institute 24's technical

²³⁴ As part of the electronics industry reforms in the mid 1980s, research institutes and factories were encouraged to voluntarily connect through emerging technical markets (see Chapter Two), but Huajing and Institute 24's union was an official (and involuntary) organizational change.

²³⁵ Over the years, the number of devices integrated on a single chip grew, and the industry moved from small scale integration (SSI) to medium scale integration (MSI) to large scale integration (LSI) to very large scale integration (VLSI). VLSI indicates at least 1000s of devices on a single chip, but today there are commonly billions of devices on a single chip. VLSI was first achieved in the United States in the 1970s.

²³⁶ Institute 24 was founded as a combination of resources and people from Institute 13 (originally called 5th Research Center), the Beijing Geological Instrument Factory Semiconductor Plant, and "a group of energetic young people," see Jiang Chenqi 蒋臣琦, "Pinbo Chuangye, Fazhan Pandeng: 24 Suo Chengli Ershi Zhounian Huigu yu Zhanwang 拼搏创业, 发展攀登: 24所成立20周年回顾与展望 (A Difficult Business, the Development Climb: Institute 24's 20th Anniversary Review and Prospect)," *Weidianzi Xue 微电子学 (Microelectronics)*, March, 1990. The author, Jiang Chenqi, was one of the first staff members at Institute 24.

²³⁷ Interview with Yin Guohai, June 19, 2009, at Anst (CRM's pak/assy/test firm). Yin Guohai was with Sichuan's Institute 24, and he joined Huajing during the merger in 1986. In 2009 Yin Guohai was Vice President of CRM's Anst, which is CRM's P.A.T. company.

²³⁸ Semiconductors (I.C.s) are manufactured in factories that are called foundries. Semiconductor manufacturing is called fabrication.

help, “some of the [recipient] factories even began to make a profit.”²³⁹ Thus, Institute 24 was expected to be a valuable partner to the 742 Factory. Institute 24’s move to Wuxi, bringing people and equipment, resulted in the 742 Factory essentially having an in-house advanced research unit for ICs, as Institute 24 established a Wuxi-branch called Institute 1424 at the factory.²⁴⁰ (This institute is later referred to as “Institute 58” or “CETC 58,” but industry personnel are reluctant to talk about Institute 58, a.k.a. Institute 1424 and Institute 24, due to its military ties.)²⁴¹

During the 7th five year plan, this new, combined organization (24 研究所无锡微电子联合体, 无锡微电子联合公, English name Wuxi United Microelectronics, from March of 1987), made strides in equipment implementation, research, and product development, setting the stage for its selection as the site for Project 908. The engineers studied the products of seven foreign companies in order to “absorb their new ideas, processes and technologies” with the goal of making similar products in China.²⁴² As early as 1987, Wuxi United

²³⁹ Jiang Chenqi 蒋臣琦, “Pinbo Chuangye, Fazhan Pandeng: 24 Suo Chengli Ershi Zhounian Huigu yu Zhanwang 拼搏创业, 发展攀登: 24 所成立 20 周年回顾与展望 (A Difficult Business, the Development Climb: Institute 24’s 20th Anniversary Review and Prospect),” *Weidianzi Xue 微电子学 (Microelectronics)*, March, 1990.

²⁴⁰ Several Chinese industry personnel said that Institute 58 was historically involved in military work. In recent years, Institute 58 has formed many small companies in the Wuxi area to commercialize military technologies.

²⁴¹ Institute 24 in Sichuan is also described as serving the military, see Jiang Chenqi 蒋臣琦, “Pinbo Chuangye, Fazhan Pandeng: 24 Suo Chengli Ershi Zhounian Huigu yu Zhanwang 拼搏创业, 发展攀登: 24 所成立 20 周年回顾与展望 (A Difficult Business, the Development Climb: Institute 24’s 20th Anniversary Review and Prospect),” *Weidianzi Xue 微电子学 (Microelectronics)*, March, 1990.

²⁴² Ibid.

Microelectronics was the first in China to undertake LSI, producing 26,480,000 units.²⁴³ At the same time, its engineers were designing and testing the first 64k RAM VLSI circuits.²⁴⁴ Until then, Chinese enterprises had had the capability only for SSI and MSI. Also during the 7th five year plan (1986-1990), the enterprise undertook Project 75, which was largely defined as the installation of a self-built 5 inch bipolar line and a self-built 5 inch MOS line,²⁴⁵ in 1988 and 1989 respectively.²⁴⁶ While some sources describe these lines as self-built, the lines may have been refurbished lines from Siemens of Germany, as other sources mention that the enterprise imported two lines from Siemens, a 4 inch and a 5 inch line, with 2-3 μ m technology, around this same time.²⁴⁷ By the late 1980s, Wuxi United Microelectronics claimed to be a supplier to almost 900 companies in China. Among China's top TV brands – including Panda, Golden Star, Peacock, and Kaige – the enterprise was supplying the I.C.s for perhaps 50 percent of the televisions. In 1985, the total revenue of Huajing was RMB278

²⁴³ Interview with Xu Juyan (居衍), July 22, 2009, at CETC 58 in Wuxi. Xu Juyan was former Chief Engineer of Institute 58 and in 2009 he was a senior advisor to CRM and Institute 58, among other roles. The 26 million units data is cited in: Zheng Shilong, Lu Zhixin and Tian Jingying 郑世隆, 陆志信 和田靖瑛, ““Huajing Jingshen”: Ji Guoying Jiangnan Wuxiandian Qicaichang 华晶精神: 记国营江南无线电器材厂 (The Spirit of Huajing: Jiangnan State-owned Radio Equipment Factory),” *Liaowang 瞭望 (Outlook)*, Period 22, 1986. DRAM is dynamic random access memory. 64k density DRAM was achieved in the United States in the early 1980s.

²⁴⁴ Fudan University alumni group interview, May 30, 2009, in Shanghai. Interviewees all studied microelectronics at Fudan Daxue from 1963, but from 1966 they did not truly study, due to the Cultural Revolution. All returned to the electronics industry in the late 1970s. Interviewees included: Xu Guochang of the Shanghai IC Industry Association, Ma Peijun of Credy Industries, Li Weide (retired), and Xu Tian who runs an industry consulting firm.

²⁴⁵ MOS is metal oxide semiconductor.

²⁴⁶ Interview with Wang Guoping, July 16, 2009, at CRM headquarters. Wang was the CEO of CRM in 2008 and had been the General Manager of Huajing in the late 1990s. Wang discussed Huajing's major 1980s projects.

²⁴⁷ Wang Jifu, “China Huajing Electronics Group Corporation,” one case from an unpublished research paper on state-owned enterprise financial reforms in China, based on interviews with Wang Guoping and other Huajing executives, circa 2000.

million, which was 50 percent higher than 1984 and six times the revenue in 1980.²⁴⁸ Figure Five shows Huajing's revenues.

Although China's centrally-planned semiconductor industry was in the process of being "released" in the late 1980s (see Chapter Two), the work at Wuxi United Microelectronics – the Jiangnan Military Project and Projects 65 and 75 – show that the central government supported critical technological projects. As the former Chief Engineer of Institute 58 put it, Wuxi United Microelectronics got "the only [semiconductor] investment in the 1980s by the central government, and at that time, the government lacked money to invest!"²⁴⁹ However, this focused, high-tech investment was being directed to an SOE with unprofitable operations and costly employee obligations such as schools, housing, and healthcare. The enterprise's financial structure would prove untenable in the 1990s during Project 908. But the state-sponsored investments at the enterprise in the 1980s and 1990s were not made in order to further the lifespan of a financially insolvent SOE nor to retain central-planning in the industry. As discussed in Chapter Two, the intention was to create at least one functioning, higher-tech I.D.M.²⁵⁰ in China to show people in China and around the world that such operations were possible in China. The hope was that an exemplary semiconductor enterprise would spur the development of other semiconductor-related

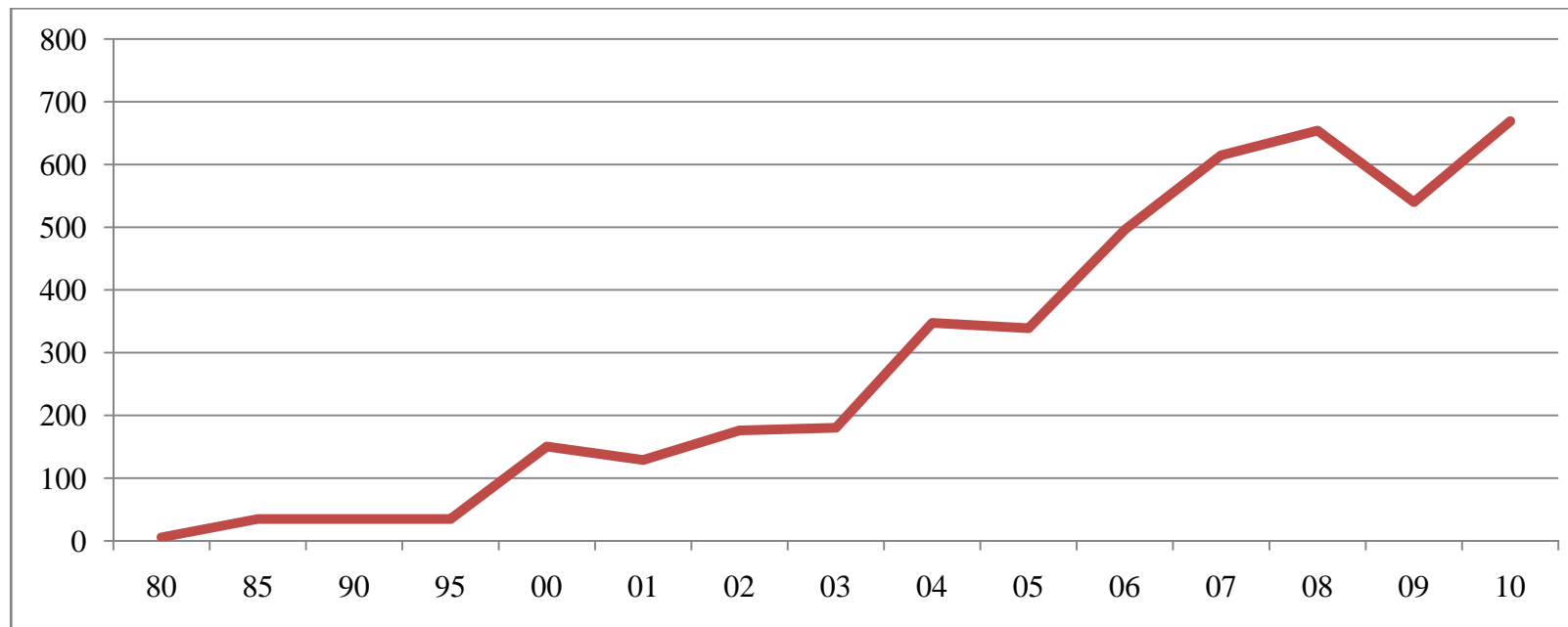
²⁴⁸ Zheng Shilong, Lu Zhixin and Tian Jingying 郑世隆, 陆志信 和田婧瑛, "“Huajing Jingshen”: Ji Guoying Jiangnan Wuxiandian Qicaichang 华晶精神: 记国营江南无线电器材厂 (The Spirit of Huajing: Jiangnan State-owned Radio Equipment Factory)," *Liaowang 瞭望 (Outlook)*, Period 22, 1986.

²⁴⁹ Interview with Xu Juyan (居衍), July 22, 2009, at CETC 58 in Wuxi. Xu Juyan was former Chief Engineer of Institute 58 and in 2009 he was a senior advisor to CRM and Institute 58, among other roles.

²⁵⁰ An I.D.M. is an "integrated device manufacturer"; this type of semiconductor enterprise conducts all the major steps in the semiconductor value chain, including design, manufacturing, and packaging/assembly/testing (P.A.T.)

Figure 5: Estimates of Huajing-affiliated Organizations' Revenues in US\$ millions

These estimates are based on ratios of revenues among Huajing-affiliated organizations. Since 2008, Huajing-affiliated organizations have combined financial statements under CRM, but previous years are estimated based on Huajing data from earlier years.



Sources include:

Zheng Shilong, Lu Zhixin and Tian Jingying 郑世隆, 陆志信 和田婧瑛, ““Huajing Jingshen”: Ji Guoying Jiangnan Wuxiandian Qicaichang

华晶精神: 记国营江南无线电器材厂 (The Spirit of Huajing: Jiangnan State-owned Radio Equipment Factory),” *Liaowang 瞭望 (Outlook)*, Period 22, 1986. CRM (China Resources Microelectronics) annual reports.

PWC, “China's Impact on the Semiconductor Industry,” 2010 and 2011, data sources China Semiconductor Industry Association, CCID, and PwC analysis.

enterprises whether domestic, foreign, state-owned or private. Nonetheless the investments in Wuxi United Microelectronics resulted in the enterprise being the first test site for a major state-sponsored semiconductor initiative and a site of many “lessons learned” that influenced future state-led projects.²⁵¹

Wuxi United Microelectronics’ selection as the site for the upcoming Project 908 (1990-1998) cemented Wuxi’s identity as the cradle of China’s contemporary semiconductor industry. The enterprise and neighboring Wuxi enterprises had made both technical and commercial gains in the 1980s, and by 1989 Wuxi had been selected as one of China’s two national semiconductor bases, and it was called the “National Southern Microelectronics Industry Base.”²⁵² But for Project 908, officials in the semiconductor industry leading group²⁵³ carefully considered which city or region to select, as their hope was that Project 908 would spawn a regional industry chain. As Xu Juyan (formerly the Chief Engineer of Institute 58) explained, “the most important event [for the industry] was the formation of Huajing in Wuxi.”²⁵⁴ Professor Li of SAIC concurred that the investment in Project 908 in Wuxi “was the main driver of change [in the industry], because there were no foreign companies at that time [in China].”²⁵⁵

²⁵¹ Interview Yu Xiekang, June 2, 2009, at JCET headquarters. Yu Xiekang was General Manager of JCET and a China Semiconductor Industry Association (CSIA) official in 2009. JCET is a large, state-affiliated ATP enterprise in Jiangsu. Yu Xiekang was General Manager of Huajing from 1987.

²⁵² Wuxi National Microelectronics Design Base Company 无锡国家集成电路设计基地有限公司, internal document, 2009.

²⁵³ The semiconductor industry leading group was under the State Planning Commission and the Ministry of Machine Building and Electronics Industry, see Chapter Two.

²⁵⁴ Interview with Xu Juyan (徐居衍), July 22, 2009, at CETC 58 in Wuxi. Xu Juyan was former Chief Engineer of Institute 58 and in 2009 he was a senior advisor to CRM and Institute 58, among other roles.

²⁵⁵ Interview with Prof. Li of Shanghai Automotive Industry Corporation 上海汽车工业(集团)总公司, May 18, 2009, in Shanghai. Actually, there were foreign companies in China in the early 1990s, but there were few semiconductor-related foreign companies at that time.

Wuxi's main competitor for Project 908 was Shanghai, as Shanghai was home to several major Chinese electronics enterprises (see Figure One) as well as being a growing base for international trade. A variety of explanations have been offered to explain Wuxi's ultimate victory. Professor Li of SAIC and several other industry personnel mentioned that Wuxi was chosen because Shanghai's air quality was already believed to be too low to accommodate the clean room standards necessary in the semiconductor industry.²⁵⁶ That said, in the 1990s, Wuxi's air quality would also become compromised by industrial pollution. In another account, Wang Guoping (Huajing's General Manager in the late 1990s and later CEO and Chairman of CRM) said that Jiangsu officials lobbied the industry leading group extensively to win the project.²⁵⁷ Finally, in his 1988 study, Denis Simon focused on Wuxi's already advanced technological capabilities as the reason for why Wuxi was favored.²⁵⁸ It is likely that each of these factors played a role. What is clear is that since Project 908, Wuxi has been recognized as the seedbed of the industry. By 2008, Wuxi had a complete semiconductor industry chain and the highest concentration of semi-conductor related enterprises, but Shanghai was China's largest semiconductor "base" among China's seven national semiconductor bases. (See Chapter Five for a discussion of China's regional bases in the semiconductor industry.)

²⁵⁶ Ibid. Denis Simon mentioned talks among MEI officials as early as 1984 and 1985 about whether to chose Wuxi or Shanghai as China's base for microelectronics, see Denis Simon, *Technological Innovation in China* (Ballinger Publishing Company, 1988), pages 136-138.

²⁵⁷ Interview with Wang Guoping, July 16, 2009, at CRM headquarters. Wang was the CEO of CRM in 2008 and had been the General Manager of Huajing in the late 1990s.

²⁵⁸ Denis Simon, *Technological Innovation in China* (Ballinger Publishing Company, 1988), pages 136-138.

Figure 1: China's Largest Semiconductor Production Facilities in the 1980s

Facility	Location
Jiangnan Semiconductor Factory	Jiangsu, Wuxi
Tianguang Electronics Factory	Gansu, Qinan
Dongguang 878 Factory	Beijing
Changzhou Semiconductor Factory	Beijing
Beijing Semiconductor #2	Zhejiang, Shaoxing
Shaoxing Electronics Factory	Shanghai
Shanghai #5 Components Factory	Shanghai
Shanghai #14 Radio Factory	Shanghai
Shanghai #19 Radio Factory	Shanghai
CAS Factory #109	Beijing
Lishan Microelectronics Corporation	Xian
Tianjin Semiconductor Factory	Tianjin

Source: From Denis Simon, *Technological Innovation in China*, page 67.

3.2 Project 908 and Huajing: 1990-1998

As part of the second semiconductor industry strategy conference held in Wuxi in February of 1989 (see Chapter Two), the Ministry of Machine Building and Electronics Industry²⁵⁹ began to consider sponsoring one significant project that would upgrade and hopefully showcase China's emerging semiconductor capabilities. At the time, industry officials also agreed that the government should encourage the industry to upgrade by investing in numerous local companies in the different semiconductor sectors, i.e., materials, equipment, design, foundry and P.A.T. (packaging/assembly/testing), although they believed that the foundry sector was the top priority.²⁶⁰ Thus, the officials of the semiconductor industry leading group (under the State Planning Commission and the Ministry of Machine Building and Electronics Industry, see Chapter Two) decided to invest in one major foundry-focused project, while also supporting upgrades in multiple enterprises across sectors. Examples of other organizations selected for upgrades and investments included 18 different design enterprises, the Beijing General Research Institute for Non-Ferrous Metals in the materials sector, and Nantong and Jiangying P.A.T. enterprises.²⁶¹

At that time, only three enterprises had the equipment and technology to be viable candidates for a significant foundry project. Those were Huajing, Huayue, and Shanghai Belling, with Huajing being the largest enterprise in the industry at the time with about 5000

²⁵⁹ The Ministry of Machine-Building and Electronics Industry was later renamed the Ministry of the Electronics Industry (MEI). In 1998, the MEI was subsumed under the Ministry of Information Industry (MII).

²⁶⁰ Foundries are high-tech and very capital intensive. Developing the ability to manufacture semiconductors, i.e., building and operating foundries, is technically and financially difficult. In 2010, a foundry cost between US\$2 and US\$10 billion to build, depending on size and technology.

²⁶¹ Interview with Wang Guoping, July 16, 2009, at CRM headquarters. Wang was the CEO of CRM in 2008 and had been the General Manager of Huajing in the late 1990s.

employees and already in possession of a self-built 5 inch foundry line. According to Wang Guoping, the Jiangsu provincial government lobbied the leading group and central government to win the project, proposing that Huajing would upgrade its existing 5 inch line and build a 6 inch line, which would be less expensive because of their existing equipment.²⁶² The budget for the foundry project was substantial, but Huajing's relatively low-cost proposal to upgrade existing equipment and its technical advances in the late 1980s led the leading group to recommend Huajing for the foundry project. As an outcome of the second strategy seminar, on April 14, 1989, the leading group got approval for the formation of a "new" enterprise to be called Huajing (华晶), which was to be a re-incarnation of the current 24 研究所无锡微电子联合体, 无锡微电子联合公. Huajing was formally established in August of 1989, with Su Guangping (苏广平) as General Manager and Teng Jingxin as Chief Engineer.²⁶³

As the key project in China's electronics industry, Project 908 sought to develop production lines for LSI circuits at the 1.0 μ m to 0.8 μ m level. The plan was to achieve annual output of 50 million LSI circuits.²⁶⁴ Specifically, Project 908 (also referred to as Project 85 or the Wuxi Microelectronics Project) was to introduce a 6 inch, 0.8 μ m production line. Total state investment in Project 908 was RMB970 million, of which 380 million was from the

²⁶² Other enterprises would likely have to import equipment.

²⁶³ Interview with Teng Jingxin, April 8, 2009, at Huajing Headquarters in Wuxi. Teng Jingxin was Chief Engineer of CRM in 2008 and former Chief Engineer of Huajing.

²⁶⁴ Zhang Longquan 章隆泉, "Huajing Jianshe Chaodaguimo I.C. Shengchanxian 华晶建设超大规模 I.C. 生产线 (Huajing to Build Large Scale I.C. Line)," *Bandaoti Zazhi 半导体杂志 (Semiconductor Magazine)*, December, 1995.

State Development Bank.²⁶⁵ According to Huajing's proposal, the 5 inch MOS line that had been the centerpiece of Project 75 would be the foundation for Project 908, and importantly, Huajing also planned to introduce technology from AT&T-Lucent.²⁶⁶

Huajing was established as a new enterprise in August of 1990, and Project 908 was intended as an 8th five year plan (1991-1995) project. However, there were significant delays in finalizing Huajing as the official site as well as delays in funding and government examinations and approvals for Project 908. These delays are reputed to have been administrative or political in nature rather than a result of Huajing's management or technical operations, but whatever the case, the delays negatively affected the productivity of Huajing's MOS line in the 1990-1995 period.²⁶⁷ The slow start up also caused Huajing's then General Manager Su Guangping to acknowledge in 1995 that Huajing's management could improve. In a published article, Su noted the need for "quality change with Huajing's enterprise management," and he said he wanted to "deepen the revolution" by creating a good compensation system and improving "inside skills" and management.²⁶⁸ That said, Huajing's

²⁶⁵ Gao Gaifang 高改芳, "Guojia Ziben Touru Xinpianye de Gean: Huajing Wuyan Jieju 国家 ▪ 本投入芯片 ▪ 的个案 : ▪ 晶的无言 ▪ 局 (The Nation's Capital in the Chip Industry: Huajing's Silent Ending)," Shanghai Baodao 上海 ▪ 道 (Shanghai Report), May 23, 2003.

²⁶⁶ CoCom export controls, discussed in Chapter Two, remained in place until 1994, and in 1996, 41 nations established the Wassenaar Arrangement on Export Controls for Conventional Arms and Dual-Use Goods and Technologies. Commonly known as the Wassenaar Arrangement, this arrangement was the post-Cold War successor to the CoCom. Wassenaar Arrangement member nations include Russia and several eastern European nations, but not China. Just as CoCom did not materially effect China's importation of semiconductor equipment in the 1980s, the Wassenaar Arrangement did not inhibit Project 908 from procuring equipment from AT&T/Lucent in the 1990s. See also Chapter Five on export controls.

²⁶⁷ China's expansive government bureaucracy was undertaking multiple reforms and initiatives during this period, so bureaucratic delays, negotiations, and conflicts were not uncommon.

²⁶⁸ Su Guangping 苏广平, "Xianzhai 'Hong Pingguo' Guangzai 'Yao Qianshu': Guanyu Zhongguo Huajing Jituan Gongsi Fazhan Xin Silu 先摘 '红苹果' 广栽 '摇钱树': ▪ 于中国华晶集团公司发展新思路 (First Pick 'Red Apple', Widely Plant 'Money Tree': Developing New Ideas for China's Huajing)," *Jiangnan*

management problems were likely similar, but not necessarily worse, than those of many SOEs in China at that time.²⁶⁹ Finally, on June 25th of 1994, Project 908 passed the national examination and was “accepted by the state.”²⁷⁰ Yet, it was not until December of 1995, the last year of the 8th five year plan, that construction for Project 908 actually commenced.

By that time, Huajing’s managers had had ample time to consider their goals and outlook in China’s rapidly emerging electronics market. General Manager Su Guangping wrote an article for the *Jiangnan Forum* in April of 1995 explaining his views.²⁷¹ His broad concern was “how can Huajing improve rapidly in [China’s] relatively weak conditions, within the competitive international environment?” Su was well aware of Huajing’s “low quality, low efficiency and high costs” relative to the global industry. Thus in terms of Project 908’s production priorities, Su wanted to emphasize scale (low-cost) production and applied products, such as consumption and life-style enhancing products, working in cooperation with domestic and overseas partners. Su thought Huajing’s ongoing focus should

Luntan 江南论坛 (Jiangnan Forum), Period 4, 1995. The author, Su Guangping, was the General Manager of Huajing in 1995.

²⁶⁹ See works addressing China’s state owned enterprises. Chen Derong, *Chinese Firms Between Hierarchy and Market: the Contract Management Responsibility System in China* (Basingstoke: Macmillan, 1995). Barry Naughton, *Growing Out of the Plan* (Cambridge: Cambridge University Press, 1995). Edward Steinfeld, *Forging Reform in China* (Cambridge: Cambridge University Press, 1998).

²⁷⁰ Su Guangping 苏广平, “Gengyun zai Weixi Guitianye, Boji yu Zhanlu Da Shichang: Huajing Gongsi de Xianzhuang yu Fazhan Silu 耕耘在微细硅田野, 搏击于战略大市场: 华晶公司的现状与发展思路 (Working Diligently in the Microtechnology Silicon Field, Fighting in a Big Strategic Market: Huajing’s Status and Development Ideas)”, *Baodaoti Jishu* 半导体技术 (Semiconductor Technology), Period 5, 1995. The author, Su Guangping, was the General Manager of Huajing in 1995. Also see Wang Jifu, “China Huajing Electronics Group Corporation,” unpublished, circa 2000.

²⁷¹ Su Guangping 苏广平, “Xianzhai ‘Hong Pingguo’ Guangzai ‘Yao Qianshu’: Guanyu Zhongguo Huajing Jituan Gongsi Fazhan Xin Silu 先摘‘红苹果’广栽‘摇钱树’: 于中国华晶集团公司发展新思路 (First Pick ‘Red Apple’, Widely Plant ‘Money Tree’: Developing New Ideas for China’s Huajing),” *Jiangnan Luntan 江南论坛 (Jiangnan Forum)*, Period 4, 1995. The author, Su Guangping, was the General Manager of Huajing in 1995.

be on capturing market share in low and mid level products, e.g., discrete devices, writing “We can push the stronger competitors to stay away from the low-end market.” Su and his team were well aware of the rapidly growing market for circuits and components in China due to both growing domestic demand for electronics and China’s increasing role as an assembler and manufacturer of electronic products for the global market. To capture market share even in low and mid-level products, Huajing would need to simultaneously maximize its existing 5 inch MOS circuit line and get the Project 908 lines up and running as soon as possible.²⁷²

Although Su thought Huajing ought to focus on low-end products, Huajing had indeed made some technical progress between 1990 and 1995. In this era, China was three generations behind international levels in semiconductor technology, and advances were somewhat hindered by import restrictions.²⁷³ For both equipment and knowledge, Huajing sent staff to Germany, the United States and Japan. For example, Huajing’s Teng Jingxin traveled to Stanford’s Electronics Research Center in 1993, and while in the United States, he also had an opportunity to study 1.5 μ m to 1.0 μ m CMOS technology at Pioneer. In 1994, Teng Jingxin also went to Japan and France to study I.C. card technology.²⁷⁴ Huajing’s research institute also invited a number of foreigner experts give talks and provide training to their staff. As for written materials, according to Xu Juyan, his engineers could get books and articles from IEEE (the Institute of Electrical and Electronics Engineers),²⁷⁵ but generally they

²⁷² Ibid.

²⁷³ See Chapter Five for more on the impact of import restrictions.

²⁷⁴ In 1991 Teng Jingxin was Huajing’s Vice Officer of Central Research Office; in 2009 he was the Chief Engineer of CRM, according to his biography, provided by the Wuxi National IC Design Base Company.

²⁷⁵ The IEEE, usually referred to as “I Triple E,” is the largest and best known association for electronics. IEEE publishes books and articles, holds conferences and other events, and develops technical standards.

could not get other books and publications from the West.²⁷⁶ In this mix of isolation and outreach, in 1993, the Huajing team produced China's first 256k DRAM,²⁷⁷ and by early 1995, Huajing had developed 1 nanometer (nm)²⁷⁸ products. In spring of 1995, Huajing produced a new generation of 2nm bipolar circuits for color televisions.²⁷⁹

However, in General Manager Su's view, producing higher technology products was a longer-term goal (and necessary in order to "get out of the condition of being controlled by others"), but Su did not see it as Huajing's immediate priority. For longer-term technical advance, Su's ideas had more to do with global integration than with Huajing's own immediate implementation of advanced production lines. Su suggested that Huajing should analyze and improve upon foreign innovations, increase its trade with foreign companies, and utilize or attract overseas Chinese talent, but he did not explicitly cite the importation of complete production lines. He also noted the need to work more closely and openly with China's own national design centers, research institutes and universities, an ironic comment

²⁷⁶ Interview with Xu Juyan (徐居衍), July 22, 2009, at CETC 58 in Wuxi. Xu Juyan was former Chief Engineer of Institute 58 and in 2009 he was a senior advisor to CRM and Institute 58, among other roles.

²⁷⁷ Su Guangping 苏广平, "Gengyun zai Weixi Guitianye, Boji yu Zhanlu Da Shichang: Huajing Gongsi de Xianzhuang yu Fazhan Silu 耕耘在微细硅田野, 搏击于战略大市场: 华晶公司的现状与发展思路 (Working Diligently in the Microtechnology Silicon Field, Fighting in a Big Strategic Market: Huajing's Status and Development Ideas)", *Baodaoti Jishu* 半导体技术 (*Semiconductor Technology*), Period 5, 1995. The author, Su Guangping, was the General Manager of Huajing in 1995.

²⁷⁸ A nano is 1 billionth of a meter. The symbol is nm.

²⁷⁹ Su Guangping 苏广平, "Gengyun zai Weixi Guitianye, Boji yu Zhanlu Da Shichang: Huajing Gongsi de Xianzhuang yu Fazhan Silu 耕耘在微细硅田野, 搏击于战略大市场: 华晶公司的现状与发展思路 (Working Diligently in the Microtechnology Silicon Field, Fighting in a Big Strategic Market: Huajing's Status and Development Ideas)", *Baodaoti Jishu* 半导体技术 (*Semiconductor Technology*), Period 5, 1995. The author, Su Guangping, was the General Manager of Huajing in 1995.

given Huajing's affiliation with the technologically renowned Institute 1424.²⁸⁰ At that time, managers from Huajing and Institute 1424 were both unhappy with their merger, see Section 3.3.

Huajing's Organization circa 1994-1995²⁸¹

- Headquarters
- Institute #1: This was Huajing's central research institute. This was likely renamed from Institute 24, a.k.a., Institute 1424 and Institute 58. The institute also has "The Wuxi IC Design Center" with 160 people, with two-thirds of having bachelors or masters and half with overseas training.
- Department #3: This consisted of the discrete devices department, bipolar circuit department, and MOS circuit department. These groups focused on production, sales and recent market driven products; this was a profit center.
- Factory #5: This was for auxillary functions including: silicon materials plant, mask plant, power plant, public abrasives plant, machine shop plant, and technical support plant.
- Employees: 5700, fifty percent with secondary education or above
- Technical Staff: 1000 engineers and 300 senior engineers.²⁸²

Huajing's Technical Awards, 1990-1995²⁸³

²⁸⁰ Su Guangping 苏广平, "Xianzhai 'Hong Pingguo' Guangzai 'Yao Qianshu': Guanyu Zhongguo Huajing Jituan Gongsi Fazhan Xin Silu 先摘 '红苹果' 广栽 '摇钱树': 关于中国华晶集团公司发展新思路 (First Pick 'Red Apple', Widely Plant 'Money Tree': Developing New Ideas for China's Huajing)," *Jiangnan Luntan 江南论坛 (Jiangnan Forum)*, Period 4, 1995. The author, Su Guangping, was the General Manager of Huajing in 1995.

²⁸¹ Su Guangping 苏广平, "Gengyun zai Weixi Guitianye, Boji yu Zhanlu Da Shichang: Huajing Gongsi de Xianzhuang yu Fazhan Silu 耕耘在微细硅田野, 搏击于战略大市场: 华晶公司的现状与发展思路 (Working Diligently in the Microtechnology Silicon Field, Fighting in a Big Strategic Market: Huajing's Status and Development Ideas)," *Baodaoti Jishu 半导体技术 (Semiconductor Technology)*, Period 5, 1995. The author, Su Guangping, was the General Manager of Huajing in 1995.

²⁸² Su Guangping 苏广平, "Xianzhai 'Hong Pingguo' Guangzai 'Yao Qianshu': Guanyu Zhongguo Huajing Jituan Gongsi Fazhan Xin Silu 先摘 '红苹果' 广栽 '摇钱树': 关于中国华晶集团公司发展新思路 (First Pick 'Red Apple', Widely Plant 'Money Tree': Developing New Ideas for China's Huajing)," *Jiangnan Luntan 江南论坛 (Jiangnan Forum)*, Period 4, 1995. The author, Su Guangping, was the General Manager of Huajing in 1995.

- 1990: Named “National Top Class Enterprise”
- 1991: Recipient of the “National Enterprise Technology Advancement Award”
- 1992: Recipient of the “National May First Labor Award”
- 1993: Approved by the Global Electro-technical Commission IECQ
- 1993: Completed contract examination (producing China’s first 256k D DRAM)
- 1994: Completed the national examination

As mentioned above, at the end of 1995, Project 908 finally was given the funding and approval to begin, and in 1996, the state “accepted” Huajing’s bipolar production line (to be used for VCR production).²⁸⁴ This line was an upgraded line and was likely a 6 inch line, built from a 5 inch line, which had been part of Huajing’s original rationale for why Huajing should be selected for Project 908. Industry personnel will refer to Huajing’s “self-built” lines as evidence of Huajing’s technical capabilities in the early 1990s, and according to Xu Juyan, the self-built 6 inch line was still in use as late as 2009.²⁸⁵

By late 1995, Project 908 was already in some disfavor. Whether or not Huajing managers and engineers were at fault, the project simply had not happened from 1991-1995 as originally planned. Indeed, in light of the failure of Project 908, the next major state-led semiconductor project -- Project 909 -- was approved to begin in 1995 in Pudong. Project 909 is discussed in Chapter Four.

²⁸³ Su Guangping 苏广平, “Gengyun zai Weixi Guitianye, Boji yu Zhanlu Da Shichang: Huajing Gongsi de Xianzhuang yu Fazhan Silu 耕耘在微细硅田野, 搏击于战略大市场: 华晶公司的现状与发展思路 (Working Diligently in the Microtechnology Silicon Field, Fighting in a Big Strategic Market: Huajing’s Status and Development Ideas)”, *Baodaoti Jishu* 半导体技术 (*Semiconductor Technology*), Period 5, 1995. The author, Su Guangping, was the General Manager of Huajing in 1995.

²⁸⁴ Wang Jifu, “China Huajing Electronics Group Corporation,” unpublished, circa 2000.

²⁸⁵ Interview with Xu Juyan (许居衍), July 22, 2009, at CETC 58 in Wuxi. Xu Juyan was former Chief Engineer of Institute 58 and in 2009 he was a senior advisor to CRM and Institute 58, among other roles.

Huajing's 6 inch line had been "accepted" by the state in 1996, but the production line that was really the penultimate goal of Project 908, which was a 6 inch line with 0.9 μ m technology from Lucent, was not implemented until 1998. On January 18th of 1998, Huajing received "approval" for Project 908 in a ceremony attended by Huajing leaders, government officials from the State Planning Commission and the Ministry of Electronics Industry, and representatives from Lucent. At that time, Huajing had a monthly production capacity of 6,000 units (annual output of 72,000 units)²⁸⁶ on a 6 inch line.²⁸⁷ (Recall, the original goal of Project 908 was annual output of *50 million* circuits on a 6 inch production line(s) at the 0.8 to 1.0 μ m level.)²⁸⁸ Despite Lucent's presence at this approval ceremony, the Lucent line was still not in use; prior to 1995, Huajing had introduced 0.9 μ m technology from Lucent, but this technology had not yet been fully implemented. In early 1998, Huajing was operating at a loss due to its Project 908 funding (which was actually interest-bearing loans from state banks), high cost structure, and lack of scale production. In April of 1998, further funding for construction at Huajing (as well as nine semiconductor design centers) was approved, and

²⁸⁶ Gao Gaifang 高改芳, "Guojia Ziben Touru Xinpianye de Gean: Huajing Wuyan Jieju 国家资本投入芯片业的个案：华晶的无言结局 (The Nation's Capital in the Chip Industry: Huajing's Silent Ending)," Shanghai Baodao 上海报道 (Shanghai Report), May 23, 2003.

²⁸⁷ In early 1998, Huajing was producing I.C.s that could be used for communications, appliances, and industrial controls, as well as smart cards and other special applications. The products and equipment passed several tests, including production yield (average yield was 80 percent), aging tests, and failure rates (actual failure rate was 0.25 percent, acceptable failure rate was <0.75 percent), see "908 Gongcheng: Huajing Xiangmu zai Xi Tongguo Duiwai Hetong Yanshou 908 工程：华晶项目在锡通过对外合同验收 (908 Engineering: The Foreign Contract of the Huajing Project was Accepted in Wuxi)," *Dianzi Zhiliang 电子质量 (Electronics Quality)*, March, 1998. (The author of this article was not shown.)

²⁸⁸ Zhang Longquan 章隆泉, "Huajing Jianshe Chaodaguimo I.C. Shengchanxian 华晶建设超大规模 I.C. 生产线 (Huajing to Build Large Scale I.C. Line)," *Bandaoti Zazhi 半导体杂志 (Semiconductor Magazine)*, December, 1995.

later that year, Huajing finally implemented the 0.9 μ m CMOS equipment from Lucent.²⁸⁹

Project 908 is usually referred to as a 1990 to 1998 endeavor, but official production may not have begun until early 1999.²⁹⁰

3.3 The Obstacles for Huajing and Project 908

Funding. Huajing's management had to operate with funding that was both delayed and expensive. Reports on the funding for Project 908 range from RMB970 million²⁹¹ to RMB1.39 billion,²⁹² with 380 million coming from the State Development Bank.²⁹³ Although the semiconductor industry leading group (under the State Planning Commission and the Ministry of the Electronics Industry) agreed to invest this sum in Project 908, in actuality, this only meant that banks were given the authority to make *loans* to Huajing for this amount. Huajing had to repay principal and interest, although the government may have eventually

²⁸⁹ Unnamed reporter, "Lucent to Complete Contract," *China Business News*, March 2-5, 1998. "Lucent...signed an acceptance certificate recently with the Chinese Government for the completion of a ...technology transfer contract. [It includes] the processing technology and related design technology and design tools of Lucent Bell Lab's 0.9 μ m CMOS."

²⁹⁰ Chen Ling of Qinghua University, "Chanye Xingcheng Jieduan 产业形成阶段 (The Industry's Formative Stage)," unpublished paper, circa 2005.

²⁹¹ Gao Gaifang 高改芳, "Guojia Ziben Touru Xinpianye de Gean: Huajing Wuyan Jieju 国家资本投入芯片业的个案：华晶的无言结局 (The Nation's Capital in the Chip Industry: Huajing's Silent Ending)," Shanghai Baodao 上海报道 (Shanghai Report), May 23, 2003.

²⁹² Zhang Longquan 章隆泉, "Huajing Jianshe Chaodaguimo I.C. Shengchanxian 华晶建设超大规模 I.C. 生产线 (Huajing to Build Large Scale I.C. Line)," *Bandaoti Zazhi 半导体杂志 (Semiconductor Magazine)*, December, 1995.

²⁹³ Gao Gaifang 高改芳, "Guojia Ziben Touru Xinpianye de Gean: Huajing Wuyan Jieju 国家资本投入芯片业的个案：华晶的无言结局 (The Nation's Capital in the Chip Industry: Huajing's Silent Ending)," Shanghai Baodao 上海报道 (Shanghai Report), May 23, 2003.

covered some of Huajing's loans.²⁹⁴ Huajing was not able to secure the full amount of the approved loans until about 1995. Once Huajing's lines were in operation, Huajing's output was too low to offset the costs of the continuously running line. Huajing also faced high energy costs and equipment depreciation.²⁹⁵ In the mid 1990s, there was a period when Huajing was unable to pay its employees their wages. As this renowned Wuxi enterprise faltered, local people recall protests by Huajing employees at Huajing's headquarters and at the homes of Huajing executives.²⁹⁶ By 1998, Huajing was in debt for principal and interest, with little revenue and no profit.²⁹⁷

Timing. In terms of timing, both officials and industry personnel viewed Project 908 as a failure due to its many delays. Although the semiconductor industry leading group approved the project in August of 1990, it was another two full years before they selected Wuxi's Huajing over Shanghai's Belling as the official site for Project 908.²⁹⁸ As discussed in the previous section, Project 908 was intended to be an 8th five year plan (1991 to 1995) project, but Huajing did not even begin construction until December of 1995. At that time, officials anticipated that the construction process itself would take another 16 months, with

²⁹⁴ Interview with Mao Chenglie, May 19, 2009, at ETEK headquarters in Wuxi. Mao Chenglie was on the ETEK senior management team in 2008. Mao Chenglie and eight other Huajing staff left Huajing with a former Huajing Vice General Manager to found ETEK in 2002.

²⁹⁵ Wang Jifu, "China Huajing Electronics Group Corporation," unpublished, circa 2000.

²⁹⁶ Several Wuxi residents recalled such protests.

²⁹⁷ Wang Jifu, "China Huajing Electronics Group Corporation," unpublished, circa 2000.

²⁹⁸ Interview with Wang Guoping, July 16, 2009, at CRM headquarters. Wang was the CEO of CRM in 2008 and had been the General Manager of Huajing in the late 1990s.

results in 1997.²⁹⁹ However, some funding was not awarded until April of 1998. Even in 1998 and 1999, Huajing's unit output did not meet the original project goals.

As will be discussed in Chapter Four, when Japan, Korea, and Taiwan were developing capital intensive and higher technology industries during their decades of rapid development, government support for technology acquisition and transfer was critical. At Huajing, however, Chinese officials essentially failed to fund and complete a timely technology transfer.

Technology and Organization. In addition, once Huajing did have new equipment, the staff had problems using the new production equipment and designing new products. As discussed in Section 3.2, General Manager Su wanted to focus on consumer applications and low-end products, making technical advances (perhaps more slowly) through global integration. Yet, Huajing's production side lacked access to appropriate designs. (The lack of connection between R&D and production is an oft-cited problem in centrally-planned economies, due to "vertical silos" within enterprises and because of the use of specialized institutes for R&D. See Chapter Two.) In the late 1980s, Huajing had tried to bridge the gap by supplementing its capabilities with R&D from the co-located Institute 24 (a.k.a., Institute 1424 and Institute 58) as well as technical experts from Dongnan University.³⁰⁰ Nonetheless, Yu Xiekang, who was General Manager of Huajing in the late 1980s, said that he did not have enough control over R&D and R&D (conducted by Institute 1424 at Huajing) was not

²⁹⁹ Zhang Longquan 章隆泉, "Huajing Jianshe Chaodaguimo I.C. Shengchanxian 华晶建设超大规模 I.C. 生产线 (Huajing to Build Large Scale I.C. Line)," *Bandaoti Zazhi 半导体杂志 (Semiconductor Magazine)*, December, 1995.

³⁰⁰ Interview Yu Xiekang, June 2, 2009, at JCET headquarters. Yu Xiekang was General Manager of JCET and a China Semiconductor Industry Association (CSIA) official in 2009. JCET is a large, state-affiliated P.A.T. enterprise in Jiangsu. Yu Xiekang was General Manager of Huajing from 1987.

providing enough new products. Yu says “I talked with the president many times about the problems between R&D and production, but the president could not re-organize, because it was a state-owned company. After six months, the president agreed to move some R&D closer to production,” but still the production side of Huajing was not working effectively with design to be able to produce higher technology products.³⁰¹ Xu Juyan, originally with Institute 24 in Sichuan and later Chief Engineer of Institute 58 (a.k.a., Institute 1424), explained that “the leaders of Huajing and Institute 58 had not wanted to join and share power in the beginning, but they were ordered by the government to combine.”³⁰² In 1990, one of the initial staff of Institute 24 in Sichuan wrote about the move to Wuxi saying “Institute 24 will never [again] be a comprehensive research center [due to the Wuxi move], and it has to find a new position again.” This individual further described the Institute 24 team as “tortured” by the move from China’s inland to the east coast and by concerns about wage gaps, their children’s futures, and the like. By 1990, long before Project 908 ever got underway, the personnel from Institute 24 already felt that they had endured several years of an unwanted, difficult, government-mandated merger with Huajing, all the while remaining a loyal and productive team.³⁰³ According to Ye Tianchun (of CAS Institute of Microelectronics), the Ministry of the Electronics Industry invested in Huajing and “let the plant do the research itself, but this turned out to be useless from 1990 to 1995 at Huajing.”

³⁰¹ Ibid.

³⁰² Interview with Xu Juyan (许居衍), July 22, 2009, at CETC 58 in Wuxi. Xu Juyan was former Chief Engineer of Institute 58 and in 2009 he was a senior advisor to CRM and Institute 58, among other roles.

³⁰³ Jiang Chenqi 蒋臣琦, “Pinbo Chuangye, Fazhan Pandeng: 24 Suo Chengli Ershi Zhounian Huigu yu Zhanwang 拼搏创业, 发展攀登: 24 所成立 20 周年回顾与展望 (A Difficult Business, the Development Climb: Institute 24’s 20th Anniversary Review and Prospect),” *Weidianzi Xue 微电子学 (Microelectronics)*, March, 1990.

Nevertheless from its inception, the intent of Project 908 at Huajing was primarily production, not necessarily R&D, which was supported by other state initiatives discussed in Section 2.1d. Design and production were *both* problematic at Huajing: after securing equipment, Huajing did not have the designs for higher tech products and it did not have the skills to use its equipment to produce higher-tech designs. These shortcomings may have been caused by technical deficiencies or by the organizational rifts resulting from the forced merger. Finally, in 1995, Institute 58 split from Huajing, and as late as 2000, Huajing staff still complained that the institutes -- 24 and others -- had never provided Huajing with useful designs.³⁰⁴ Anyway, after the mid 1990s, the five and 6 inch MOS lines were no longer considered “advanced” in the global industry, so Project 908 had failed to establish an “advanced” Chinese semiconductor enterprise.

Foreign Challengers. Related to Huajing’s inability to produce higher-tech products was the fact that China’s market was increasingly opening, so factories in China were able to import higher quality foreign components and I.C.s.³⁰⁵ There was less demand for Huajing’s copies of (already outdated) foreign I.C.s, and further, “Huajing had a wide product line, but it was not a leader in any product segment.”³⁰⁶ To combat these problems, Huajing set up several joint ventures in Shenzhen and Zhuhai in 1993 and 1994, as the market in southeast China for I.C.s and related products was growing. These ventures focused on product development, marketing and sales. The intention of this southeast expansion was not only for

³⁰⁴ Wang Jifu, “China Huajing Electronics Group Corporation,” unpublished, circa 2000.

³⁰⁵ Interview with Prof. Li of Shanghai Automotive Industry Corporation 上海汽车工业 (集团) 总公司, May 18, 2009, in Shanghai.

³⁰⁶ Interview with Mao Chenglie, May 19, 2009, at ETEK headquarters in Wuxi. Mao Chenglie was on the ETEK senior management team in 2008. Mao Chenglie and eight other Huajing staff left Huajing with a former Huajing Vice General Manager to found ETEK in 2002.

Huajing to capture market share but more generally to expand the role of state-owned semiconductor companies in China's growing southeastern market.³⁰⁷ As China's electronics market grew, Chinese enterprises (Huajing included) became known as providers of low-cost, low-end discrete devices, but customers trusted imports for I.C.s and higher quality discrete devices.

Management. Huajing's managers had had success in running their state-owned enterprise in the 1980s. However, as SOE managers they had less experience in finance, marketing, quality control, and human resource management, which were all functions that were increasingly important in China's growing and opening electronics industry. According to a former Huajing engineer, "Huajing's orders were from the government, and Huajing got loans from the government. [Generally] Huajing's management had a central-planning focus."³⁰⁸ (This obstacle would begin to be rectified in 1997, with new and foreign management, as discussed Section 3.4 below.) Huajing's General Manager Su Guangping recognized the need for "quality change within Huajing's enterprise management," along with a better compensation system.³⁰⁹ Indeed, in the pre-1995 period, Huajing lost a number of engineers because salaries were so low that, when possible, engineers emigrated to Singapore

³⁰⁷ Zhong Fu 中福, "Huajing Xingban Hezi Gongsì Jinjun Nanfang Shichang 华晶兴办合资公司进军南方市 (Huajing Establishes a Joint Venture to Expand into the Southern Market)," *Weidianzi Jishu 微电子技术 (Microelectronics Technology)*, May, 1994.

³⁰⁸ Interview with Mao Chenglie, May 19, 2009, at ETEK headquarters in Wuxi. Mao Chenglie was on the ETEK senior management team in 2008. Mao Chenglie and eight other Huajing staff left Huajing with a former Huajing Vice General Manager to found ETEK in 2002.

³⁰⁹ Su Guangping 苏广平, "Xianzhai 'Hong Pingguo' Guangzai 'Yao Qianshu': Guanyu Zhongguo Huajing Jituan Gongsì Fazhan Xin Silu 先摘 '红苹果' 广栽 '摇钱树': 关于中国华晶集团公司发展新思路 (First Pick 'Red Apple', Widely Plant 'Money Tree': Developing New Ideas for China's Huajing)," *Jiangnan Luntan 江南论坛 (Jiangnan Forum)*, Period 4, 1995. The author, Su Guangping, was the General Manager of Huajing in 1995.

or the United States or other foreign destinations for better livelihoods.³¹⁰ Finally, Huajing's reputation in the late 1990s and early 2000s as a provider of low-end products to mostly Chinese enterprises suggests that Huajing lacked marketing expertise and quality control.

3.4 Enterprise Solutions Emerging from Project 908

Huajing attempted a large-scale project of national importance and in doing so Huajing faced difficulties that were common in China's reforming and opening economy. In the 1990s, Huajing's reputation changed from renowned to disparaged. Nonetheless, in response to the difficulties and failure of Project 908, Huajing undertook a number of reforms that previewed the structure and focus of the broader semiconductor industry in China in the early 21st century. Further, the so-called lessons learned at Huajing were instructive as the Ministry of the Electronics Industry planned Project 909, SMIC and other semiconductor industry-related policies.

From Old Management to New

In 1997, owing to Project 908's lack of results and Huajing's mounting production losses and inability to meet payroll, the central and provincial governments "ordered" Huajing to restructure.³¹¹ Around this time, a number of senior Huajing leaders were asked to retire (with generous retirement packages), and a new generation of younger Huajing managers were promoted, including Wang Guoping. According to Wang and Teng Jingxin, younger

³¹⁰ Interview with Li Zhihong, March 26, 2009, at Chipown headquarters in Wuxi. Li Zhihong was General Manager of Chipown in 2009 and had previously worked at Huajing. Other industry personnel mentioned the phenomenon of staff leaving Huajing to work abroad (or domestically) for better pay.

³¹¹ Wang Jifu, "China Huajing Electronics Group Corporation," unpublished, circa 2000.

individuals were allowed to ascend due to a belief that Huajing needed open-minded, creative, and energetic managers. (Teng Jingxin was part of the older generation, but he was allowed to keep his job.)³¹² As Xu Juyan put it, when Huajing was changing its management team, “they wanted to follow the example of allowing the young [to emerge and lead]. If the I.C. industry is to prosper, it needs young people for talent and passion. ...Like Intel and HP and Fairchild were built by young people.”³¹³ Thus in 1997, Wang Guoping, then age 36, was named Executive Vice President of Huajing and soon after he was named General Manager. Wang had not lived or studied abroad, but his approach (as will be shown in the following sections) reflected global norms and trends. With Huajing in crisis and support from above for real change, Wang and his team pursued the tactics and strategies below.

From Enterprise to Individual Accounting Units

The management team decided to restructure Huajing with a gradual unit-by-unit approach. Wang emphasizes that his team’s first important move was to establish individual accounting units for each part of Huajing’s operations. The management team’s view was that – through individual accounting – each unit would begin to function almost as an independent, market-facing company. Wang emphasized the difficult and important process of implementing standardized, transparent accounting for each unit, restructuring the enterprise so that Huajing’s main office oversaw the new accounting units. In late 2000, Wang and his management team further restructured by establishing groups for standard

³¹² Interview with Wang Guoping and Teng Jingxin, July 16, 2009, at CRM headquarters. Wang was the CEO of CRM in 2008 and had been the General Manager of Huajing in the late 1990s. Teng Jingxin was the Chief Engineer of CRM in 2009 and the former Chief Engineer of Huajing.

³¹³ Interview with Xu Juyan (许居衍), July 22, 2009, at CETC 58 in Wuxi. Xu Juyan was former Chief Engineer of Institute 58 and in 2009 he was a senior advisor to CRM and Institute 58, among other roles.

managerial functions. These new functions included: “general management, production operations, science quality, human resources, finance and accounting, and materials supply” as well as departments devoted to sales.³¹⁴ Despite these necessary changes, Huajing remained a deeply indebted state-owned enterprise.

Establishing Taiwan Links and the Foundry Model

The reforms discussed above were important, but Huajing’s most notable feat in the 1997 to 1999 timeframe -- when it was still ostensibly undertaking Project 908 -- was its adoption of the Taiwan-originated “dedicated foundry model.”³¹⁵ In 1997, the Ministry of the Electronics Industry and the China Semiconductor Industry Association brought a Taiwanese semiconductor business delegation to visit Huajing in Wuxi. This visit ultimately culminated in Huajing adopting the foundry model to serve both Chinese and international customers.³¹⁶

³¹⁴ “Huajing Weidianzi Gufen Youxian Gongsi Shunli Touru Guifanhua Yunzuo 华晶微电子股份有限公司顺利投入规范化运作 (Huajin Microelectronics Co. Ltd. Smoothly Standardizes Operations),” *Weidianzi Jishu 微电子技术 (Microelectronic Technology)*, January, 2001. The author of this article is not shown.

³¹⁵ Into the 1990s, most major global semiconductor firms operated under the “integrated device manufacturer (I.D.M.)” business model. In an I.D.M., one vertically integrated company designs, fabricates (i.e., produces or manufactures), and packages/assembles/tests (P.A.T.) its own semiconductors, using its own foundry for fabrication. This foundry model was first developed in Taiwan in 1987 at the Taiwan Semiconductor Manufacturing Corporation (TSMC). The foundry model is in contrast to the I.D.M. model. Under the foundry model, a stand-alone foundry leases its capacity to any number of customers. Customers design their semiconductors and then simply lease foundry capacity for fabrication. The foundry does not sell semiconductors into the market. That said, one company can act as a foundry while also having other revenue streams.

³¹⁶ Zhu Yiwei 朱贻纬 of the China Semiconductor Industry Association, “Liangnan Jicheng Dianlu Chanye Jiaoliu Shinian Huigu 两岸集成电路产业交流十年回顾: 三, 华晶上华 (Ten Years of Cross-Strait Exchanges in the I.C. Industry: Part 3, CSMC),” available in the archives of www.CSIA.com accessed in 2009.

In late September and October of 1997, Huajing began negotiations with Taiwanese counterparts for the purpose of structuring a business that might resurrect Huajing's loss-making CMOS lines.³¹⁷ After many sessions, on December 18, 1997, the two sides agreed to co-operate in running the 5-inch and 6-inch CMOS lines. Huajing would provide the plant, production equipment and the original MOS plant's 200 employees. The Taiwanese team would found a company called CSMC in Hong Kong, and CSMC would provide capital, management and overseas customers for Huajing. The Taiwanese group was led by Peter Chen; in the 1980s, Chen had successfully founded Mosel Electronics.³¹⁸ In late 1997, the Huajing-CSMC agreement was approved by "the leading organs of the state,"³¹⁹ and the two sides commenced joint work on February 1, 1998.³²⁰

The arrangement above is often referred to as CSMC "leasing" Huajing's facilities, in order to operate the facilities using the foundry model. Yet, at that time, China's domestic semiconductor industry was not yet open to Taiwan. Why was this first, ad hoc arrangement with Taiwan able to proceed? According to Wang Guoping, when the Huajing leaders were initially sorting out their relationship with CSMC, they simply did not involve provincial and national officials. As Wang put it "We didn't really talk about it or ask for permission, and no

³¹⁷ The initial group from Taiwan consisted of: Xiong Cainan and Feng Mingxian from Taiwan, Xiao Chenghui from Hong Kong, and Peter Chen (Chen Zhengyu), a Chinese-American.

³¹⁸ Peter Chen (Chen Zhengyu) has a Ph.D from Cornell and has also worked for several global semiconductor firms, including Fairchild.

³¹⁹ Zhu Yiwei 朱贻纬 of the China Semiconductor Industry Association, "Liangnan Jicheng Dianlu Chanye Jiaoliu Shinian Huigu 两岸集成电路产业交流十年回顾: 三, 华晶上华 (Ten Years of Cross-Strait Exchanges in the I.C. Industry: Part 3, CSMC)," available in the archives of www.CSIA.com accessed in 2009.

³²⁰ Ibid.

one really said no.”³²¹ (As we will see in Chapter Four, by this time, national leaders’ attention had begun to shift to the new Project 909 in Shanghai.) Of course, the Ministry of the Electronics Industry had arranged the initial business delegation from Taiwan, and ultimately Huajing’s arrangement got approval from the state. Yet, Wang and others expressed pride and some surprise in their own initiative in bringing Taiwanese into a nationally renowned (but challenged) Chinese enterprise. Essentially, Taiwanese managers and engineers began working in Wuxi, helping Huajing’s managers move China’s Project 908 toward an acceptable endpoint, if not exactly success.³²²

The immediate purpose of the CSMC-Huajing arrangement was to bring capital into Huajing by leasing the foundry, but the larger purpose was to secure Taiwanese management and longer-term financial stability. The Taiwan team sent a General Manager and several staff and brought in orders, as Huajing did not yet have marketing and sales capabilities to attract foreign orders. (Huajing’s marketing and sales functions would be more solidly established in 2000).³²³ Under CSMC leadership, CSMC managers worked with Huajing staff to solve problems with finance, marketing, and quality control. In 1998 and 1999, orders, equipment utilization, and salaries all began to increase. In 1998, the operation lost about US\$1million, but after 15 months, output quantity and quality had significantly improved,³²⁴

³²¹ Interview with Wang Guoping, July 16, 2009, at CRM headquarters. Wang was the CEO of CRM in 2008 and had been the General Manager of Huajing in the late 1990s.

³²² Interview Wang Guopin and Teng Jingxin, July 16, 2009, at CRM headquarters. As a counterpoint, Xu Juyan (formerly of Institute 58) said “The Chinese government allowed the CSMC deal because there were many joint ventures at that time.” However, while international joint ventures were increasingly common in China, at that time, China’s domestic semiconductor industry was not open to Taiwan.

³²³ Interview with Xu Juyan (许居衍), July 22, 2009, at CETC 58 in Wuxi. Xu Juyan was former Chief Engineer of Institute 58 and in 2009 he was a senior advisor to CRM and Institute 58, among other roles.

³²⁴ Zhu Yiwei 朱贻伟 of the China Semiconductor Industry Association, “Liangnan Jicheng Dianlu Chanye

reaching 13,000 units per month in 1999, twice the monthly production of 1998. CSMC moved from loss-making to break-even, verging on profitable. (Recall, in April of 1998, Huajing got additional funding from the state and finally implemented the equipment from Lucent.)

In 1999, Huajing and the Taiwan team again entered negotiations to further define and advance their arrangement. After repeated talks, they agreed to form an official joint venture starting from August 1, 1999.³²⁵ The joint venture was called Wuxi CSMC-HJ Co., Ltd, and it was located in Wuxi's new National High Technology Development Zone. Huajing owned 49 percent of the joint venture, and CSMC raised another US\$6 million of capital.³²⁶ This joint venture was only a part of Huajing; it covered only the agreed upon fabrication lines. Working together, production quantity and quality continued to improve: by late 1999, the 6 inch line had reached 60,000 units per month (roughly ten times 1998),³²⁷ and in 2000, monthly output reached 70,000 units.³²⁸

CSMC's lease of Huajing in 1997 was a pivotal turning point for Huajing. With this arrangement, Huajing adopted the foundry model that was being used with much success in

Jiaoliu Shinian Huigu 两岸集成电路产业交流十年回顾: 三, 华晶上华 (Ten Years of Cross-Strait Exchanges in the I.C. Industry: Part 3, CSMC)," available in the archives of www.CSIA.com accessed in 2009.

³²⁵ Publicly available company documents of China Resources Microelectronics.

³²⁶ Wang Jifu, "China Huajing Electronics Group Corporation," unpublished, circa 2000.

³²⁷ Zhu Yiwei 朱贻纬 of the China Semiconductor Industry Association, "Liangnan Jicheng Dianlu Chanye Jiaoliu Shinian Huigu 两岸集成电路产业交流十年回顾: 三, 华晶上华 (Ten Years of Cross-Strait Exchanges in the I.C. Industry: Part 3, CSMC)," available in the archives of www.CSIA.com accessed in 2009.

³²⁸ In 2000, Wuxi CSMC-HJ produced "229 different I.C.s using...technology from Lucent. Also...developed more than 30 new technologies...and 36 new MOS products for applications" according to Jifu Wang in "China Huajing Electronics Group Corporation," unpublished, circa 2000.

Taiwan and had become the new model for the global semiconductor industry.³²⁹ As well, Huajing was engaging closely with foreign (Taiwanese) management and technical talent and was benefitting from new sources of funding and customers. CSMC had more success with operating on the relatively simpler foundry model than Huajing had had with trying to operate on the I.D.M. model. Contemporary China Resources Microelectronics (CRM) documents refer to CSMC's founding in Hong Kong in 1997 as the origin of the enterprise, despite the enterprise's much longer history on the Mainland. (Recall, Huajing has been called CRM since 2002.)

Finally, Huajing's relationship with CSMC was a major step forward in terms of technology transfer from abroad. Prior to CSMC, Huajing had imported equipment from Siemens (late 1980s), Toshiba (1980s and 1990s), and Lucent (1990s), as well as software from Promis Systems of Canada (1996),³³⁰ and in each of these cases, the technology transfer had included training. However, Huajing had had limited results in utilizing the foreign technology. The arrangement with CSMC, however, represented a more complete transfer and integration of management technology as well as material technology from abroad. For example, Peter Chen brought several of his former Taiwanese managers from Mosel to work at CSMC in Wuxi. In hindsight, Wang Guoping said "To seek outside partners...was the

³²⁹ The foundry model is an example of industry de-verticalization. In the foundry model, fabrication is essentially out-sourced. Semiconductor manufacturing is highly complex, but outsourcing was increasingly possible due to the modularization of electronics as well as electronic communication. The primary benefit to customers of the foundry model is that they can design and sell semiconductors without making the huge capital investment necessary for building and maintaining an in-house foundry. In the semiconductor industry, high utilization of foundry capacity is key for profitability. For foundries (that is, enterprises or divisions of enterprises which are operating on the foundry model), the benefit of having an array of customers is that the foundry can try to fully utilize its capacity by carefully staging orders from different customers. From the late 1990s, the foundry model became prevalent in the global semiconductor industry, with Taiwanese firms leading this trend.

³³⁰ Pecht, Michael, *The Chinese Electronics Industry: The Definitive Guide for Companies and Policy Makers* (Norwich, NY: William Andrew Publishing, 2006), page 114.

only way out. Choosing the Chinese [Taiwanese] management team was based mainly on its rich experience in operating overseas and on the foundry model. Looking back, reviewing the options...cooperation with the Chinese [Taiwanese] was correct.”³³¹

From Vertical Integration to Sectoral Businesses

Separating the foundry to be run jointly with CSMC provided a critical financial bailout for Huajing,³³² but it also foreshadowed Huajing’s continued restructuring by sector, that is, its pursuit of vertical disintegration.³³³ The key value-chain sectors in the semiconductor industry are:

Materials

V

Design > Fabrication (foundry) > Packaging/Assembly/Testing (P.A.T.)

^

Equipment

By 1999, Huajing had combined the P.A.T. work of its bipolar and MOS plants to form one P.A.T. business unit. Then, in 2000, Huajing established Wuxi Huajing Microelectronics to focus on discrete device manufacturing. By late 2000, the management team had also established individual groups to focus on design (Wuxi Huajing Guike Microelectronics) and

³³¹ “CRM: Internally and Externally to Challenge the New Target,” *China Electronics News*, July 18, 2007. The author of this article was not listed.

³³² By leasing the foundry to CSMC, Huajing was able to use the lease income to support its remaining operations.

³³³ Vertical disintegration is a business model in which separates companies undertake different parts of the production process.

other groups to focus on materials.³³⁴ In this way, Huajing further restructured to designate materials, design, foundry, and P.A.T. as separate spheres of work. Of course, the separation of R&D and production had been problematic under central planning, and for Huajing the lack of coordination between R&D and production was still a problem in the early 1990s when Huajing ostensibly was working with Institute 1424. However, by 2000, Huajing's business environment had changed in several ways such that there was less concern about gaps between R&D and production. Some examples: the foundry was fabricating *customers'* designs; Huajing's design institutes were aligned with its production lines (e.g., the "device design institute" and the "bipolar design institute" served their respective production lines); and the design institutes were actually part of Huajing rather than merely "affiliated with" Huajing, as had been the case with Institute 1424.

In the early 2000s, Huajing (by then called "China Resources") formalized its vertical dis-integration, establishing individual businesses by sector, including:

Design: Wuxi China Resources Semico Co., Ltd.

Foundry: CSMC Technologies; Wuxi China Resources Semiconductor Wafers & Chips

P.A.T.: Wuxi China Resources Micro-Assembly Technology, Ltd.

Discrete Devices: Wuxi China Resources Huajing Microelectronics Co., Ltd.

Note that China Resources retained the Huajing name in the business that was established to focus on discrete devices, which were the low-end devices for which the Huajing brand was renowned. Huajing's P.A.T. business, as well as the P.A.T. sector generally, is analyzed in Chapter Five. (P.A.T. is a lower-end but still technical sector.)

³³⁴ "Huajing Weidianzi Gufen Youxian Gongsi Shunli Touru Guifanhua Yunzuo 华晶微电子股份有限公司顺利投入规范化运作 (Huajin Microelectronics Co. Ltd. Smoothly Standardizes Operations)," *Weidianzi Jishu 微电子技术 (Microelectronic Technology)*, January, 2001. The author of this article is not shown.

From Central to Municipal Control, From Debt to Stock

By 2000, Huajing had made progress in terms of both revenue and organization, but it was still a centrally controlled state-owned enterprise (despite having one sub-company that was a joint venture with CSMC), and despite some debt relief, Huajing still had significant debt. Further ownership, financial, and managerial reforms were needed.

In 2000, the central government transferred Huajing from the (central) Ministry of Information Industry³³⁵ to the Wuxi municipal government. The city of Wuxi offered Huajing significant financial and policy support, including establishing a Microelectronics High Tech Park.³³⁶ To reduce Huajing's costs, the Wuxi government took responsibility for Huajing's schools, hospital and other community services. With these changes, Huajing came under the control of the Wuxi Asset Management Company (WAMC), which consisted of the Wuxi State Asset Committee and banks that had loaned money to Huajing. At that time, Huajing may have owed around RMB530 million to the National Adjustment Fund. With the transfer to Wuxi, Huajing's debt was converted to stock. The WAMC owned 59 percent of Huajing's stock, and the banks held the remaining 41 percent. The new Wuxi-controlled Huajing had a board of directors, management committee, and stockholders. The intention was that each of these groups would have clear roles and responsibilities, and Huajing would

³³⁵ In 1998, the Ministry of the Electronics Industry merged with the Ministry of Posts and Communications to become the new Ministry of Information Industries.

³³⁶ Gao Gaifang 高改芳, "Guojia Ziben Touru Xinpianye de Gean: Huajing Wuyan Jieju 国家资本投入芯片业的个案：华晶的无言结局 (The Nation's Capital in the Chip Industry: Huajing's Silent Ending)," Shanghai Baodao 上海报道 (Shanghai Report), May 23, 2003. The National Adjustment Fund (国家调节基金) had previously been part of the High-Tech Venture Capital Fund of the State Development Planning Commission (国家计委的高科技风险投资基金).

follow China's newly implemented corporate laws and regulations.³³⁷ The influence of government officials would be confined to their role on the board of directors, and they would not be involved in daily operations.³³⁸ That year, the enterprise was renamed "China Huajing Electronics Group Limited." By taking ownership of Huajing, the city of Wuxi sought to reinforce (or regain) its vital role in China's semiconductor industry. For Huajing, the new ownership and management structures meant increased management autonomy, but the debt and revenue problems continued.

Huajing's Organization in 2000³³⁹

Total Employees: 4,393, about one third with college degrees

Engineers and Technicians: 2,300, many with international training from
Toshiba, Siemens, etc.

Assets: RMB3 billion

Primary Products:

(1) transistors, semiconductors and related products

³³⁷ China enacted a new "Company Law" in July of 1994; this law established new forms of ownership as well as new corporate governance mechanisms. Historically, China's state owned enterprises were not companies in the Western sense. They were vehicles of the government, assets to be utilized to meet the central plan. These assets were owned by the state on behalf of the people. In the late 1980s and early 1990s, Chinese officials experimented with a number of reforms aimed at establishing some legal basis for corporate forms and at giving some responsibilities and independence to managers in the state owned enterprises. Prior to the 1994 law, China's state owned enterprises were not independent legal entities and they lacked property rights commonly attributed to "property" in the West, such as the right of ownership, the right to use, the right of returns on property, and the right to transfer property ("alienation.") The Company Law of 1994 established the legal basis of joint stock companies and limited liability companies (although, of course, not all state owned enterprises were immediately reformed into these new structures.) For limited liability companies and joint stock companies, the New Company Law established shareholder rights and duties as well as structures of corporate governance, i.e., the roles and duties of corporate boards and directors and the requirements for disclosure, transparency, and monitoring of company records.

³³⁸ Wang Jifu, "China Huajing Electronics Group Corporation," unpublished, circa 2000. During this era, many of China's state owned enterprises underwent structural and ownership reforms. In the semiconductor industry, however, Huajing's restructuring process was unique. China's other "key" semiconductor enterprises were established as Sino-foreign joint ventures and, after Huajing, China's two follow-on semiconductor "national champions" were structured anew (see Chapter Four.) Thus, the restructuring of Huajing was not a model that influenced the larger industry or that was copied in other semiconductor enterprises. The specifics of Huajing's ownership restructuring (details of which were not available in full for this study) seem not to be germane to the larger story of the industry's development. That said, Section 3.4 highlights "enterprise solutions" that *were* germane to the industry's development.

³³⁹ Ibid.

(2) bipolar analog I.C.s

(3) MOS I.C.s

Subsidiary Products:

Silicon materials and epitaxial wafers, precise molding dies, lead-frames for discrete devices and I.C.s, photo-masks, hyper pure water, N₂, H₂, O₂ and industry gases

Customers: approximately 2000 including: Konka, Changhong, HiSense, TCL, Amoisonic, Great Wall, Haier, Panda, Chunlan and overseas customers from Hong Kong, Taiwan, Japan, Singapore, India, Indonesia, and South America.

From Huajing (Wuxi) to China Resources (Hong Kong)

Huajing's ongoing financial problems eventually led to its acquisition by yet another state-owned enterprise. But the new owner -- despite being state-owned -- would bring new capital and opportunities to Huajing.

In 1999 and 2000, with growing debt and lack of investment capital, Huajing's managers realized that Huajing could not survive much less thrive in the fast changing semiconductor industry. Thus, in September of 1999, Huajing and the Wuxi Asset Management Company (WAMC) sought international partners (in addition to CSMC) in order to gain investment capital, but there were no takers. By 2001, Wuxi and Huajing officials believed that they could only save Huajing by finding "like minded investors" to inject new capital, and thus they decided to pursue resource-rich Huarun (华润), English name China Resources (CR), of Hong Kong. Huajing's rising executive Wang Guoping backed this strategy, just as he had backed the strategy of bringing in CSMC from Taiwan.³⁴⁰

³⁴⁰ "Zaibao Huajing: Wuxi Gongye San Da Chongzu Jiedu zhi Yi 再造华晶: 无锡工业三大重组解读之一 (Recycling Huajing: Three Interpretations of Wuxi's Industrial Reorganization)," *Wuxi Ribao 无锡日报* (*Wuxi Daily*), October 9, 2002. The author of this article is not listed.

China Resources was and is a large Chinese state-owned enterprise group,³⁴¹ and it is one of the largest companies in all of Hong Kong and China. (Revenues were HK\$110 billion and assets were HK\$240 billion in 2010.)³⁴² China Resources is a holding company that operates businesses across a spectrum of industries. In 2000, China Resources was aggressively expanding in mainland China, including in the electronics industry. Despite being state-owned, China Resources' experience base and management quality were perceived as being at an international level. Yet, the decision to cooperate with China Resources was fraught: many Huajing staff were uncertain about their own and Huajing's future under China Resources because China Resources was viewed as a foreign company. Nonetheless, in July of 2001, China Resources and Huajing signed an "agreement in principal" to restructure Huajing.³⁴³

After a longer than expected approval process and a complex, multi-step restructuring, China Resources' completed an acquisition of Huajing in September of 2002.³⁴⁴ The key steps were as follows:³⁴⁵

³⁴¹ See Chapter Four, Section 4.5 (4.4?), for an explanation of China's large enterprise groups.

³⁴² Huarun 华润, *Huarun 70 Nian! 华润70年 (Huarun at 70!)* (Hong Kong: Huarun, 2008). See a synopsis of China Resource's history at <http://www.crc.com.hk/aboutus/historry/>. China Resources was originally founded in 1938 in Hong Kong as an enterprise to raise funds for the CCP. From the early 1950s, it was China's import and export company in Hong Kong. In 1983, it restructured as China Resources Holdings Company, Ltd., expanding into many industries in Mainland China and listing on the Hong Kong exchange in 1992. Although located in Hong Kong, China Resource's management team is from Mainland China, and it is one of China's largest enterprise groups and a member of China's "national team," see Chapter Four, Section 4.42. The group has holdings in retail, textiles, medicine, and finance as well as land, power, cement, gas and electronics. China Resources had over 200,000 employees in 2010.

³⁴³ "Zaibao Huajing: Wuxi Gongye San Da Chongzu Jiedu zhi Yi 再造华晶: 无锡工业三大重组解读之一 (Recycling Huajing: Three Interpretations of Wuxi's Industrial Reorganization)," *Wuxi Ribao 无锡日报 (Wuxi Daily)*, October 9, 2002. The author of this article is not listed.

³⁴⁴ Ibid.

³⁴⁵ Publicly available China Resources company documents.n

- In 2000, China Resources founded China Resources Microelectronics (CRM) as a holding company.
- In 2001, China Resources' previously existing microelectronics company, called China Resources Logic Ltd., acquired CRM. Both continued to exist, but with CRM subordinate to China Resources Logic.
- In 2002, CRM acquired Huajing; Huajing was renamed Wuxi CRM Holding Company. CRM had not acquired CSMC-HJ, but CSMC-HJ continued to lease the foundry from Wuxi CRM.
- In 2004, CSMC-HJ listed on the Hong Kong exchange, and in 2006, China Resources Logic acquired CSMC through CRM.

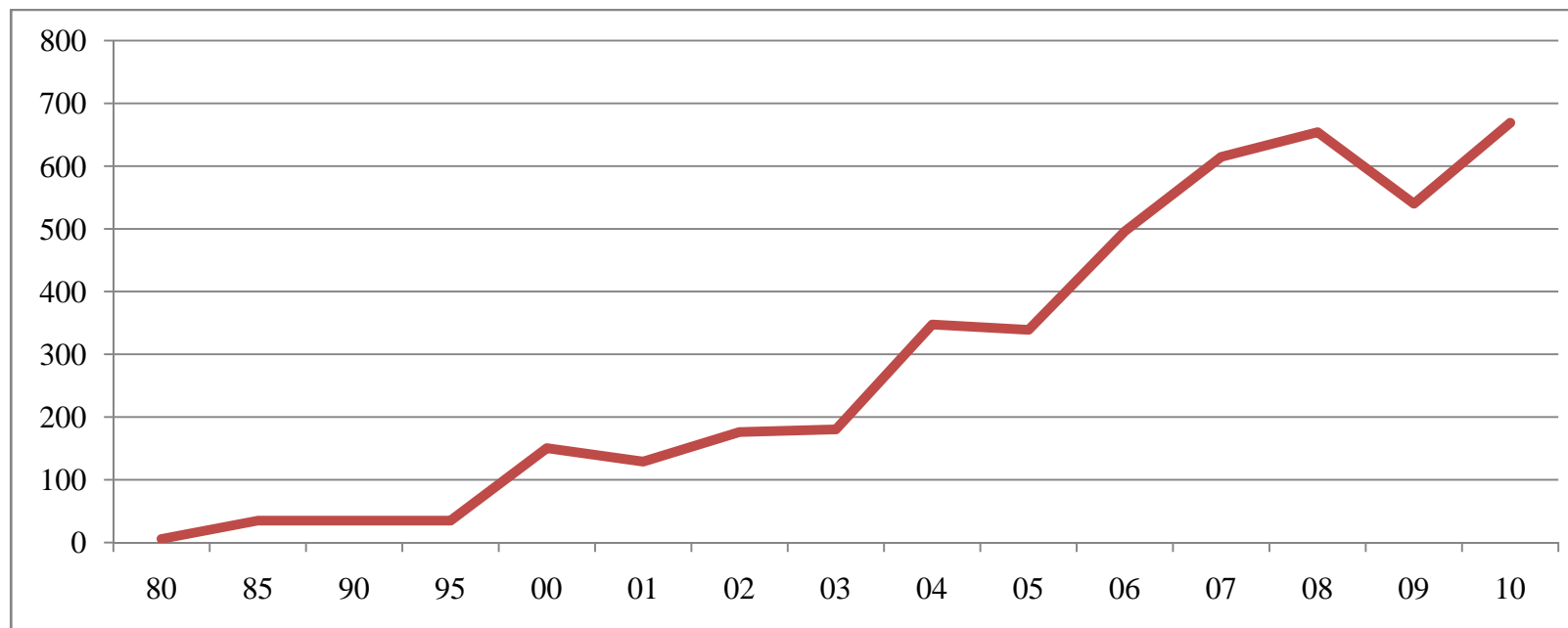
In the 2002 agreement under which China Resources acquired Huajing, Huajing's debt was restructured and reduced by RMB324 million to RMB569 million. China Resources had four years to repay the debt, until December of 2005. Wuxi CRM operates to this day as part of the China Resources enterprise group, and CRM has businesses in the various sectors of the semiconductor value chain, e.g., design, foundry, and P.A.T. CRM's revenues grew rapidly from 2002.³⁴⁶ Figure Five shows Huajing and CRM's revenue.

With China Resources' acquisition of Huajing, the state did not lose assets (assets were not privatized), the outstanding loans to WAMC were repaid, and the city of Wuxi benefited from Huajing's continued operations, which provided jobs and tax revenue. Nonetheless, in the eyes of some industry personnel, Huajing's sale to CR was a loss because CR was not a long-standing, mainland semiconductor enterprise. Huajing, a national champion, had not been able to achieve financial and technical success on its own.

³⁴⁶ China Resources planned to invest RMB 4 billion in Huajing in the three to five years after re-establishing Huajing as CRM.

Figure 5: Estimates of Huajing-affiliated Organizations' Revenues in US\$ millions

These estimates are based on ratios of revenues among Huajing-affiliated organizations. Since 2008, Huajing-affiliated organizations have combined financial statements under CRM, but previous years are estimated based on Huajing data from earlier years.



Sources include:

Zheng Shilong, Lu Zhixin and Tian Jingying 郑世隆, 陆志信 和田婧瑛, ““Huajing Jingshen”: Ji Guoying Jiangnan Wuxiandian Qicaichang

华晶精神: 记国营江南无线电器材厂 (The Spirit of Huajing: Jiangnan State-owned Radio Equipment Factory),” *Liaowang 瞭望 (Outlook)*, Period 22, 1986.

CRM (China Resources Microelectronics) annual reports.

PWC, "China's Impact on the Semiconductor Industry," 2010 and 2011, data sources China Semiconductor Industry Association, CCID, and PwC analysis.

3.5 Huajing, Project 908, and the Evolution of China's Domestic Semiconductor Industry

Project 908 did not materialize as planned on a number of fronts: the long wait from 1990 to 1995 for approvals and funding, the exodus of Institute 1424 in 1995, seeking help from Taiwanese managers in 1997, the restructuring from central to municipal ownership in 2000, the myriad internal reorganizations from 1997 through 2000, and finally the acquisition by Hong Kong-based China Resources. Project 908 did not result in China having an “advanced semiconductor enterprise” with Huajing standing as a beacon to other Chinese and foreign enterprises, despite real product advances by 2000.³⁴⁷ Nonetheless, Huajing’s rectification process resulted in many changes that previewed the relatively successful future of Huajing (a.k.a. CRM), and Huajing’s reforms also previewed the future of China’s domestic semiconductor industry, as the industry further reformed and globalized. More broadly, Huajing’s history demonstrates how a “national champion” high-tech, state-owned enterprise attempted to reform and advance from the late 1980s to the early 2000s, a critical period in China’s economic and industrial development.

Many of the enterprise solutions that Huajing undertook will resurface in the following chapters, as we look at the two major follow-on projects, Project 909 and SMIC (Chapter Four), and as we look at China’s further integration with the global semiconductor industry (Chapter Five.) We will see personnel from Huajing and other so-called old (i.e., state) enterprises managing seemingly “new” enterprises. As one example, a number of the executives from Taiwan and Hong Kong who were involved in the original planning of the

³⁴⁷ See “China’s Huajing to Supply Lucent with Telecom I.C. Chips,” *AsiaPulse News*, April 3, 2000. Lucent signed a contract to purchase telecom I.C. chips that were being produced on the equipment that Lucent transferred to Huajing. Between 1998 and 2000, Huajing had produced more than 70,000 (MOS technology) chips, of 229 types, with production yields of over 95 percent. Huajing had also “independently developed” over 35 additional types of (MOS technology) chips for various applications. (The author of this article was not shown.)

CSMC-Huajing went on to play major roles in some of China's other important semiconductor enterprises, such as SMIC, Grace Semiconductor, and others.³⁴⁸ Indeed, older industry personnel refer to Huajing as the Whampoa Military Academy of China's semiconductor industry not because of Huajing's historical military connections but because so many semiconductor industry talents were "trained" at Huajing.³⁴⁹

Also, just as Huajing brought in Taiwanese talent in 1997, as China further opens to the global semiconductor industry in the 2000s, Taiwan's influence will quickly be seen throughout the industry in China. This will especially be true at SMIC, but also in China's broader adoption of the [Taiwan originated] foundry model. In effect, Project 908's "failure" came to serve as the launching pad for both cross-strait semiconductor business relationships and for China's identity as a global site for foundry production. In Project 909 and SMIC, officials will apply lessons learned from Huajing and will enlist significant foreign partnerships from the start and take new approaches to funding, in terms of quantity, timing and sources.

Amid and after Project 908, Chinese officials retained the vision of developing one large, successful Chinese I.D.M., but most of the industry eventually followed the vertically disintegrated business model that Huajing adopted and that was indeed the new global model.³⁵⁰ And, China's adoption of the foundry model would foster human resource development and innovation in China, as new design houses and P.A.T. firms emerged to work with the foundries, as we will see in Chapter Five.

³⁴⁸ Zhu Yiwei 朱贻纬 of the China Semiconductor Industry Association, "Liang'an Jicheng Dianlu Chanye Jiaoliu Shinian Huigu 两岸集成电路产业交流十年回顾: 三, 华晶上华 (Ten Years of Cross-Strait Exchanges in the I.C. Industry: Part 3, CSMC)," available in the archives of www.CSIA.com accessed in 2009.

³⁴⁹ The Whampoa Military Academy was the famous military academy in early 20th century China (under the Guomindang) where many well-known military leaders were trained.

³⁵⁰ By the late 1990s, advances and standardization in E.D.A. (electronic design automation, which are software tools used to design semiconductors) and advances in inter-firm electronic communications enabled electronics firms to focus on their so-called core competencies. Non-core work could be more easily outsourced, and customer and supplier relationships could be managed electronically.

Chapter Four

State Led Development and Enterprise Led Development: China's National Champions and Their Global Partners

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In Chapter Three, we saw the origins and eventual outcomes of China's first major state sponsored semiconductor project, Project 908 at Huajing in Wuxi. Project 908, instigated in 1990, followed a cascade of new policies in the 1980s for China's electronics and semiconductor industries, covered in Chapter Two. Project 908 was – and is – often called a failure, and it is little referenced in Chinese or foreign sources,³⁵¹ although Chinese industry elders now seem to recognize Wuxi and Project 908 at Huajing as the “cradle” of China's domestic semiconductor industry. Despite Project 908's challenges and shortcomings, the enterprise solutions implemented at Huajing previewed key changes in China's domestic semiconductor industry from 1990 to 2000 and beyond, especially in the manufacturing sector. Key changes included: engaging foreign partnerships and management; improving state support for key projects; vertically dis-integrating enterprises by sector; adopting the foundry model;³⁵² and accepting investment from Taiwan. Importantly, because of the central government's prioritization of microelectronics, Project 908's obstacles and eventual solutions received high level official attention, and lessons from Project 908 were applied to

³⁵¹ iSupply, a leading global industry research organization, published a report in 2002 called “Semiconductor Wafer Manufacturing in China: A Panacea or a Global Investment Trap?” This report devoted just three sentences to Project 908 concluding with “Unfortunately, Project 908 was never as successful as initially hoped, primarily due to poor management,” page 4. In Michael Pecht's *China's Electronics Industry* (Amsterdam: Elsevier Science, 2006), Pecht's only reference to Project 908 is as follows: “In 1998, Huajing set up six inch lines with technology transferred from Lucent as part of National Project 908.”* The footnote ends with “Because of the bureaucracy and low level management of state owned enterprises, the project resulted in huge deficits and was regarded as a failure.”

³⁵² Until the 1990s, most major global semiconductor firms operated under the “integrated device manufacturer (I.D.M.)” business model. In an I.D.M., one vertically integrated company designs, fabricates (i.e., manufactures), and packages/assembles/tests (P.A.T.) its own semiconductors, using its own foundry for fabrication. This foundry model was first developed in Taiwan in 1987 at the Taiwan Semiconductor Manufacturing Corporation (TSMC). The foundry model is in contrast to the I.D.M. model. Under the foundry model, a stand-alone foundry leases its capacity to any number of customers. Customers design their semiconductors and then simply lease foundry capacity for fabrication. The foundry does not sell semiconductors into the market. That said, a company can have a foundry while also having other revenue streams.

other enterprises and influenced industry policy. From Project 908 we begin to see how Chinese officials learned from the experiences of individual enterprises, and in this way, we see both “state led development” and “enterprise led development” in the semiconductor industry, as will be analyzed more fully in Section 4.4 of this chapter.

This chapter looks at the major state supported³⁵³ semiconductor projects of the 1990s that followed Project 908. The research centers on three endeavors: 1) China’s establishment of five “key” enterprises (*wu da zhugan qiye* 五大主干企业), four of which were Sino-foreign joint ventures (Section 4.1), 2) Project 909, which largely consisted of establishing Huahong-NEC (华虹-NEC), a new Sino-Japanese joint venture (Section 4.2), and 3) the establishment of Semiconductor Manufacturing International Corporation (SMIC, *Zhongxin Guoji* 中心国际), which was a new wholly foreign owned enterprise, registered in the Cayman Islands but headquartered in Shanghai (Section 4.3). Project 908 provided funding for the five key enterprises, one of which was Huajing. Huajing was thus a key enterprise, but Huajing was also considered a “national champion” (*guojia guanjun* 国家冠军) while the other key enterprises were not. As we will see in this chapter, Project 909’s Huahong-NEC and SMIC were also considered national champions. The chronology was Project 908 (Huajing), followed by the establishment of China’s key enterprises, then Project 909 (Huahong-NEC), and finally SMIC. However, these were all long-term projects (construction alone took several years), and because each of the projects was instigated in the ten years

³⁵³ Here, the phrase “state supported” indicates that a project or enterprise was in some way supported by the state but was not necessarily state owned.

between 1990 and 2000, there was actually much overlap in timing and operations, although they were all separate projects with unique facilities.

This chapter reveals the origins, goals, and contributions of these projects and enterprises and ultimately considers how they add to our understanding of “state led development” and national champion enterprises in China’s contemporary economic history. Other scholars such as Chalmers Johnson, Alice Amsden, and Robert Wade have studied the extent to which state led development and industrial policies fostered rapid economic development in Japan, South Korea, and Taiwan, respectively, in the latter half of the 20th century. Their studies on these three nations are broad-based. They address state led development and industrial policies that were designed to influence enterprises and trade across many industries, but they also address the entire modern economic history of a nation as well as global economic history and economic theory. Similarly, many studies of China’s economy since reform and opening have also been broad-based, with a number of studies addressing China’s state owned sector across industries.³⁵⁴ These studies aim to show how China on the whole is developing or how China’s state owned sector is developing, including the legal and financial structures of state owned enterprises. Such studies have revealed fundamental, cross-industry trends and issues, e.g., China’s gradual, experimental approach to economic reforms, the ongoing role of state owned enterprises, the “soft” budgets of state owned enterprises, and others. Yet, these studies do not necessarily reveal how particular

³⁵⁴ Chen Derong, *Chinese Firms Between Hierarchy and Market* (Basingstoke: MacMillan Press, 1995); Edward Steinfeld, *Forging Reform in China* (Cambridge: Cambridge University Press, 1998); Peter Nolan, “Beyond Privatization: Institutional Innovation and Growth in China’s Large State Owned Enterprises,” *World Development*, Volume 27, Number 1, 1999; Dylan Sutherland, *China’s Large Enterprises and the Challenge of Late Industrialization* (London: Routledge, 2003).

industries in China have developed during the reform era.³⁵⁵ As important as the state owned sector is, industries in China have been influenced by more than just the state sector since reform and opening. Further, different types of industries (i.e., heavy industries, light industries, high technology industries) have likely developed in different ways.³⁵⁶ For example, the contemporary history of the semiconductor industry in China may suggest how other high technology industries (e.g., the life sciences or new energy) have developed, but it is likely less relevant to industries such as steel and textiles. Thus, this study does not take a cross-industry, broad-based approach. Instead, this research is concerned with how a particular industry developed in China, including state policies and projects and state owned enterprises, but also industry-specific requirements for technological catch-up, foreign partnering and investment in China, global knowledge sharing, and global trade.³⁵⁷

After considering China's key and national champion enterprises, this chapter introduces the notion that, in the 1990s, the semiconductor industry in China was both "state

³⁵⁵ The notable exception to this approach is Peter Nolan, *China and the Global Business Revolution* (London: Palgrave Press, 2001.) Nolan's concern is whether China's state owned "national team" is having success in China and globally, and he includes eight industry case studies. Ling Liu's *China's Industrial Policies and the Global Business Revolution: The Case of the Domestic Appliance Industry* (New York: Routledge, 2005) looks at the effectiveness of industrial policy in the appliance industry in China by considering how three state owned Chinese appliance companies evolved. Other studies do include cases on state ownership in particular industries, but the cases are usually presented to support broader claims about state ownership, and thus the cases are not necessarily meant to capture the multi-dimensional history of their industry. Steinfeld's *Forging Reform* presents China's steel industry as a "bellweather" (page 24) for state owned enterprise reform and property and ownership institutions. Steinfeld documents that lack of hard budgets for these enterprises, concluding that China's state owned enterprises were quite troubled (page 249). Also using case studies of state owned enterprises in the iron and steel industries are John Hassard, Sheehan, Zhou, Terpstra-Tong, and Morris, *China's State Enterprise Reform* (New York: Routledge, 2007).

³⁵⁶ In China, industries varied widely in terms of their level of development upon reform and opening, their requirements for physical and human capital, and their position in domestic and international trade. Further, within a particular industry, individual sectors may have developed differently. In the semiconductor industry, the manufacturing sector was directly affected by state projects in the 1990s, but the semiconductor P.A.T. sector was less affected. The P.A.T. sector is effectively a high technology industry in its own right.

³⁵⁷ Industry-specific and technology-specific developments figure prominently in economic and business history, i.e., the new technologies of coal, steam, and telegraph and related new industries including rail and telecom.

led” and “enterprise led.” That is, the state indeed defined and supported certain projects and enterprises (state led development), but the experiences of enterprises also influenced Chinese policy makers (enterprise led development.) Indeed, top central government officials were well aware of the obstacles that China’s key and national champion semiconductor enterprises faced. In the 1990s, officials and enterprise leaders more often resolved problems through one-off solutions rather than through top down policies designed to influence all enterprises or trade. Reforms to China’s centrally planned semiconductor industry were announced in 1986 and 1987 (Chapter Two), but it was only after 2000 that officials announced new, industry-wide policies for the semiconductor industry. Thus, in this particular high technology industry, for a period of about fifteen years, enterprise led development (bottom up input from enterprises) influenced the formation of new, industry-wide policies that Chinese officials did not put in place until after 2000 (see Section 4.4.)

A note on terms: In discussing the 1990s, it is appropriate to refer to “the semiconductor industry *in China*” rather than “*China’s* semiconductor industry.” In this decade, China’s major state supported semiconductor enterprises all had foreign partners. Also in the 1990s, foreign electronics and semiconductor-related firms began to establish operations in China. In this way, the industry in China transitioned from being “China’s” industry to being a site for the global industry.

In this chapter we will see that, in the 1990s, Chinese officials approached the establishment of each of the three national champions (Huajing, Huahong-NEC, and SMIC) differently, but one belief remained the same throughout each of the projects. Chinese officials believed that state support for a particular large-scale production enterprise would ultimately attract and foster the growth of non-state firms, both foreign and domestic. The

goal of these state supported projects was not to create a “national” semiconductor industry. The goal was to show that a high technology production enterprise could function in China, despite China’s less than ideal operating environment (discussed in Chapter Two, Section 2.43)³⁵⁸ and that such an enterprise would ultimately foster the establishment and growth of other enterprises – regardless of ownership – throughout the industry value chain.

As we will see, each of the national champions enjoyed official and financial support at the highest levels. Leading central government officials were directly involved in planning, management, and oversight. These included Premier Li Peng, President Jiang Zemin, Shanghai’s Mayor, the head of China’s Ministry of the Electronics Industry, and top electronics experts from the Chinese Academy of Science. The funds invested – ultimately well over US\$2 billion – were outsized; for example, the funding for Project 909 alone was equal to almost seven percent of China’s entire reported military budget for 1995.³⁵⁹

Why did Chinese leaders choose to invest in large-scale semiconductor fabrication facilities (that is, semiconductor production enterprises) to foster the semiconductor industry in China? This decision may seem counterintuitive, given the technological complexity and cost of these facilities, in addition to the cut-throat global competition in the industry. In fact, the Chinese government was simultaneously making related investments in education, design, and industrial clusters to support the semiconductor industry, as we will see in Chapter Five.

³⁵⁸ Section 2.43 deals with issues related to moving away from central planning, but foreign semiconductor-related firms also saw China’s operating environment as less than ideal in the 1990s. Problems included the lack of transparent rules for foreign investment, high and inconsistent tariffs on imported equipment, materials, and semiconductors, lack of protection for intellectual property, and rampant smuggling of electronics components in China, among others. See Section 4.43 for more detail.

³⁵⁹ China’s reported military budget in 1995 was US\$7.6 billion, according to GlobalSecurity, a US-based, non-governmental organization. However, the Stockholm International Peace Research Institute estimates that China’s total 1995 military-related expenditures may have been almost 3 times higher than the reported budget.

But there were reasons why officials initially prioritized investing in large-scale *production* enterprises. First, Chinese leaders were still in the process of partially dismantling and consolidating China's formerly centrally planned semiconductor industry, and they wanted to create just a few advanced enterprises. Second, the Chinese government invested in large production enterprises because of China's low technological level in production and because of the hope that better capabilities in production would lead to capturing a larger part of China's growing semiconductor market. In describing late industrializers, Alice Amsden noted "The shop floor tends to be the strategic focus of firms that compete on the basis of borrowed technology. ...It is there that borrowed technology is first made operational and later optimized. ...Incremental, yet cumulative, improvements in productivity and product specification are essential to enhance price and quality competitiveness."³⁶⁰ Indeed, in China too, semiconductor industry leaders planned to use borrowed technology to make improvements in manufacturing that would – eventually – advance the broader industry.

Officials did not create these key and national champion enterprises because they believed that state ownership (or state investment) was the most profitable form of ownership. In the Chinese industry sources available for this study, Chinese leaders make no argument for the financial or technical performance of state owned or state invested enterprises. Rather, they seem eager for the growth of non-state firms. Again, the hope in establishing these enterprises was that numerous non-state firms would emerge alongside the state supported enterprises, ultimately resulting in a vibrant, diverse industry chain. Thus, the aim of these enterprises was not first and foremost profit, nor import substitution, nor to preclude foreign competitors in China. Chinese leaders increasingly recognized the need for profits to sustain

³⁶⁰ Alice Amsden, *Asia's Next Giant* (Oxford: Oxford University Press, 1989), page 5.

semiconductor operations, yet in the available sources, there was no mention of the enterprises being bound to specific business plans, timelines, or financial models, even though most of the government's investment came in the form of loans that had to be repaid.³⁶¹

The final and perhaps most important reason why the Chinese government invested in large production enterprises related to capital. In the 1990s, the technology of the global semiconductor industry had advanced to the point that, according to a Rand analysis, only companies with more than approximately US\$5 billion in annual revenues likely had the capital to build competitive semiconductor fabrication facilities.³⁶² As no Chinese firm had this level of capital and China lacked capital markets, the only way for a relatively advanced semiconductor production enterprise to emerge was through government support.

As we will see in Sections 4.2 and 4.3, Huahong-NEC and SMIC's outcomes were mixed. Project 909's Huahong had trouble attracting a foreign partner and resorted to guaranteeing potential partners a protected segment of China's market. SMIC faced a number of intellectual property-related lawsuits. Both Huahong-NEC and SMIC were viewed by industry personnel as not well managed, due in part to their ties to the state. These problems and critiques confirmed perceptions that business practices in China were problematic and institutions were weak, yet we will see that these enterprises did manage to enlist numerous foreign partnerships.

³⁶¹ There could have been timelines for profitability and loan repayment, but these were not mentioned in the sources used, despite frequent mention of other financial matters, i.e., revenue results and investments. The goals mentioned were almost always technological, not financial. Of course, the inability of Chinese state owned enterprises to pay back loans is a well-documented problem, see for example, Steinfeld, *Forging Reform*.

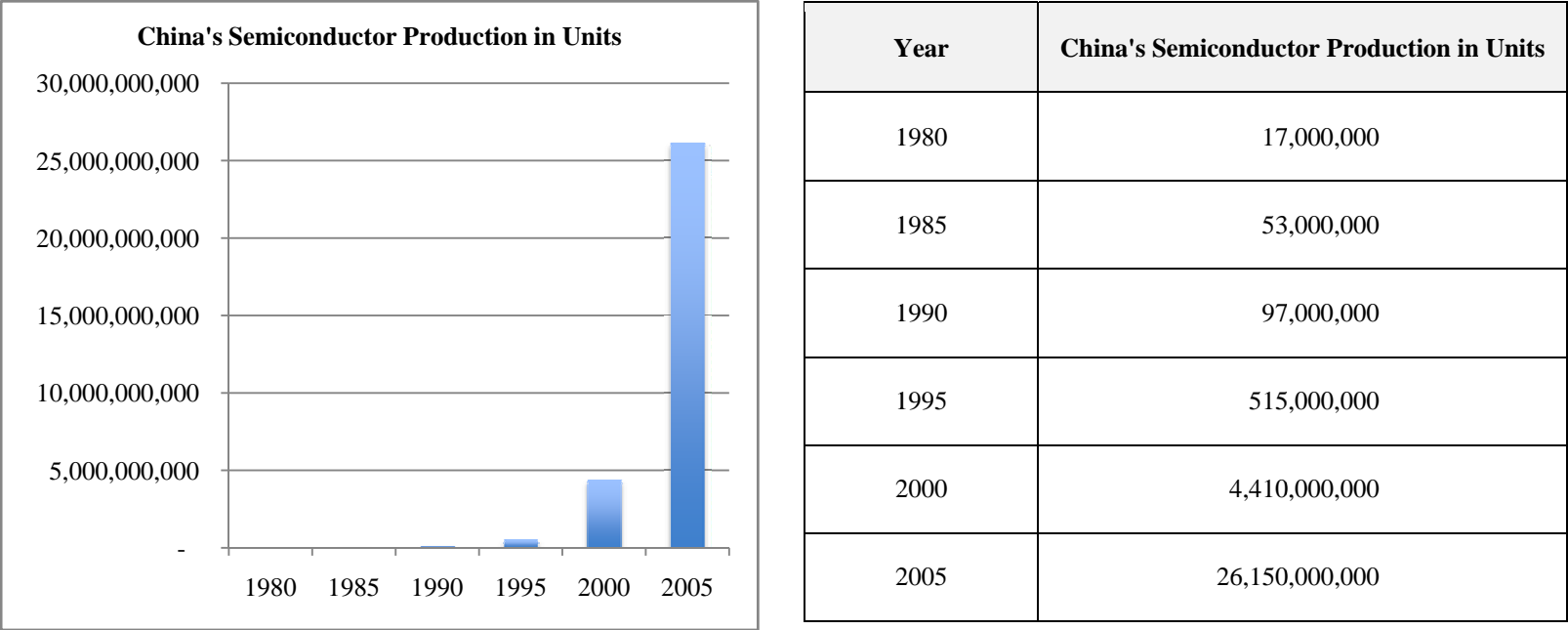
³⁶² Rand National Defense Research Institute (M. Chase, K. Pollpeter, J. Mulvenon), "Shanghai-ed?: The Economic and Political implications of the Flow of IT and Investment Across the Taiwan Straits," July of 2004.

Despite their serious problems, these enterprises bridged the era of the centrally planned semiconductor industry of the 1980s with the post-2000 globally linked era. What were the ultimate contributions of Huahong-NEC, SMIC, and China's key enterprises? These enterprises resulted in significantly increased semiconductor production in China (see Figure Six) and Chinese firms (or Sino-foreign joint ventures) remained among the largest semiconductor firms operating in China in the 2000s, despite the arrival of foreign semiconductor firms (see Figure Seven.) These enterprises also employed thousands of Chinese staff, exposing them to more advanced technology as well as to foreign partners and customers, and thus these enterprises made significant contributions to China's talent pool. Finally, the experiences of these enterprises and the obstacles they faced prompted policy changes and changes in enterprise organization and management that benefited the entire industry. Officials announced new policies in 2000 for investment, tax, trade, financing, and intellectual property protection. These policies supported the key and national champion enterprises, but they also applied to the larger semiconductor industry in China, including non-state and foreign firms.

4.1 China's Five "Key" Semiconductor Enterprises

As Project 908 was being planned and implemented in the late 1980s and early 1990s, Chinese officials were still following through on plans to divest, consolidate, and strengthen China's remaining state owned semiconductor enterprises. In the 1980s, China state owned semiconductor industry had had some 340 semiconductor-related enterprises, with most

Figure 6: Semiconductor Production in China



This chart is compiled from the following sources:

1) Zhu Yiwei 朱贻伟, *Zhongguo Jichengdianlu Chanye Fazhan Lunshu Wenji 中国集成电路产业发展: (China's IC Industry Development: Collected Works)*, Beijing: Xinshidai 新时代出版社 (New Times Press), 2006, pages 127, 163 and 164.

2) Ling Chen and Lan Xue, "Global Production Networks," *China and the World Economy* (published by Chinese Academy of Social Sciences), Volume 18, Number 6, 2010, page 114. Chart footnotes: a) Chen and Xue, "Global Production Networks," this amount refers to investment in the five key enterprises (including Huajing) from 1985-1995.

Figure 7: Largest 15 Semiconductor Firms in China in 2003 by Revenue

Chinese enterprises in *italics*.

Note: These are the firms with highest revenues *operating* in China.

These are not the same as the largest semiconductor *suppliers* to the Chinese market because most of the semiconductors that meet China's market demand are imported.

Analysis:

Of the top 15 firms' revenue in 2003, "Chinese" firms constituted 47 percent.

The "Chinese" firms were a mix of ownership forms.

Rank	Headquarters	Name	Revenue in 2003 (US\$ million)	2003 Notes on "Chinese" Firms
1	US	Motorola	962	
2	<i>China/Cayman Islands/International</i>	SMIC	350	SMIC is a WFOE registered in the Cayman Islands.
3	Japan	Renesas	195	
4	<i>China/Japan</i>	Huahong-NEC	188	Huahong-NEC of Project 909 is a Sino-Foreign JV.
5	<i>China/US</i>	Leshan	149	LeShan has a JV with Motorola and provides mainly discrete devices.
6	Switzerland	Shenzhen Sai STMicroelectronics	125	
7	US	Intel	109	
8	<i>China</i>	Jianxin XinChao	108	XinChao is a state owned group.
9	<i>China/Netherlands</i>	ASMC	94	ASMC has a JV with Netherlands-based Philips and serves mainly as a foundry for Philips.
10	<i>China/Japan</i>	Nantong-Fujitsu	92	Nantong-Fujitsu is a Sino-foreign JV.
11	<i>China</i>	JCET	84	JCET is large state owned P.A.T. enterprise near Wuxi.
12	<i>China/Hong Kong</i>	China Resources Microelectronics/CSMC	77	CRM is a member of the CR enterprise group; it includes Huajing and CSMC of Project 908.
13	<i>China</i>	Datang	75	Datang is a state owned enterprise group in electronics-related industries.
14	Singapore	ChipPAC	73	
15	<i>China/Japan</i>	Shougang-NEC	68	Shougang-NEC is a Sino-foreign JV; Chinese partner is Beijing Shougang, a steel enterprise group.

Source: PWC, "China's Impact on the Semiconductor Industry, 2004," data sources include CSIA, CCID, and PwC analysis.

"Chinese" revenue:	1,285	47%
Other revenue:	1,464	53%
Total revenue:	2,749	100%

making discrete devices while only about twenty enterprises could actually produce integrated circuits.³⁶³ Recall from Chapter Two that as early as 1982, the State Council Leading Group for the Revitalization of the Electronics Industry was setting strategies to reform the semiconductor industry, including a policy called “Control Fragmentation and Control Chaos” (*zhi san, zhi luan* 治散, 治乱). This strategy referred to the fact that the state industry had too many organizations that were not effectively cooperating. This strategy was discussed in the 1980s while industry leaders were dispersing more advanced, imported semiconductor equipment to thirty-three semiconductor sites, with few results.

In the mid to late 1980s, the Leading Group for the Revitalization of the Electronics Industry decided to technologically upgrade just a handful of semiconductor enterprises while investing in two Bases and one “Point,” the city of Xian.³⁶⁴ Indeed, in 1989, the leading group held a conference in Wuxi (see Chapter Two) resulting in a specific strategy for the semiconductor industry for 1989 through 1995. The strategy included allocating RMB5 billion (about US\$600 million) to the two Bases as well as to Project 908 and the five “key” semiconductor enterprises.³⁶⁵ The goal was for the five key enterprises to meet more than 60 percent of China’s domestic sales volume by 1995.

³⁶³ Zhu Yiwei 朱贻伟, *Zhongguo Jichengdianlu Chanye Fazhan Lunshu Wenji* 中国集成电路产业发展: 论述文集 (*China’s Integrated Circuit Industry Development: Collected Works*), Xinshidai Chubanshe 新时代出版社 (New Times Press), 2006, pages 127-128. Discrete devices are the components that go into semiconductors, e.g., resistors, capacitors, transistors, etc., while integrated circuits are actual semiconductors.

³⁶⁴ The North Base included Beijing, Tianjin and Shenyang, and the South Base included Jiangsu, Shanghai, and Zhejiang. Certain high technology industry parks were associated with the two bases. The North Base had two parks in Beijing: 1) the North Microelectronic Technology Research and Development Base and 2) the North Microelectronic Production Base. The South Base was initially defined as Wuxi and but eventually Shanghai also had the Caohejing technology park and the Zhangjiang technology parks among other parks in the Shanghai-Suzhou-Wuxi corridor, see iSupply, “Panacea,” 2002, page 21.

³⁶⁵ The 1989 Wuxi conference also determined that China’s semiconductor industry needed to achieve scale production, enhance R&D, and develop special purpose semiconductors. Yu Zhongyu (President of China’s

China's five key enterprises were established between 1988 and 1991, but these oft-quoted dates are misleading because most of the five enterprises did not begin production until several (or more) years later, as facilities had to be built, equipment procured, etc. These enterprises were essentially consolidations of some of China's existing semiconductor factories and institutes, mainly those that had relatively higher levels of technology and production.³⁶⁶ Figure Four identifies the five key enterprises, their partners, capabilities, etc.³⁶⁷

Importantly, Chinese officials were able to find foreign partners and establish a joint venture for each of the key enterprises except Huayue.³⁶⁸ At Huajing, the CSMC-Huajing joint venture formed in 1997-1998 was just one unit of the larger enterprise; recall, CSMC-Huajing only covered Huajing's five and six inch CMOS lines, while the larger Huajing remained in place. Notably, however, for the other three joint ventures (each formed well before CSMC-Huajing), the joint venture was the primary semiconductor enterprise. The joint venture was not just a sub unit of a larger state owned semiconductor enterprise. Of the three, the one variation on this structure was Shougang-NEC which was part of the larger

Semiconductor Industry Association), "China's I.C. Industry, the Status Quo and Future," a presentation delivered at Stanford University, 2005. Hu Qili 胡启立, *Chao Dagui Mo Jichengdianlu Gongcheng Jishi 超大规模集成电路工程纪实* (Ultra Large Scale Integrated Circuit: Project Records), Beijing: Dianzi Gongye Chubanshe 电子工业出版社 (Electronics Industry Publishing House), 2006, pages 14-16.

³⁶⁶ Zhu, Wenji, page 162.

³⁶⁷ Interview with Zhou Weiping, July 15, 2009, at ASMC headquarters in Shanghai. Zhou is C.E.O. of ASMC and a former General Manager of Shanghai Belling. Also, Chen Ling, "Chanye Xingcheng Jieduan 产业形成阶段 (The Industry's Formative Stage)," Qinghua University paper, circa 2005. Chen notes that RMB2.5 billion was spent by 1995, citing the *China Electronics Industry Yearbook*, 1996, page 125.

³⁶⁸ Huayue apparently sought but did not find a foreign partner. Huayue exists to this day, but it considered a lower technology semiconductor enterprise.

Figure 4: China's Five Key Semiconductor Enterprises

Five Key Enterprises	Founded	Prior Enterprises Joining	Initial Joint Venture Foreign Partner	Location	Estimates of Initial Investment circa 1990*	Production in 1995	Staff in 2000*	Products and Market*
Huajing/CSMC (Project 908)	1989	#742 Factory (Wuxi) and Institute 24 (Sichuan)	CSMC of Hong Kong, with Taiwan Mgmt	Jiangsu, Wuxi		2, 3, 5 micron 4 inch line: 140,000 units/yr 5 inch line: 130,000 units/yr	1600 tech staff plus other employees	discrete devices, bipolar and CMOS ICs, primarily for TVs and audio equip, per IEEE 1995
Huayue	1988	#871 Factory (Gansu and Shaoxing branch)	[Lacked a foreign partner as of 1995]	Zhejiang, Shaoxing		3, 5 micron 3 inch line: 120,000 units/yr 4 inch line: 60,000 units/yr		a candidate for Project 908 in 1990; analog devices and bipolar ICs for TVs and phones
Shanghai Belling (China's first Sino-foreign microelectronics joint venture)	1988	#14 Factory (Shanghai) and Shanghai Electronics and Operation Instruments Holding Company	Shanghai Bell Telephone Equipment Mfg Co, which was a joint venture with Alcatel Bell of Belgium	Shanghai	US\$82.4 m	2.4, 5 micron 4 inch line: 120,000 units/yr	500+ employees, of which 200 are tech staff	ICs for Shanghai Bell Telephone, the first switch-maker to use locally made circuits, per IEEE 1995
ASMC (Advanced Semiconductor Manufacturing Corporation); Chinese name Shanghai Xianjin, formerly known as Shanghai-Philips.	1988	#5 and #7 and #19 Factories (Shanghai)	Philips of the Netherlands (Also Nortel of Canada from approx 1995-2000)	Shanghai		3 micron 5 inch line: 120,000 units/yr	450+ employees	began as a foundry; Philips transferred older tech and producing for export
Shougang-NEC	1991	Beijing Shougang Gongtie (Capital Steel)	NEC (Nippon Electric Company) of Japan	Beijing	US\$240 m	1.2, 1.5 micron 6 inch line: 36,000 units/yr	800+ employees	color TVs, air conditioners, VCDs, IC cards, clocks, palm PCs

This chart is compiled from the following sources:

1) Interview with Zhou Weiping, July 15, 2009, at ASMC headquarters in Shanghai. Zhou is C.E.O. of ASMC and a former General Manager of Shanghai Belling.

2) Zhu Yiwei 朱贻伟, *Zhongguo Jichengdianlu Chanye Fazhan Lunshu Wenji 中国集成电路产业发展: (China's IC Industry Development: Collected Works)*, Beijing: Xinshidai 新时代出版社 (New Times Press), 2006, pages 162 and 164.

3) Wang Yangyuan and Wang Yongwen 王阳元 and 王永文, *Wo Guo Jichengdianlu Chanye Fazhan Zhilu: cong Xiaofei Daguo Zouxian Chanye Qiangguo 我国集成电路产业发展之路: 从消费大国走向产业强国 (China's Integrated Circuit Industry Development Path: From a Big, Consuming Nation to a Strong, Industrial Nation)*, Kexue Chubanshe 科学出版社 (Science Press), 2008, page 294.

4) iSupply, "Semiconductor Wafer Manufacturing in China: A Panacea or a Global Investment Trap?," Q3, 2002, page 11.

5) Michael Pecht, Weifeng Liu and David Hodges, "Chapter Two: Electronics Manufacturing Update," Office of Naval Research and U.S. Department of Commerce, 2000-2001.

Shougang state owned enterprise, but Shougang was a steel enterprise, so Shougang-NEC was the primary semiconductor enterprise.

Each of the key enterprises relied to a significant extent on its foreign partner for technology, capital, and access markets, and once operational, each had significant scale and focused on higher-quality production. The decision to partner with foreign firms aligned with strategies that had been articulated as early as 1985 and 1986, recapped below from Chapter Two. The *italics* added below highlight alignment between the strategic guidelines of 1985 and the formation of the key enterprises.

1985 Strategic Guidelines:³⁶⁹

7. Increase electronic applications including, for example, Chinese character programs and microcomputers.
8. *Use foreign technology to advance China's technology, including engaging in joint ventures with foreign firms.*
9. Create an integrated electronics supply chain – equipment to final products – *with emphasis on quality mass production and large-scale integrated circuits.*
10. Allow markets and competition to play a greater role in the industry while *relying on unified, national-level plans for projects that required very large investments.*
11. Coordinate the development of the electronics, communications and telecommunications industries.
12. Design a system to allocate central funding through competitive bids (versus grants) and *leverage foreign capital.*

The key enterprises also benefitted from the following State Council preferential policies for the semiconductor Industry, adopted in 1986:³⁷⁰

1. The government will extract less capital from enterprises.

³⁶⁹ In 1985, the leading group published a document called “The Strategy for the Development of China’s Electronics and Information Industries” which had strategies for 1986 and forward. Denis Simon summarized the 1985 document, see Denis Simon and Detlef Rehn, *Technological Innovation in China* (Cambridge: Ballinger Publishing, 1988), pages 63-64.

³⁷⁰ Industry-wide tax reforms in the early 1990s overrode and essentially de-activated these semiconductor-friendly tax policies, see Chapter Two.

2. Imported equipment will be exempt from tariffs for major, approved projects.
3. Enterprises will be exempt from value-added tax.
4. Enterprises will pay only half of their income tax.

With the establishment of these new enterprises, China's semiconductor leaders had furthered structural reform and consolidation of the formerly centrally planned industry. Nonetheless, the five key enterprises did not entirely replace nor consolidate the state owned industry. In the 1990s, China still had perhaps over thirty integrated circuit manufacturers and perhaps dozens more semiconductor-related factories for discrete devices. However, most of the over thirty so-called integrated circuit manufacturers were not designing nor producing (fabricating) integrated circuits but rather were only doing P.A.T. The key enterprises, in contrast, were doing fabrication, as well as some design, although the technology that the foreign partners provided for fabrication was not leading edge.

These five key enterprises (including Project 908's Huajing) essentially represent the foundation of China's contemporary domestic semiconductor industry.³⁷¹ These enterprises – with four of the five being Sino-foreign joint ventures – arguably fostered the industry chain in the 1990s in terms of technology, equipment, quality, management, and sales, largely by working with their foreign partners.³⁷² Along with these five key production enterprises, by the mid 1990s, China had ten or more semiconductor-oriented special equipment companies and more than twenty semiconductor design houses. Several key enterprises served export markets via their foreign partners, and by the 1990s, due to overall reforms of China's

³⁷¹ Wang Yangyuan and Wang Yongwen 王阳元 和 王永文, *Wo Guo Jichengdianlu Chanye Fazhan Zhilu: cong Xiaofei Daguo Zouxian Chanye Qiangguo 我国集成电路产业发展之路：从消费大国走向产业强国* (China's Integrated Circuit Industry Development Path: From a Big, Consuming Nation to a Strong, Industrial Nation), Kexue Chubanshe 科学出版社 (Science Press), 2008, page 294.

³⁷² Zhu, Wenji, page 127-128; also Hu, *Gongcheng Jishi*, pages 14-16.

planned economy, they could also sell to “non-affiliated” enterprises within China.³⁷³ The enterprises benefited from foreign capital through their partners, and Shanghai Belling was the first of these enterprises to be publicly listed, joining the Shanghai Exchange in October of 1998.³⁷⁴ By 1995, industry leaders claimed that the five key enterprises indeed constituted perhaps 60 to 80 percent of all sales of integrated circuits (that is, actual semiconductors rather than merely discreet devices) by Chinese domestic enterprises, as planned,³⁷⁵ representing significant industry consolidation.

Despite these advances, China’s domestic industry was still not producing in large volumes, it was not technologically “caught up” with the global industry, most profits were found in the Sino-foreign joint ventures, and China still did not yet have a full semiconductor industry value chain. Hu Qili, the leader of Project 909, explained that by 1995 there were “certain achievements, but we could not say we had already obtained success.”³⁷⁶ The formation of the joint ventures was a necessary step forward, but it was not sufficient for real technological advance in China’s semiconductor industry.

4.2 Project 909 and National Champion Huahong-NEC

In 1995, China was still nearly twenty years behind the global technology level in semiconductor production with most production lines in China using five inch or less

³⁷³ Denis Simon, “The Microelectronics Industry Crosses a Critical Threshold,” *The China Business Review*, 2001, page 6

³⁷⁴ Ibid., page 4

³⁷⁵ Zhu, *Wenji*, page 163, estimates sixty percent or more. Hu, *Gongcheng Jishi*, page 15, estimates 80 percent or more. Chen Ling and Lan Xue, “Global Production Networks,” *China and the World Economy*, Volume 18, Number 6, 2010, page 114, estimates sixty percent.

³⁷⁶ Hu, *Gongcheng Jishi*, page 116.

technology. Investment in the industry to that time had been only RMB5 billion, see Figure Two.³⁷⁷ Despite the reforms and restructuring of the state-owned industry, research and development were still largely separate from production and not sufficiently funded, and thus Chinese semiconductor production personnel had little opportunity to learn and utilize new technologies. Most of China's semiconductor-related products were still discrete devices rather than actual integrated circuits, and even with the key enterprises ramping up, production in China only met a small fraction of the rapidly growing market for semiconductors in China, see Figure Eight.³⁷⁸

By mid 1995, China's semiconductor industry leaders realized that their premier project, Project 908, was not going to result in China being home to an advanced semiconductor enterprise. Project 908 had been intended as a five-year project from 1991 to 1995, but in 1995, the project was still underfunded due to bureaucratic delays, and the planned technology transfers and production outcomes had not been realized. Worse, by 1995, industry leaders realized that, due to the rapidity of technological advance in the semiconductor industry, the production technology that Project 908 was planning to implement (six inch, 0.9 μ m) was no longer the global standard. Indeed, by 1995, Taiwan alone already had some ten production lines that were using *eight* inch production equipment.³⁷⁹ Even if Project 908 was completed, with six inch and 0.9 μ m production technology it would fall short of its goal of being a world-class semiconductor enterprise.

³⁷⁷ Zhu, *Wenji*, page 163-164.

³⁷⁸ Ibid., page 128-129

³⁷⁹ Hu, *Gongcheng Jishi*, page 11.

Figure 2: Gap Between China and Global Leading Technology (year attained)

	Wafer Size in Inches (larger is more advanced)	
Year	Global	China
1970	2	1.5
1975	4	1.5
1980	5	2
1985	6	3-4
1990	6-8	3-4
1995	8	6
2000	12	6-8
2005	12	12
2010	12-18	12

< Shougang-NEC

< Huahong-NEC and CSMC-Huajing

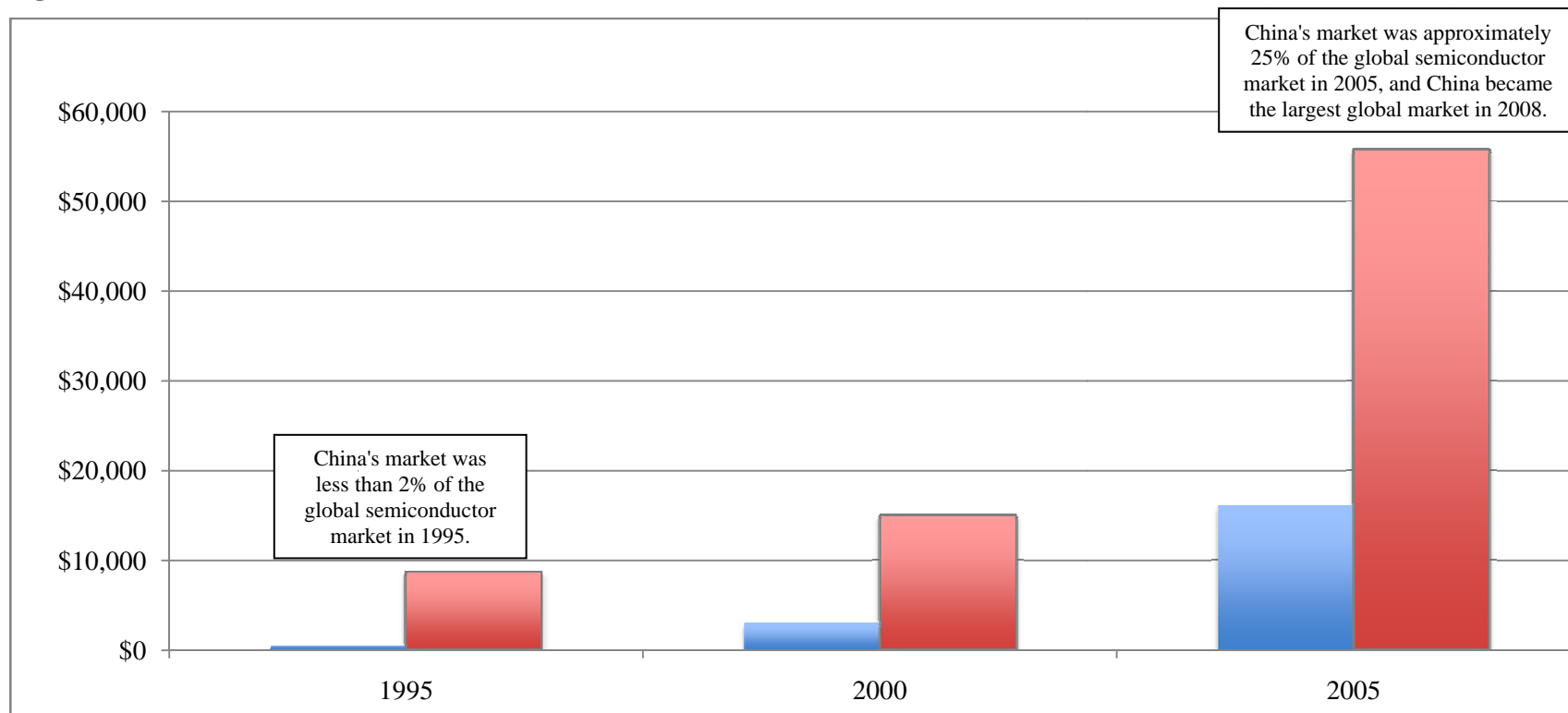
< SMIC

	Small Scale Integration	Medium Scale Integration	Large Scale Integration	Very Large Scale Integration	Ultra Large Scale Integration
Global	1958	1964	1966	1976	1986
China*	1965	1972	1972	1986	1999

The years indicated for China seem optimistic. They may reflect technological understanding more than actual production capabilities.

Source: Zhu Yiwei 朱贻伟, *Zhongguo Jichengdianlu Chanye Fazhan Lunshu Wenji 中国集成电路产业发展: (China's IC Industry Development: Collected Works)*, Beijing: Xinshidai 新时代出版社 (New Times Press), 2006, page 69.

Figure 8: China's Estimated Semiconductor Production (blue) and Market (red), in US\$ millions



This graph is constructed from the following sources:

1) PWC, "China's Impact on the Semiconductor Industry, 2004, 2006, and 2012," data sources include China Semiconductor Industry Association, CCID, and PwC analysis.

2) Wang Yangyuan and Wang Yongwen 王阳元 and 王永文, *Wo Guo Jichengdianlu Chanye Fazhan Zhilu: cong Xiaofei Daguo Zouxian Chanye Qiangguo* 我国集成电路产业发展之路：从消费大国走向产业强国 (China's Integrated Circuit Industry Development Path: From a Big, Consuming Nation to a Strong, Industrial Nation), Kexue Chubanshe 科学出版社 (Science Press), 2008, page 123, per CSIA.

Note: The PWC analyses uses data from CSIA and CCID, both associated with China's Ministry of the Information Industries.

The data includes all enterprises operating in China, including foreign enterprises, not just Chinese owned or state owned enterprises.

Bureaucratic obstacles were common across industries at that time in China, but for the semiconductor industry, such delays were particularly problematic because of the fast pace and high cost of technological upgrading.

Despite the discouraging state of Project 908, China's central leaders remained fully committed to somehow supporting the development China's semiconductor industry, designating it a "pillar industry" in China's ninth five year plan (1996-2000). Recall from Chapter Two that Li Peng, China's Premier from 1988 to 1998, had led China's State Council Leading Group for the Revitalization of the Electronics Industry from 1982. With his leadership and support, national officials held work conferences in both January and April of 1995 for the electronics industry. Hu Qili, the leader of China's Ministry of the Electronics Industry and the future leader of Project 909, was present at these conferences. In Hu's compilation on Project 909 called *Ultra Large Scale Integrated Circuit: Project Records*,³⁸⁰ he included notes on the top leaders' comments on China's semiconductor industry. According to Hu, during planning sessions for China's ninth five year plan (1996-2000) in December of 1995, Premier Li Peng and President Jiang Zemin voiced strong commitment for the semiconductor industry, with Premier Li Peng saying "Spare no cost! (*Bu xi dai jie*, 不惜代价)." President Jiang Zemin, who had recently visited semiconductor giant Samsung in South Korea, said that China must accelerate the development of its semiconductor industry, saying "Smash the pot, sell the iron (*Za guo mai tie*, 砸锅卖铁)!", that is, do whatever is necessary and be willing to sacrifice everything. President Jiang said China's semiconductor

³⁸⁰ Hu Qili 胡启立, *Chao Dagui mo Jichengdianlu Gongcheng Jishi 超大规模集成电路: 工程纪实* (*Ultra Large Scale Integrated Circuit: Project Records*), Beijing: Dianzi Gongye Chubanshe 电子工业出版社 (Electronics Industry Publishing House), 2006.

industry must be lifted, and he repeatedly stressed the importance and urgency of the industry's development.³⁸¹ Officials knew that China's economic reforms were creating tremendous annual growth in the demand for semiconductors. Demand was driven by the need for semiconductors in electronic consumer goods, computers, and new electronic information systems that Chinese organizations were increasingly implementing. From the experiences of Japan, South Korea, and Taiwan, China's top central government officials recognized semiconductors as critical to commerce, industry, living standards, national security, and as a general measure of China's technological and business competency.³⁸² Project 908 may have been faltering due largely to bureaucratic obstacles, but Li Peng, Jiang Zemin, and other leaders remained open to new approaches, new plans, and better prioritization (both political and financial) for the semiconductor industry.

4.21 The Origins of Project 909

In November of 1995, top officials from China's Ministry of the Electronics Industry and the State Council held a rapid series of meetings on the semiconductor industry, with the primary outcome being an immediate release of RMB4 billion (approximately US\$500 million) to support China's largest ever electronics project. The project would be called Project 909, and it would primarily establish a new national champion semiconductor enterprise with 8 inch, 0.5 μ m technology as well as funding other investments in the

³⁸¹ Hu, *Gongcheng Jishi*, page 4. Hu described Jiang's comments: "We must more quickly develop our country's semiconductor industry, we definitely must 'smash the pot and sell the iron' to make the semiconductor industry rise up." (*Bixu jia kuai fazhan wo guo jichengdianlu chanye, jiushi, 'Za guo mai tie,' ye yao bandaoti chanye ti shang qu!* 必须加快发展我国集成电路产业, 就是, '砸锅卖铁', 也要把半导体产业搞上去!")

³⁸² Hu, *Wenji*, pages 7-8.

semiconductor industry chain. Project 909's enterprises would be grouped under the new Shanghai Huahong Group, and they would eventually include: national champion Shanghai Huahong-NEC (discussed below) as well as Beijing Huahong I.C. Design Company, Shanghai Huahong I.C. Design Company, Shanghai Huahong International (U.S.-based), Shanghai Hongri International Company (a sales company), and the Shanghai Huahong Jitong Smart Card System Company.

The RMB4 billion allocated for these organizations was a significant investment. For comparison, RMB4 billion was equal to about 6.6 percent of China's entire reported military budget for 1995.³⁸³ Early in these meetings, Hu Qili and Liu Jianfeng, both of the Ministry of the Electronics Industry, had shared with Premier Li Peng the problems plaguing Project 908, namely the slow approvals and resultant lack of funds, and therefore the technology that Project 908 was pursuing was already behind the global standard. According to Hu, Li Peng bluntly asked "How much money do you need?" Hu indicated at least US\$1 billion, as this was the global norm for an eight inch line. Li Peng responded that he would put a block of U.S. currency directly from his Premier's Fund into the Ministry of the Electronics Industry's account, although this money would ultimately have to be repaid. With this transfer, the Ministry of the Electronics Industry would essentially have a "current passbook account" (*huoqi cunzhe*, 活期存折) from which to draw funds for Project 909, and they would not need approvals from different government offices to access funds.³⁸⁴

³⁸³ China's reported military budget in 1995 was US\$7.6 billion, according to GlobalSecurity, a US-based, non-governmental organization. However, the Stockholm International Peace Research Institute estimates that China's total 1995 military-related expenditures may have been almost 3 times higher than the reported budget.

³⁸⁴ Hu, *Gongcheng Jishi*, pages 3-7.

The following timeline demonstrates the involvement of – and sense of urgency among – China’s highest ranking officials in authorizing, funding, and initiating Project 909, all within just four months from November of 1995 to March of 1996.

- November 23, 1995: The Ministry of the Electronics Industry and the National Bureau of Foreign Specialists submit a joint report called Document #826 to the State Council. This report proposes Project 909.³⁸⁵
- December 11, 1995: Premier Li Peng and Vice Premiers meet in Beijing to discuss semiconductors. They phone Hu Qili and ask him to fly to Beijing the following morning to discuss the state of the industry and the proposed Project 909.
- December 13, 1995: Premier Li Peng leads a working conference on Project 909.³⁸⁶ According to Hu, it was on this day that Li Peng committed treasury deficit money, initially RMB4 billion in U.S. currency, to fund Project 909.
- December 23, 1995: The State Council approves Project 909.³⁸⁷
- December 27, 1995: The Ministry of the Electronics Industry and the Shanghai Municipal Government send a jointly drafted report called Paper #920 on Project 909 to the National Planning Committee.³⁸⁸
- January 17th, 1996: Premier Li Peng, Vice Premier Wu Banguo, members of the State Council, and semiconductor industry leaders all conference in a Shanghai hotel. The conference confirms to all that the State Council and central government have decided to pursue Project 909.³⁸⁹
- March 29, 1996: The National Planning Committee officially approves Project 909.³⁹⁰
- April 9, 1996: Shanghai Huahong, home of Project 909, is founded in Shanghai’s Pudong district.³⁹¹

³⁸⁵ Wang and Wang, *Wo Guo Jichengdianlu Chanye*, page 296.

³⁸⁶ Hu, *Gongcheng Jishi*, pages 24-25.

³⁸⁷ Wang and Wang, *Wo Guo Jichengdianlu Chanye*, page 296.

³⁸⁸ Hu, *Gongcheng Jishi*, pages 24-25.

³⁸⁹ *Ibid.*, page 24-25.

³⁹⁰ *Ibid.*, page 27.

³⁹¹ Wang and Wang, *Wo Guo Jichengdianlu Chanye*, page 296.

- Later in 1996: The State Council adds another US\$100 million in funding for Project 909, creating a total investment of about US\$600 million, approximately RMB4.8 billion.³⁹²

Central leaders supported Project 909 with significant funding, but this was not to be simply a case of throwing good money (and more of it) after bad. In 1995, Project 908 was still blundering along, so how was Project 909 going to be different? Going into Project 909, China's semiconductor industry leaders had learned a number of lessons from their past experiences, and Project 909 would incorporate these lessons. Hu Qili explicated three "misunderstandings" from the past that leaders were considering when planning Project 909.³⁹³ The first misunderstanding was that by simply importing advanced equipment China would be able to manufacture semiconductors. Actually, semiconductor manufacturing was not possible without the technical experience to use and maintain the equipment and without the existence of the whole complex semiconductor industry chain for parts, materials, etc. The importation of 24 second hand production lines in the 1980s enabled a handful of Chinese enterprises to upgrade somewhat (see Chapter Two), but production was still not large scale nor was the production equipment at global standards. The second misunderstanding was trying to acquire leading edge technology (as was the goal of Project 908) without considering China's domestic market, which was dominated by demand for low and medium technology semiconductors. Indeed, even by 2002, industry data indicated that some eighty-five percent of China's demand was for semiconductor products at six inch and 0.5 μ m or simpler

³⁹² Ibid. Also Hu, *Gongcheng Jishi*, page 5. Project 909 also included eight design institutes which got RMB262 million in funding from the central government, along with another RMB382.5 million from other sources. See Chapter Five.

³⁹³ Hu, *Gongcheng Jishi*, pages 16-18.

technology.³⁹⁴ In addition, leading edge technology is more costly and advances and changes quickly. Purchasing such equipment can drain funds without succeeding in capturing leading edge technology, which is a moving target. The third misunderstanding was that money alone would enable China to successfully join the global semiconductor industry. In 1995, an eight inch production line cost over US\$1 billion (and the new 12 inch lines were well over US\$2 billion.) Annually, another twenty percent of the initial cost of the line would be incurred for operating and maintenance costs, ongoing equipment upgrades, technological training, and other costs. These additional annual costs were mandatory because if updating, etc., fell behind, customers would migrate to other suppliers. The key to supporting these costs and technological demands was to have access to international talent and capital. As Hu put it, success would require “an excellent team... cooperative, persistent and with a long term, common goal...with international standards and [able to] attract talented people....[and with] the ability to finance in international capital markets.”³⁹⁵ Having the money to establish a production line would not ensure ongoing success. Thus, from their experiences in the 1980s, through Project 908 and into Project 909, China’s semiconductor industry leaders were calibrating their approach in this industry.

Project 908 centered on acquiring higher technology equipment, and so would Project 909, but Project 909 would differ by also bringing in the necessary talent and product designs from the start. As we will see, Project 909 and SMIC brought in talent from overseas, including overseas Chinese.³⁹⁶ Further, Project 909 would make targeted investments in

³⁹⁴ iSupply, “Panacea,” page 15.

³⁹⁵ Hu, *Gongcheng Jishi*, pages 16-18.

³⁹⁶ The Chinese government was simultaneously making investments in education and research, which would ultimately enhance the local tool pool. See Chapter Five.

research and other activities to support the whole semiconductor industry chain. As Wang Guoping of Huajing and Project 908 put it “[It is] easiest to build the production line, but harder to have the talent and products. Huajing got the [production] line, but 909 would introduce technical teams and products.”³⁹⁷ Generally, Projects 908 and 909 are viewed by Chinese semiconductor personnel as well as by foreign observers as having been production oriented,³⁹⁸ but Project 909 intended to foster the whole semiconductor industry chain, especially through its support for design initiatives, addressed further in Chapter Five.³⁹⁹

4.22 The Goals of China’s New National Champion

Project 909 had two broad goals. The first was to bring in and coordinate extensively with foreign partners. In planning Project 909, Hu Qili wrote that the leaders believed “We must depend on collaboration, not self-development.”⁴⁰⁰ Project 909 needed additional capital as well as advanced foreign technology, foreign management and technical talent, foreign product designs along with the associated intellectual property (I.P.), I.P. protection, and access to markets. Indeed, at the January 17, 1996 meeting, the State Council decided that Project 909 could bring in any willing foreign companies for participation and

³⁹⁷ Interview with Wang Guoping, July 16, 2009, at China Resources Microelectronics (formerly Huajing) headquarters. Wang was the C.E.O. of CRM in 2008 and had been the General Manager of Huajing in the late 1990s.

³⁹⁸ Interview with Ye Tianchun, July 3, 2009, at the CAS Institute of Microelectronics in Beijing. Ye is the Director of the Microelectronics Institute and a top advisor on national semiconductor industry policies. Also, the brief descriptions of Project 909 in foreign sources tend to characterize it as production-oriented, see Dimitri Kessler, “Capital Accumulation and the Information Industries of Mainland China,” University of Wisconsin dissertation, 2005. See various works by Michael Pecht.

³⁹⁹ Wang and Wang, *Wo Guo Jichengdianlu Chanye*, page 298.

⁴⁰⁰ Hu, *Gongcheng Jishi*, page 37. In pages 37-43, Hu assesses China’s shortcomings in the semiconductor industry.

investment.⁴⁰¹ According to Hu, the “harsh reality [is]....we must bring in international management and technical partners, as have other countries. Eventually we will lay a foundation for further development.”⁴⁰² Indeed, in the semiconductor industry, Japan, South Korea and Taiwan all began by using foreign technology and later were able to develop technology themselves. The hope was that Project 909 would “break the vicious cycle of technology catch-up...[by] building up a product line, [and later] being able to self-develop, but we must have I.P....” through foreign partnerships.⁴⁰³ Early in the planning stages of Project 909, Hu met with U.S. semiconductor experts, and they advised him to partner with multi-national companies that could provide I.P. and I.P. protection and markets, saying that Huahong (Project 909’s primary production enterprise) should share stock with foreign partners.⁴⁰⁴ Both the Chinese and their potential foreign partners were aware of China’s weak legal protection for I.P. at that time. This was a problem, but companies could also find ways to work around the problem, for example, by not sharing leading edge designs or by keeping design work out of China.⁴⁰⁵ By cooperating with global enterprises, Project 909 attempted from the start to resolve the insufficiencies in China’s semiconductor industry.⁴⁰⁶

The second and no less important goal of Project 909 was to serve China’s domestic semiconductor market, as well as the export market, and in doing so, to earn the profits necessary to sustain operations. Wang Yangyuan, who would later co-found SMIC, explained

⁴⁰¹ Ibid., page 38.

⁴⁰² Ibid., pages 38-39.

⁴⁰³ Ibid., pages 167-168. Stressing this point, Hu wrote “Without I.P., enterprises can be born, but can not grow up, and might be killed.”

⁴⁰⁴ Hu, *Gongcheng Jishi*, pages 38-39.

⁴⁰⁵ China enacted enhanced protections for I.P. after 2000; see Chapter Five.

⁴⁰⁶ Wang and Wang, *Wo Guo Jichengdianlu Chanye*, page 298.

that Project 909 was founded on two principals. The first was foreign partnering, per above, and the second principal was that the project must be market oriented to “bring profit, so that it can form a good cycle of industry revenue and investing.”⁴⁰⁷ The Project 909 leaders planned to establish a Sino-foreign joint venture (with shared stock) so that Huahong could get foreign technology, I.P., and market access. In this way, Project 909 would have more advanced technology but would also be “market led” rather than strictly “technology led.” In choosing this approach, the Project 909 team was reflecting on the experiences of Huajing and Project 908. According to Wang Guoping (current C.E.O. of the former Huajing), Huajing had wanted to “be an Intel,” studying advanced, foreign products and trying to find products they could produce. Eventually, however, Huajing had to return to focus “on China’s domestic market and simple products and not shoot so high.”⁴⁰⁸ China’s top leaders were also following the approach and progress of Project 909. President Jiang Zemin advocated a market led approach, often asking Hu Qili about Project 909 and reminding him to pay attention to the market.⁴⁰⁹ During conversations regarding Huahong’s partner-to-be NEC of Japan (which could provide export markets), Vice-Premier Zhu Rongji⁴¹⁰ repeatedly said that the market is the key to Project 909’s success, because markets will lead to profits, and thus Huahong’s semiconductor operations could be maintained and upgraded over time.⁴¹¹

Following these ideas, in early 1997, the Ministry of the Electronics Industry researched

⁴⁰⁷ Ibid., page 296.

⁴⁰⁸ Interview with Wang Guoping, July 16, 2009, at China Resources Microelectronics (formerly Huajing) headquarters. Wang was the C.E.O. of CRM in 2008 and had been the General Manager of Huajing in the late 1990s.

⁴⁰⁹ Hu, *Gongcheng Jishi*, page 6.

⁴¹⁰ Zhu Rongji had been Mayor of Shanghai from 1987 to 1991, and he is credited with establishing Shanghai’s new Pudong economic district, where Huahong was (and is) located. He became Vice-Premier of China in 1991, and he then served as Premier of China from 1998 until 2003.

⁴¹¹ Hu, *Gongcheng Jishi*, page 60.

China's domestic market and proposed that Project 909 focus on producing selected products, such as I.C. cards or telecomm-related I.C. products for China's domestic market.⁴¹² By exceling in a particular segment of China's market, Project 909 would (hopefully) be profitable and could gradually stop "relying on national subsidies."⁴¹³

China's semiconductor industry leaders established Project 909's two tangible goals of foreign partnering and serving the market, but these goals served higher purposes. Chinese officials did not intend for Project 909 to only result in a new state owned enterprise with better equipment and more funding for design work, as some foreign summaries suggest. Officials planned for Project 909 to foster China's whole semiconductor industry value chain. Yes, Project 909 would fund a new production enterprise, Huahong, with eight inch, 0.5μm technology, as well as design and sales organizations. The intention, however, was that all these organizations would make use of international talent and global capital markets. In addition, the leaders of Project 909 would press for better domestic tax and tariff policies in the semiconductor industry to make China more attractive to global firms.⁴¹⁴ Finally, the hope was that Project 909 would give foreign investors more confidence in China and even promote the development of other industries, i.e., finance and construction, in Shanghai.⁴¹⁵

⁴¹² I.C. cards are also known as C.P.U. cards or smart cards. These e-cards can be used for bankcards, metrocards, identification cards, etc. Hu, *Gongcheng Jishi*, pages 132-133. The issue of Project 909 and Huahong focusing on China's I.C. card market is addressed further below.

⁴¹³ Hu, *Gongcheng Jishi*, page 40.

⁴¹⁴ Ibid., pages 11-13, 18, and 25.

⁴¹⁵ Hu, *Gongcheng Jishi*, page 81.

4.23 Project 909's Sponsorship, Leadership, and Talent

From the start, Project 909 had powerful political sponsorship. Industry leaders recognized that the previous pillar project, Project 908, was faltering due to bureaucratic delays,⁴¹⁶ and they determined that Project 909 would not suffer the same fate.⁴¹⁷ Project 909 was thus co-invested by the State Council and the Central Party, the first time the two groups had co-invested in a major project, and the project was directly under these two groups. According to Hu, the State Council and the Central Party gave the Ministry of the Electronics Industry a “military order” to carry out Project 909. That said, he also describes Project 909’s initial funds as coming from the “Premier’s Fund,” and in another instance he says that Project 909 was funded by the State Council and Shanghai’s municipal government, with a sixty-forty split.⁴¹⁸ Whatever the precise sources of the government’s investment, the project had powerful financial backers. To execute the project, the Ministry of the Electronics Industry and Shanghai’s municipal government jointly established the Project 909 Promotion Committee, and Shanghai created the Shanghai Support Project 909 Leading Group. Shanghai Mayor Xu Kuandi was this group’s leader, and Shanghai’s Vice Mayor and top CCP official were also involved. Shanghai’s various governmental departments were told to give Project 909 a “green light, to treat it as a special case, [and] every department should make a bridge or road to ensure this project can pass.”⁴¹⁹ According to Hu, to have “so many

⁴¹⁶ Ibid., page 4.

⁴¹⁷ Project 908 was a national priority, yet bureaucratic obstacles prevented timely funding. The precise nature of these bureaucratic or political obstacles are unclear, but it is not surprising that even a high priority project could be delayed given China’s bureaucracy and the rapid pace of organizational and economic changes in China.

⁴¹⁸ Hu, *Gongcheng Jishi*, pages 3-7.

⁴¹⁹ Hu, *Gongcheng Jishi*, page 79.

high profile people involved...this was seldom seen.”⁴²⁰ This high level political sponsorship decreased bureaucratic delays and ensured funding for Project 909, but the need for high level officials to send word through the ranks to “treat [this project] as a special case” indicates that, generally, bureaucracy was still a hindrance in China.

As for Huahong, Hu Qili was appointed Chairman; prior to this position, Hu had been a leader of China’s Ministry of the Electronics Industry since 1989. Members of the January 17, 1996 conference also appointed Huahong’s Board of Directors, and the Ministry of the Electronics Industry appointed Huahong’s C.E.O. The Shanghai municipal government was supposed to appoint Huahong’s General Manager, but ultimately Huahong’s foreign partner insisted on providing the General Manager.

With leaders installed, the challenge was to staff Huahong with capable managerial and technical talent. Project 908’s Huajing supplied thirty staff directly to Project 909,⁴²¹ and between 1997 and 2000, another 300 managers left Huajing, although it is unclear how many of these individuals ultimately migrated to Huahong. Ye Xiekang recounted “The government had given Wuxi the focus [for the semiconductor industry], then chose Shanghai. So, people left Huajing...[This was] good for the industry...,”⁴²² suggesting that a portion of these Huajing-trained personnel ultimately went to Huahong and other Chinese enterprises. In addition to Huajing, Huahong’s leaders recruited talent from across China to participate in

⁴²⁰ Ibid., page 80.

⁴²¹ Interview with Wang Guoping, July 16, 2009, at China Resources Microelectronics (formerly Huajing) headquarters. Wang was the C.E.O. of CRM in 2008 and had been the General Manager of Huajing in the late 1990s.

⁴²² Interview with Yu Xiekang, General Manager of Jiangsu Changjiang Electronics Technology (JCET), June 2, 2009, JCET headquarters near Wuxi.

Project 909 and sought staff from the Chinese Academy of Science's (C.A.S.) Institute of Microelectronics in Beijing, which was China's top semiconductor related research institute.

Despite recruiting the best domestic talent, Huahong still needed foreign managers and technical staff. Later, when Huahong negotiated with potential foreign partners, foreign firms insisted that Huahong supply a top management team for eight inch production, but Huahong simply could not find such managers within China's domestic talent pool. For example, C.A.S. Institute of Microelectronics offered staff and support to Huahong, but the C.A.S. personnel really had no experience with eight inch production. Hu says "we were determined to break the rules and use huge money to recruit a large group of overseas experienced management and technical talent to participate in Project 909." The belief was that, overall, such compensation would be a small part of the total value these individuals could bring to Huahong.⁴²³ The lack of talent in China made Project 909 even more dependent on a foreign partner, and this problem was not unique to Huahong. Recall, around this same time Huajing was considering bringing in Taiwanese managers. Like Hu at Huahong, Wang Guoping at Huajing seemed to have been uninhibited – even eager – to bring foreign managers into a Chinese national champion. (Indeed, Wang said he "would have quit" if others on his management team had not agreed to bring in foreign help, but his management team was in full agreement.) Apparently, these national champion enterprises were quite open to international leadership.

⁴²³ Hu, *Gongcheng Jishi*, page 41-42. Twice, delegations from Project 909 went to Silicon Valley to try to recruit Chinese overseas students. Students were very interested, and a one hour recruiting meeting turned into a post-lam discussion in a California hotel room. However, ultimately the students were concerned about the likely rigidity of a state owned enterprise and most did not join Huahong. Yet, many stayed in touch with Huahong leaders and provided value advice and services in the ensuing years, see page 42.

4.24 Huahong and International Partnering

In 1996 when Huahong began to look for an international partner for its primary production enterprise, the global semiconductor industry was entering a cyclical slump. From 1992 to 1996, global semiconductor revenues had grown over twenty percent annually, and semiconductor firms had built a number of six inch and eight inch production lines. By 1997, however, the supply of semiconductors came to exceed demand, and prices fell.⁴²⁴ In this environment, global semiconductor firms mostly stopped building new lines, and thus Huahong faced a difficult environment in which to find a partner. Another potential problem for Huahong was U.S. export controls on high technology, dual use technology. Chinese leaders were very concerned that U.S. export controls would cause the U.S. government to obstruct Huahong's negotiations with U.S. firms. However, when Huahong approached potential U.S. partners, the U.S. firms were not primarily concerned with export controls, as around this same time, the U.S. administration was in the midst of loosening restrictions on dual-use technology to China.⁴²⁵

⁴²⁴ The semiconductor industry is cyclical. In semiconductor production, improving different production factors (technical skills as well as humidity, temperature, vibration, etc.) leads to increased production yields over time. That is, a higher percentage of units produced can be sold. So, as production improves, a fixed amount of investment in a production line will result in lower per unit costs, as yields increase. A line is set up for a fixed number of wafers per month, but the production yield on those wafers can improve from ten to ninety percent as production technique is perfected through trial and error. In the global industry, as all firms producing a particular semiconductor product learn and improve, all yields go up, and thus output goes up, and thus price per unit goes down. So, average unit cost changes over the product life cycle. Initially unit cost is high, but later, it is very low. Yet, unit costs tend to fall faster than price. Even as price per unit decreases, a firm continues to fully utilize its line to sell the most product it can. The variable cost per chip is very low (fixed costs are staff, equipment, research, etc.), so a company will continue to maximize the throughput of a line, even when price per unit goes down. (Because of high fixed costs, if demand goes up, semiconductor firms can not respond quickly with new capacity.) If demand falls due to less demand for electronic-related goods, then semiconductor prices fall sharply because output stays nearly the same. For more explanation, see Baldwin, "The Impact of the US-Japan Semiconductor Agreement," 1994, pages 130-134.

⁴²⁵ Hu, *Gongcheng Jishi*, pages 65-66. U.S. actions regarding high technology exports to China in the late 1990s are addressed further in Chapter Five.

To find a foreign partner, the Project 909 team contacted some twenty to thirty global firms, but initially the responses were not encouraging. Huahong's lack of an existing revenue stream and profit was likely a major cause for concern. Despite the project leaders' ostensible focus on markets and profits, this research found no actual business plan nor any mention of a business plan or financial model for Huahong. In the case of U.S. semiconductor firms, executives were cynical toward Project 909. Foreign industry personnel had a number of concerns. Project 908 had gotten no results, demonstrating that China lacked technology and talent. As for Project 909, it lacked a business plan, was desperate for a partner, and was offering an unattractive minority stake in Huahong. Finally, foreigners believed that working in China was often even more problematic than expected.⁴²⁶ Foreigners expected to face inconsistent and opaque rules and regulations, interventions from Chinese officials, culture and skill gaps between foreign and Chinese personnel, and other obstacles, and foreigners believed that these problems were usually worse than expected.

Faced with little interest from foreign partners, Project 909's two goals of "serving the market" and "partnering with foreigners" ultimately became linked. In *Project Records*, Hu added the following explanation:

"Turning point: On one cold, dark winter night in late 1996, I was alone thinking. 909 was under construction, but did not yet have a partner. I could not sleep. ... Li Peng had said cooperation with the U.S. is based on following the contract and avoiding political disturbances, so try to ask them to make economic promises. But at that time, all factors indicated that 909 negotiations will be delayed a long time. Facing this, on January 12, 1997, I... made some concrete suggestions for negotiations. There are two urgent things: negotiations and market. Those two are connected. The last stepping stone is the market, if the market is concrete, then we have ways to bring in technology and can negotiate with foreign companies. For foreign companies, the real concern is the I.C. card. China's

⁴²⁶ Denis Simon, "From Cold to Hot," *China Business Review*, November-December, 1996. Also, Hu, *Gongcheng Jishi*, page 46.

government controls this market. Huahong will never fail if we master this market. If we take concrete and powerful steps in this area, then we can strengthen our position in negotiations.”⁴²⁷

China’s market for I.C. cards (social security cards, metrocards, etc.) was growing under China’s “Three Goldens” project. From 1993, China’s State Council had sought to develop China’s information infrastructure through the Three Goldens. The Three Goldens included: 1) the “Golden Bridge,” which would electronically connect a number of national ministries, 2) the “Golden Card” for various banking cards, and 3) the “Golden Gate,” which would electronically connect the Ministries of Foreign Trade and Customs. Largely from these projects, China was forecasted to have the largest I.C. card market in Asia by the year 2000.⁴²⁸ The Three Goldens project supported China’s information modernization, and it had the added benefit of fostering the semiconductor industry. The Ministry of the Electronics Industry hosted the Golden Projects Office and coordinated most Golden-related projects. Indeed, Hu Qili had been a leading proponent of the Three Goldens from the early 1990s.⁴²⁹ Now, Hu saw an opportunity to simultaneously support the Three Goldens and Project 909.

In early 1997, just after Hu proposed using China’s I.C. card market as a negotiating chip for Huahong, China’s government took steps to define and protect this market, i.e., setting the manufacturing location and creating a certification diploma system for I.C. cards. Then, in March 1997, the State Council announced that all Chinese government organizations would adopt I.C. cards, using Huahong’s (future) products. With the market better defined,

⁴²⁷ Hu, *Gongcheng Jishi*, page 46-48.

⁴²⁸ *Asia Pulse*, “China to be the World’s Largest Telephone I.C. Card Market,” May 31, 1999.

⁴²⁹ Professor Liang Xiong-Jian, Beijing University of Posts and Telecommunications, “Convergence and China’s National Information Infrastructure” in M. Hukill and R. Ono, C. Vallath, editors, *Electronic Communication Convergence* (Singapore: 1999).

potential foreign partners “changed their attitude toward Project 909.” Essentially, this was a quid pro quo of technology transfer for market access. Several potential partners entered into negotiations, including Siemens, IBM, Rockwell, and Toshiba. Siemens, for example, made significant concessions in order to have the opportunity to capture China’s I.C. card market.⁴³⁰

After more than a year of negotiations with several firms, Huahong agreed to a partnership with NEC of Japan in July of 1997. In Hu’s comments on the negotiation process, he seems surprised that only five firms entered negotiations and that negotiations were difficult and took over a year. Yet, this level of participation and timeline seems reasonable. In fact, given that Huahong had zero revenues and that Project 908 had shown no results at its five year mark, it is actually surprising that five renowned global semiconductor firms would consider partnering with Huahong and that negotiations were completed within only a year. Even much smaller partnerships and merger and acquisition transactions – with proven revenue – commonly take a year or more to finalize. Perhaps the offer of China’s I.C. card market did indeed “change attitudes.” The following recaps the timeline:

Huahong’s Establishment Phase:

- April 9, 1996: Shanghai Huahong, home of Project 909, is founded in Shanghai’s Pudong district.⁴³¹
- March, 1997: The State Council decides that all Chinese governmental organizations will adopt I.C. cards, using Huahong’s (future) products.⁴³²
- July 17, 1997: Huahong and NEC form Huahong-NEC.⁴³³

⁴³⁰ Hu, *Gongcheng Jishi*, pages 46-48 and 138. China’s quid pro quo of offering market access in exchange for technology transfer is discussed further in Section 4.43.

⁴³¹ Wang and Wang, *Wo Guo Jichengdianlu Chanye*, page 296.

⁴³² Hu, *Gongcheng Jishi*, pages 138.

- July 31, 1997: Construction begins on Huahong-NEC.

Huahong-NEC's Production Phase:

- February 23, 1999: Huahong-NEC DRAM trial production is underway.⁴³⁴
- July, 1999: Huahong-NEC begins to sell products.
- September 25, 2001: Project 909 passes its “national acceptance” check.⁴³⁵
- July, 2004: Huahong-NEC begins high volume production of China's 2nd generation I.D. card.⁴³⁶

Why did the Project 909 leaders ultimately select a Japanese partner rather than a U.S. or European partner? Industry observers have said that NEC was selected over U.S. firms due to U.S. export restrictions,⁴³⁷ and Chinese officials were indeed initially concerned that the U.S. government would impede China's negotiations with U.S. firms. However, several factors indicate that U.S. export controls were not why Huahong chose Japan's NEC. First, the U.S. government was in the process of loosening high technology export controls to China in the mid to late 1990s. Second, U.S. firms were generally eager to enter China in the 1990s, although they were suspicious of the specifics (or lack of specifics) around Project 909, as mentioned above.⁴³⁸ Further, once Project 909 was able to guarantee revenue by offering

⁴³³ Wang and Wang, *Wo Guo Jichengdianlu Chanye*, page 296.

⁴³⁴ Chen Ling, “*Chanye Xingcheng Jieduan*.”

⁴³⁵ Hu, *Gongcheng Jishi*, page 259.

⁴³⁶ *Ibid.*, pages 139-140.

⁴³⁷ For example, Denis Simon in “Critical Threshold” said “Because of the continued restrictions on technology transfer posed by the U.S. and several other countries, the PRC government picked Japan's NEC Corp. to form the joint venture [for Project 909].”

⁴³⁸ See Chapter Five for more on this first and second point.

China's newly protected I.C. card market, U.S. and European firms began to actively negotiate to partner with Project 909. Finally, it is important to recall that China and NEC commenced production in Beijing in March of 1995 at their joint venture Shougang-NEC. NEC had proven to be respectful⁴³⁹ of its Chinese partners, and it had been able to persevere in ramping up a major operation in China. (Shougang-NEC was established in 1991 and began production four years later in 1995.) Thus, issues other than U.S. export controls were likely the determining factor in Huahong choosing a Japanese partner.

Project 909 and Huahong succeeded in establishing a joint venture with the world's second largest semiconductor enterprise, NEC of Japan, but this was not NEC's first venture in China. Since 1994, NEC had been in a semiconductor-oriented joint venture with China's state owned Shougang enterprise in Beijing. Owing to this existing venture, NEC had been one of the first international companies that Chinese leaders, including Premier Li Peng and Hu Qili, had personally contacted for a possible partnership on Project 909. Thus, while the Project 909 team was conducting negotiations with various potential partners throughout 1997, a team at NEC was independently analyzing the potential benefits of working with the new

⁴³⁹ Hu, *Gongcheng Jishi*, page 53-54. Hu includes an aside among his reports on Project 909 that suggests that a lack of respect from U.S. semiconductor experts soured Huahong on partnering with a U.S. firm. In the midst of a section on negotiations with NEC, Hu added: "Here, I must mention our Mr. Ye Xuanji, the Chairman of Guoye Company. ... In March 1997, he got in touch with friendly U.S. semiconductor companies. After learning our situation and requirements [regarding Project 909], those companies said 'We are willing to support and help, but we can not because China...[can not solve its many industry problems], and the key point is that Chinese talents are not satisfying. If you listen to us, we believe if China uses US\$1 billion for semiconductor investment, why not use that money to dig several more tunnels under Shanghai? This way, you will not waste your money!'" Hu wrote: "This conversation really hurt Mr. Ye (*shoudao hen da ciji*, 受到很大刺激) and firmed his mind to help Project 909. He called us continuously through the night that night, saying he wanted to get in touch with NEC [owing to Shougang-NEC in Beijing]... [Later] Mr. Ye sought to test NEC's attitude in Japan. NEC's C.E.O. and senior officials met with Mr. Ye. ... If NEC gets into Project 909, then [we] will realize mutual benefit, and NEC can get high praise from China's central government, then [this would be] helpful for the whole company [NEC] and development in China. ... The [NEC] leader seeks profits... and he considers the long-term strategic development of China." From Hu's account, the suggestion by U.S. experts that the Chinese should dig tunnels rather than invest in the semiconductor industry was disrespectful and short sighted. The U.S. experts may not have realized Mr. Ye's influence in China. As a company chairman, they might have taken him as a businessperson rather than a government official.

Huahong. From this analysis, NEC came to view partnering with Huahong as a long term strategy, with an eye toward producing I.C. cards and telecomm-related semiconductors for the Chinese market.⁴⁴⁰

Under the new Huahong-NEC joint venture, NEC agreed to transfer eight inch, 0.5 μ m technology to Huahong, but NEC insisted on providing the General Manager for Huahong-NEC and running production operations as well as sales and marketing. Importantly, NEC could immediately provide an export market for Huahong-NEC memory products (DRAM), which initially would be about 80 percent of Huahong-NEC's production.⁴⁴¹ NEC also offered five months of training in Japan for 450 Chinese engineers.⁴⁴² NEC committed that the joint venture would be profitable within five years, which would necessitate NEC eventually transferring technology of less than 0.5 μ m,⁴⁴³ a positive for Huahong. Notably, none of the main Chinese sources mention any frustration or disagreement over NEC's demand to provide the General Manager and to run both production and sales.⁴⁴⁴

Project 909 and Huahong are commonly referred to as being a US\$1.2 billion investment,⁴⁴⁵ however, the Chinese government did not directly fund this amount. US\$200 million came from Japan and another US\$500 million may have been a future commitment in equity. According to Wang Yangyuan, funding for Huahong-NEC included:⁴⁴⁶

⁴⁴⁰ Ibid., pages 52-60.

⁴⁴¹ Wang and Wang, *Wo Guo Jichengdianlu Chanye*, page 296.

⁴⁴² Jifu Wang, "China Huajing Electronics Group Corporation", unpublished business case study, 2000.

⁴⁴³ Hu, *Gongcheng Jishi*, pages 52-60.

⁴⁴⁴ Wang and Wang, *Wo Guo Jichengdianlu Chanye*; Hu, *Gongcheng Jishi*; Zhu, *Wenji*; CSIA.

⁴⁴⁵ Sources such as iSupply, PriceWaterhouseCoopers, Michael Pecht's works, and other articles refer to Project 909 as a US\$1.2 billion project.

⁴⁴⁶ Wang and Wang, *Wo Guo Jichengdianlu Chanye*, page 296. Accounts differ as to the ownership and funding of Project 909 and Huahong. Recall, according to Hu, Project 909 was co-invested by the State Council and

Registered capital:

US\$500 million from Huahong

US\$130 million from NEC

US\$70 million from Japan Electronics

Other investment:

US\$500 million, guaranteed by Huahong's and NEC's equity shares

Total investment:

US\$1,200 million (approximately RMB10 billion)

With strong Chinese sponsorship, available funds, and an experienced foreign partner, Huahong-NEC production was underway in February of 1999, just 18 months after the enterprise was established. The rapidity with which Huahong-NEC launched was a big improvement over the years of delays at Project 908's Huajing. Further, owing to NEC's market, Huahong-NEC had an immediate market and claimed to be profitable as early as 2000, although industry personnel typically say that Huahong-NEC was operational for a number of years before achieving profitability.⁴⁴⁷

the Central Party. Yet, Hu also described Project 909's investment funds as coming from the State Council and Shanghai's municipal government, with a sixty-forty split, see Hu 5-6. According to Denis Simon, Project 909's majority shareholders were the China Information Industry Holding Co. with 52.5 percent and Shanghai Instrumentation and Electronics Holding Co. at 47.5 percent, see Denis Simon, "From Cold to Hot," *China Business Review*, November-December, 1996. US\$500 million was likely the original RMB4 billion investment. Hu described it as coming directly from the Premier's Fund, although he also said it had to be repaid, suggesting it was a loan. Wang mentions US\$500 million as a bank loan collateralized on HH-NEC equity.

⁴⁴⁷ Ibid., page 297. Some Chinese semiconductor industry personnel disputed that Huahong-NEC was profitable in its early years. Even Wang, later on page 297, mentions that Huahong-NEC has had "continuous profit" since May of 2004, which is closer to the start of profitability that most industry personnel recall.

4.25 Huahong-NEC's Results

In 2005, five years after commencing production, Huahong-NEC was listed among the top ten global semiconductor foundries, and it has remained on that list each year since.⁴⁴⁸ In its early years, Huahong-NEC progressed on a number of fronts: it adopted the foundry model, expanded its product and customer base, acquired I.P. from foreign partners, began producing I.C. cards for the domestic market, and extended significant equity to a U.S. firm.

From 2002, Huahong-NEC changed its business model from an I.D.M. to a foundry,⁴⁴⁹ following the global trend, and it shifted from primarily producing DRAM to producing I.C. cards as well as a variety of semiconductor products for its foundry clients. By late 2003, foundry revenues constituted about ninety percent of Huahong-NEC's total revenue. An important organizational change in 2003 was Huahong's take over of management and operations from NEC, putting Huahong-NEC under Chinese control. From 2004 to 2007, Huahong-NEC claimed profitability.⁴⁵⁰

Initially, Huahong-NEC's sales orders had all been exports for NEC's customers, but Huahong-NEC quickly developed other sales channels. Early on, Huahong-NEC produced DRAM products for export to NEC's customer base, but at the same time, Huahong-NEC established sales organizations in China to better understand and serve China's market.

⁴⁴⁸ Len Jelinek, "China Research: Q4, 2004," *iSupply*, 2004.

⁴⁴⁹ Into the 1990s, most major global semiconductor firms operated under the "integrated device manufacturer (I.D.M.)" business model. In an I.D.M., one vertically integrated company designs, fabricates (i.e., produces or manufactures), and packages/assembles/tests (P.A.T.) its own semiconductors, using its own foundry for fabrication. This foundry model was first developed in Taiwan in 1987 at the Taiwan Semiconductor Manufacturing Corporation (TSMC). The foundry model is in contrast to the I.D.M. model. Under the foundry model, a stand-alone foundry leases its capacity to any number of customers. Customers design their semiconductors and then simply lease foundry capacity for fabrication. The foundry does not sell semiconductors into the market. That said, a company can have a foundry while also having other revenue streams.

⁴⁵⁰ Wang and Wang, *Wo Guo Jichengdianlu Chanye*, page 297.

Huahong also established locations in a number of foreign countries. Huahong-NEC first expanded its customer base by serving Chinese branches of Japanese companies, but eventually Huahong-NEC served customers in all provinces of China, Taiwan, South Korea, the U.S., and other countries.⁴⁵¹

Huahong gained intellectual property and intellectual property protection through its joint venture with NEC as well as through other partner arrangements. Early on, for example, Huahong managed to secure an agreement with Belgium's IMEC on intellectual property for 0.18-0.13 μ m technology.⁴⁵² Huahong then used this cooperation as a bargaining chip to convince NEC to transfer this same level of production technology to Huahong. A major benefit of Huahong gaining intellectual property rights was that Huahong could transfer its intellectual property to other groups and other companies in China. Importantly, Huahong's cooperation with foreign partners on design and intellectual property also made possible Project 909's design initiatives.⁴⁵³

Through I.P. sharing agreements with its partners, Huahong eventually began to produce and sell I.C. cards in China using its own (and co-owned) I.P. The I.P. was developed by one of the Project 909 design firms, the Huahong Integrated Circuit Company. Previously, Chinese organizations had largely purchased I.C. cards from foreign suppliers. After Huahong-NEC developed I.C. card products, various Chinese government organizations purchased these I.C. cards for subway ticket machines, metro-cards, bank cards, identification

⁴⁵¹ Hu, *Gongcheng Jishi*, pages 149 and 153. Wang and Wang, *Wo Guo Jichengdianlu Chanye*, page 297.

⁴⁵² *Ibid.*, pages 176-177. Some members of IMEC's team did not trust Huahong's capabilities and were against sharing I.P. with Huahong.

⁴⁵³ *Ibid.*, pages 176-178. Jiang Shoulei led the Huahong group to Belgium. Jiang was formerly at Huajing, and he later led Huahong's sales affiliate, Hongri. Under the agreement with IMEC, Huahong would send ten people per year for four years to Belgium to work with IMEC design staff. Wang and Wang, *Wo Guo Jichengdianlu Chanye*, page 298.

cards, social security cards, and other uses. Indeed, between 2003 and 2004, Huahong-NEC's revenue's nearly doubled, as 2004 was the year that Shanghai, Beijing, Shenzhen, and other cities introduced social security (I.C.) cards for residents.⁴⁵⁴

Huahong continued to globally integrate through various partnerships. A good example is Huahong-NEC's 2003 re-organization into a three-way joint venture between the U.S., Japan, and China. That year Jazz Semiconductor, a California-based foundry that focuses on serving the aerospace and defense industries, joined Huahong-NEC. Jazz Semiconductor exemplifies global integration in the semiconductor industry. Jazz was founded by Shu Li, originally from China, but educated and working in the U.S. for many years.⁴⁵⁵ In 2003, Jazz Semiconductor obtained an eleven percent equity stake and board seat on Huahong-NEC. Jazz was founded in 2002 just a year before its venture with Huahong-NEC. It was a spinoff from U.S. semiconductor company Conexant Systems, which had previously spun-off from (U.S.) Rockwell Semiconductor in 1999. The Carlyle Group, a leading U.S. private equity firm, was the majority shareholder at Jazz's founding. In 2008, Jazz became a subsidiary of TowerJazz of Israel, while maintaining its venture with Huahong-NEC.⁴⁵⁶

⁴⁵⁴ Wang and Wang, *Wo Guo Jichengdianlu Chanye*, page 297. Hu, *Gongcheng Jishi*, pages 80-81 and 138-139. The Huahong Integrated Circuit Company was a Project 909 design firm jointly founded by the Huahong Group, the State Investment Electronics Company, Shanghai Research Institute of Metallurgy, Shanghai Academy of Science, and the Shanghai Fudan High-Tech Company.

⁴⁵⁵ As a successful business executive, Shu is a member of the U.S.-based Committee of 100, a group of prominent Chinese-Americans from a variety of fields. The group is a non-profit, non-partisan organization that brings a "Chinese-American perspective to issues concerning Asian-Americans and U.S.-China relations." See www.committee100.org.

⁴⁵⁶ Jazz Semiconductor press releases and website, see www.jazzsemi.com. Also in 2003, Jazz announced a partnership with China's ASMC, one of China's key semiconductor enterprises. Jazz's products are for use in wireless communications, optical networking, power management and other ultra-high performance applications.

As a globally integrated, relatively advanced semiconductor enterprise, Huahong-NEC arguably fostered – at least to a degree – China’s semiconductor industry chain, which was the original intention of Project 909. According Wang Yangyuan, “Huahong-NEC set a huge good example for the whole industry and pushed related policies to come up....With its profits, Huahong-NEC proved that China has the conditions and environment [for the semiconductor industry]...including the facilities, markets, [technical] specialists, and policies.”⁴⁵⁷

4.26 Huahong-NEC’s Contributions to the Industry

Huahong-NEC made progress, but it also faced a number of policy-related obstacles. The enterprise faced inconsistent importation costs, inconsistent tax policies, a huge black market for smuggled electronics goods, and limited access to foreign capital. The following discussion addresses these obstacles, and in responding to these obstacles, we begin to see how Huahong-NEC’s experiences helped to shape China’s business and policy environment for the semiconductor industry.

When Huahong-NEC was established in 1997, China’s official value added tax (V.A.T.) on imported semiconductors and discrete devices was 17 percent in addition to other import-related costs. Owing to this high cost, electronic components were commonly smuggled into southeast China.⁴⁵⁸ Indeed, buyers in China often bought electronic

⁴⁵⁷ Wang and Wang, *Wo Guo Jichengdianlu Chanye*, page 298.

⁴⁵⁸ Smuggling was widely reported as prevalent in China, especially in the 1990s as China’s economy was growing and import-export policies remained problematic, i.e., high tariffs on many imported products, inconsistent policies, etc. For a description of China’s smuggling problems and the government’s anti-smuggling campaign of the late 1990s, see Dali Yang, *Remaking the Chinese Leviathan: Market Transition and the Politics of Governance in China* (California: Stanford University Press, 2004.)

components by the kilo, that is, in bulk, rather than by the unit. A former Huajing manager claimed that even state owned enterprises (including Huajing) commonly and knowingly sought smuggled semiconductors well into the 1990s. According to this source, there were several reasons: enterprises' inability to self-produce more advanced semiconductors, the general lack of supply in China, and the higher price of legally imported semiconductors and discrete devices. Seeing an opportunity, this particular manager left Huajing in 1991 to start a trading company. In the first half of the 1990s, he imported semiconductors and discrete devices from Hong Kong, including products made by Motorola, Philips, and Toshiba, and he sold these products to Chinese state owned enterprises at double his cost. He openly acknowledged that his trade was illegal smuggling, but he seemed to view smuggling as unsurprising, acceptable, and necessary during that period.⁴⁵⁹

High importation costs and the resultant smuggling affected Huahong-NEC as well as foreign companies. As Huahong-NEC sought to win customers in China, the manager of Huahong's domestic sales unit complained that potential clients would say "I do not care if it is legal or smuggled in, I just need products at cheap prices."⁴⁶⁰ Competing against smugglers, Huahong-NEC's sales unit found it difficult to secure domestic sales. As for global firms, they either had to either pay exorbitant costs to legally import semiconductors into China or they had to forfeit profits to middlemen who might ultimately sell into Mainland China via smuggling. Given this situation, Huahong-NEC leaders pressured Chinese officials to change

⁴⁵⁹ Interview with David Gong, June 2, 2009, at Inchange Semiconductor in Wuxi. Mr. Gong had been a manager at Huajing until leaving in 1991 to form a trading company. In 1991, Mr. Gong's new firm was a collectively owned, township and village enterprise (T.V.E.) in Wuxi. By 1994, under China's new Company Law, he was able to change the ownership structure. In 2009, Mr. Gong's company was called Inchange, and it was a private, Wuxi-based company with 100 employees, with half of its sales domestic and half foreign, see www.iscsemi.com.

⁴⁶⁰ Hu, *Gongcheng Jishi*, page 149.

the V.A.T. and tariff levels and take action against smuggling;⁴⁶¹ ultimately, the changes Huahong-NEC advocated would benefit both Chinese enterprises as well as foreign enterprises.

In 1998, the Chinese government did undertake a large-scale, anti-smuggling campaign. This campaign was not only to help the electronics industry, but nonetheless, the anti-smuggling programs and results were significant enough that by late 1998 and 1999, Chinese semiconductor firms, including Huahong-NEC, reported that they were no longer losing significant sales to smugglers.⁴⁶²

Anti-smuggling measures were helpful, but China's tax environment in the late 1990s remained problematic. At seventeen percent, China's value added tax rate was significantly higher than that of Europe (six percent), Taiwan (five percent), and Japan (three percent).⁴⁶³ Depending on negotiations with officials, total imports costs could vary from five to thirty percent, but seventeen was the official rate.⁴⁶⁴ Also, China's V.A.T. was a production V.A.T. instead of a consumption V.A.T. A production V.A.T. allowed the Chinese government to collect taxes on production-related activities, rather than collecting taxes on consumption. Most other countries used a consumption V.A.T., which is less onerous for production companies. In China, for example, if a semiconductor enterprise imported a US\$1 billion production line, then the enterprise would pay a (production) V.A.T. of US\$170 million. In

⁴⁶¹ Ibid., pages 149-150.

⁴⁶² Ibid., pages 150-151.

⁴⁶³ Countries often have a standard V.A.T. rate and a reduced rate for specified products. These rates quoted in a semiconductor industry report likely reflect "reduced" V.A.T.s that countries charged on semiconductor-related goods. For example, in 2012, the U.K.'s standard V.A.T. was twenty percent, but its reduced V.A.T. rate was five percent for certain types of goods.

⁴⁶⁴ U.S. Semiconductor Industry Association, prepared by Dewey Ballantine LLP, by T. Howell, B. Bartlett, W. Noellert, and R. Howe, "China's Emerging Semiconductor Industry," 2003, Figure 11, pages 20-21

addition the enterprise would pay customs taxes, bringing the total tax burden to about 24 percent of the US\$1 billion cost, which was much higher than tax costs in other countries.⁴⁶⁵

Recognizing the discouraging nature of China's tax policies in this critical industry, the Chinese officials took measures to help Huahong-NEC. The enterprise was able to secure a tax holiday and an exemption from the normal tariffs and import-related value added taxes for production-related equipment and raw materials during construction. After initiating operations, Huahong-NEC was granted the same preferential policies that Shanghai's Pudong New District offered Sino-foreign joint ventures and high technology firms. These included ongoing tax breaks on imported spare parts and raw materials and the ability to negotiate with the Shanghai government for a certain total level of tax free importation.⁴⁶⁶ For Huahong-NEC, as had been the case for the Sino-foreign semiconductor joint ventures, officials negotiated subsidies, taxation, and import costs on a one-off basis.

From their experiences with individual enterprises, industry leaders began formulating new policies for the semiconductor industry in the late 1990s. New policies were announced (though not implemented) on June 25 of 2000 via State Council Document #18 called "Policies to Encourage the Software and Integrated Circuit Industries."⁴⁶⁷ This breakthrough document (addressed in Chapter Five) benefitted domestic semiconductor enterprises as well as Sino-foreign joint ventures and wholly foreign owned enterprises. Document #18 sought

⁴⁶⁵ Wang and Wang, *Wo Guo Jichengdianlu Chanye*, pages 345-348.

⁴⁶⁶ Hu, *Gongcheng Jishi*, page 25.

⁴⁶⁷ Wang and Wang, *Wo Guo Jichengdianlu Chanye*, page 348. The document is "18 Hao Wenjian: Guli Ruanjian Chanye he Jichengdianlu Chanye Fazhan de Ruogan Zhengce 18 号文件：鼓励软件产业和集成电路产业发展的若干政策 (Document 18: Some Policies to Encourage the Software and Integrated Circuit Industries)." This document is available from the Chinese Electronics Standardization Institute (*Zhongguo Dianzi Jishu Biaojunhua Yanjiusuo* 中国电子技术标准化研究所) at www.chinasoftware.com.cn/calling_info_detail.asp?id=47.

to streamline approval processes for new enterprises, as well as improve tax policies, customs duties, foreign exchange regulations, and intellectual property protection.

In addition to advocating reduced V.A.T. tax and other costs, Project 909 leaders had sought additional access to international sources of funding. In Hu's records on Project 909, he introduces his and his colleagues' early consideration of venture capital as a possible mechanism for funding certain semiconductor ventures. According to Hu:

"In November 1997, the Vice President of Huahong, Lu Dechun, and Yang Guang from the Ministry of the Electronics Ministry visited America, especially Silicon Valley. They came back and told me, in America,... semiconductor design company [costs] can be US\$3 million in the first two years, and maybe you can not even make your own product. I was really worried about this. Because [in our case] the investment is coming from national assets, so we need to keep it appreciating. If all the money is spent, and we can not see achievement, how can I report [back to the government, the people]?"

"So because... the risk is very high, why not invest in some existing design companies to reach our mission? At the same time, the venture capital concept jumped into my mind. At that time, this venture capital concept was just introduced from overseas to China and lots of other people were very concerned about its ability... [would it really work?] I invited Chinese-American venture capital firms to give lectures in the Ministry of the Electronics Industry and their ideas inspired us. ... In the early 20th century [in the U.S.], several wealthy families gave up railroad, oil, and other traditional industries to invest in computers and new technology, and they created IBM, so IBM is a good model of venture capital success... [also Intel, Sun, etc.]"⁴⁶⁸

Project 909 leaders believed that success in the semiconductor industry would depend on access to international capital. Ultimately, officials responded with two policy changes in support of this belief. In January of 1998, the Ministry of Information Industries (formerly the Ministry of the Electronics Industry) issued new regulations to facilitate foreign investment in semiconductor manufacturing. The new *Guiding Catalog of Foreign*

⁴⁶⁸ Hu, *Gongcheng Jishi*, pages 153-154.

Investment in Industry listed semiconductors among China's "encouraged" industries; in encouraged industries, foreign investments and foreign invested enterprises were likely to get government approval. Following this, in June of 1999, China's Ministry of Science and Technology confirmed that semiconductor enterprises could seek "venture capital and other sources of funding that were previously off limits."⁴⁶⁹

These policies changes and the impending Document #18 (to be issued in 2000) were not exclusively predicated on Huahong-NEC's needs. However, as a national champion led by Chinese officials, the experiences of Huahong-NEC directly influenced policy makers.

4.3 National Champion SMIC

During the 1990s China's semiconductor industry leaders concentrated on developing China's domestic production capability, but all the while, demand for semiconductors in China was exploding with annual growth of thirty to forty percent. Project 908, based in state owned enterprise Huajing in Wuxi, finally began producing and selling in 1998 and 1999 with

the help of the Taiwanese managers at CSMC (Huajing's partner), using the foundry model. By 2000, Huajing was indeed producing the highest quantity and widest variety of discrete devices in China, as well as producing a limited volume of integrated circuits.⁴⁷⁰

Project 909's Huahong-NEC also began selling products in 1999. China's key enterprises (mostly Sino-foreign joint ventures) were also in production by the late 1990s.

Nonetheless, by 2000, these China-based producers were still about ten years behind the global leading technology, and they were struggling to supply even perhaps 10 percent

⁴⁶⁹ Denis Simon, "Critical Threshold."

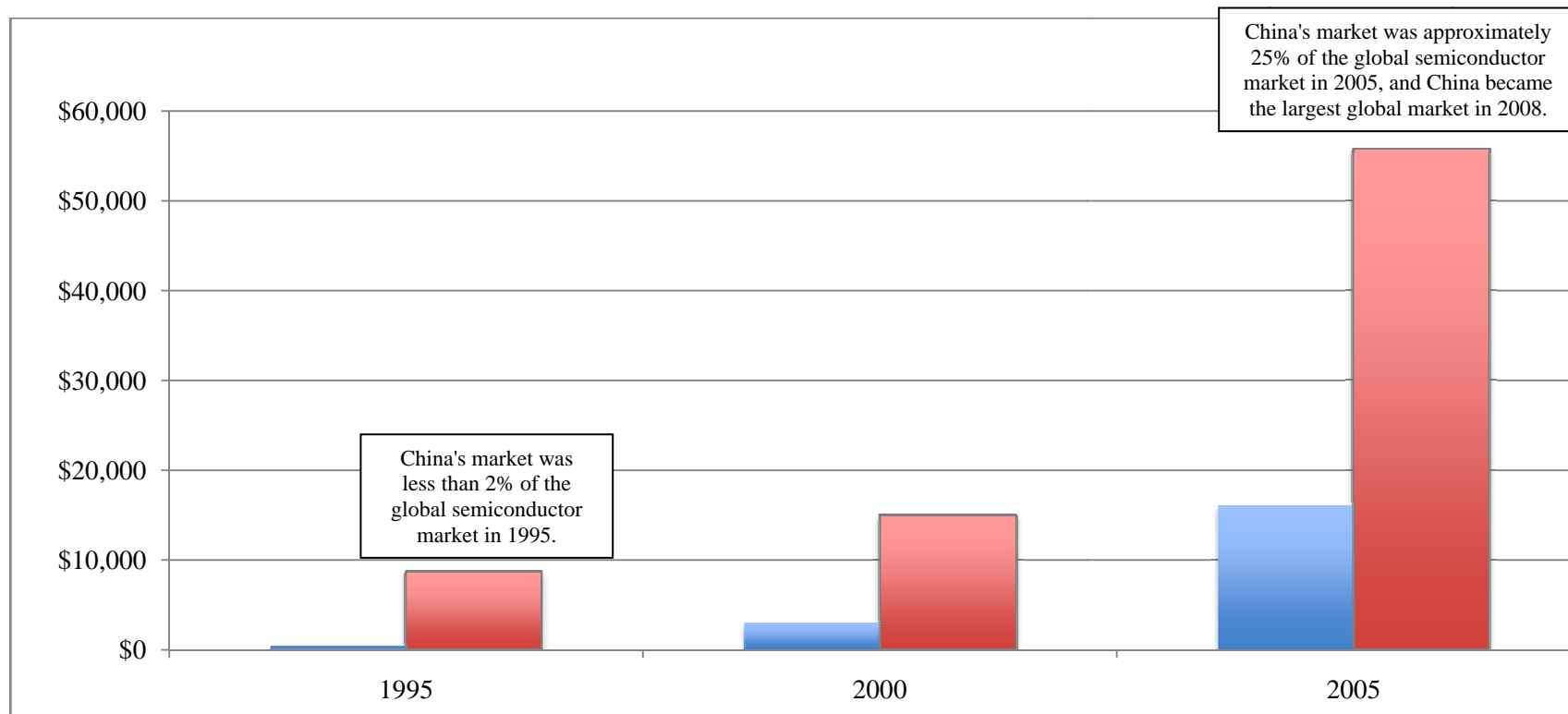
⁴⁷⁰ Wang, "China's Huajing."

(estimates vary) of China's rapidly expanding market, see Figure Eight. The key enterprises, Huajing, and Huahong-NEC were making strides, but Chinese officials still believed that the China's government needed to support the industry's growth through targeted initiatives.⁴⁷¹

Learning from Huajing's and Huahong-NEC's experiences and seeking further global integration, China's next major state supported project would be a semiconductor enterprise called Semiconductor International Manufacturing Corporation (SMIC, *Zhongxin Guoji*, 中心国际.) SMIC would utilize the foundry model from its inception and be China-based but established as a wholly foreign owned enterprise (W.F.O.E.), registered in the Cayman Islands. SMIC was considered by both foreign observers and Chinese industry leaders to be a national champion enterprise for China that was capable of competing in the global industry. The primary goals for SMIC were to increase semiconductor production within China, to advance managerial and technological levels, and to further integrate China's semiconductor

⁴⁷¹ Could China's large and growing market for semiconductors have fostered the emergence of more semiconductor production without government support? In the case of the semiconductor industry in the 1990s, Chinese leaders believed that targeted state support for the industry was necessary due to the high capital costs, the technological complexity, and China's difficult operating environment, including high import costs, lack of legal protection for I.P., etc.

Figure 8: China's Estimated Semiconductor Production (blue) and Market (red), in US\$ millions



This graph is constructed from the following sources:

1) PWC, "China's Impact on the Semiconductor Industry, 2004, 2006, and 2012," data sources include China Semiconductor Industry Association, CCID, and PwC analysis.

2) Wang Yangyuan and Wang Yongwen 王阳元 and 王永文, *Wo Guo Jichengdianlu Chanye Fazhan Zhilu: cong Xiaofei Daguo Zouxiang Chanye Qiangguo* 我国集成电路产业发展之路：从消费大国走向产业强国 (China's Integrated Circuit Industry Development Path: From a Big, Consuming Nation to a Strong, Industrial Nation), Kexue Chubanshe 科学出版社 (Science Press), 2008, page 123, per CSIA.

Note: The PWC analyses uses data from CSIA and CCID, both associated with China's Ministry of the Information Industries.

The data includes all enterprises operating in China, including foreign enterprises, not just Chinese owned or state owned enterprises.

industry with the global industry. (Technically, SMIC would be a competitor of Huahong-NEC, but because Huahong-NEC had the domestic I.C. card market and NEC's customers, the two enterprises initially were not directly competing for the same customers.) SMIC was neither an unequivocal success nor an unequivocal failure, but its development and contributions were – and remain – important to the semiconductor industry in China. Like Huajing and Huahong-NEC, the history of SMIC demonstrates how Chinese leaders sought to advance a critical, high technology industry.

Because SMIC was and remains an international company, publicly available sources such as annual reports, industry reports, and articles cover much of its development. This section also makes use of accounts from SMIC cofounder and former Chairman Wang Yangyuan from his book *“China's Integrated Circuit Industry Development Path: From a Big, Consuming Nation to a Strong, Industrial Nation.”*⁴⁷² Prof. Wang was a Director of SMIC from 2001 and was named Chairman in 2005. From 1999 (if not earlier), Prof. Wang worked with several overseas ethnic Chinese to cofound SMIC, including Richard Chang of the U.S. and Taiwan. Richard Chang was the better-known of the SMIC cofounders, and he was C.E.O. of SMIC from 2000 to 2009. Mr. Chang agreed to an interview for this study in 2009, but he cancelled the interview on short notice. As we will see, 2009 was a tumultuous year for Mr. Chang at SMIC, and he ultimately resigned later that year.

⁴⁷² As an academican of the Chinese Academy of Sciences and Dean of the Institute of Microelectronics at Peking University, Wang is a leading scientist in China. His lengthy book primarily covers the minutia of technical advances in semiconductor technology, but he also includes the history of the global industry, and later in the book, he recounts the experiences of SMIC as well as other major national semiconductor projects. See, Wang Yangyuan and Wang Yongwen 王阳元, 王永文, *Wo Guo Jichengdianlu Chanye Fazhan Zhilu: Cong Xiaofei Daguo Zouxian Chanye Qiangguo* 我国集成电路产业发展之路：从消费大国走向产业强国 (*China's Integrated Circuit Industry Development Path: From a Big, Consuming Nation to a Strong, Industrial Nation*), Kexue Chubanshe Science Press 科学出版社 (Science Press), 2008.

4.31 The Origins of SMIC

China's first successful example of cooperation with ethnic-Chinese from Taiwan in the semiconductor industry had been Huajing's work with CSMC. In the late 1990s, with CSMC-Huajing and Huahong-NEC underway, the Chinese government was on the verge of issuing new tax and investment policies for the semiconductor and software industries via Document #18 in June 2000. Well aware of the upcoming policy changes under Document #18, Wang Yangyuan began to work with Richard Chang and other overseas ethnic Chinese semiconductor experts to found SMIC. Established in April of 2000 in Shanghai, SMIC was to be a high volume, high technology foundry.

The founding and development of SMIC is closely tied to SMIC cofounder and first C.E.O., Richard Chang of Taiwan and the U.S. Richard Chang (also called Zhang Rujing and Ru Gin Chang) was born in Nanjing, China, but went to Taiwan before his first birthday when the CCP took control of the mainland in 1949. He was thus raised and educated in Taiwan, though he later came to the U.S. to pursue a master's degree in engineering. After graduate school, he joined U.S.-based Texas Instruments where he remained for about twenty years. Notably, Richard Chang was responsible for establishing six new semiconductor fabrication facilities in Asia and Europe during his time at Texas Instruments. After leaving Texas Instruments in 1997, Mr. Chang returned to Taiwan and, backed by investors, he founded Worldwide Semiconductor Manufacturing Company (WSMC), which was essentially a semiconductor foundry. Between 1997 and 2000, in the space of just two to three years, Richard Chang commenced operations at WSMC and sold it to Taiwan's largest foundry

company, Taiwan Semiconductor Manufacturing Corporation (TSMC.)⁴⁷³ TSMC had been founded by another former Texas Instrument's executive from Taiwan, Dr. Morris Chang (no relation to Richard Chang.) The two men's tenure at Texas Instruments overlapped, but according to Morris Chang, Richard Chang was "several levels below me at Texas Instruments," and they did not know one another well at that time.⁴⁷⁴ After WSMC, Richard Chang's next venture would be SMIC in mainland China.

China's market for semiconductors continued to expand, but the global semiconductor industry went into another slump in 2000. (Recall that the previous cyclical downturn was in 1997.) From 2000 to 2001, global industry revenue decreased by more than thirty percent, and global expenditures on capital equipment were also significantly down.⁴⁷⁵ It was during this downturn that Chinese semiconductor leaders supported the establishment and construction of SMIC. China's central government and the Shanghai municipal government both offered SMIC preferential policies for land and other benefits.⁴⁷⁶ Owing to SMIC's construction and other semiconductor production upgrades, from 2000 to 2001, equipment expenditures in China increased by 113 percent, in stark contrast to the global industry decline in capital expenditures.⁴⁷⁷ To avoid Wassenaar restrictions,⁴⁷⁸ SMIC imported eight inch

⁴⁷³ Bruce Einhorn and Morris Chang (interview script), "China's Fabless Appeal," *Businessweek*, September 22, 2002.

⁴⁷⁴ Ibid.

⁴⁷⁵ Wilson Yu (former General Manager of CSMC-Huajing), "China Now: CSMC's Experience as the Pioneer Open Foundry in China," *Future Fab International*, Issue 12, 2001.

⁴⁷⁶ Interview with Prof. Yang, June 8, 2009, in Shanghai. Prof. Yang (retired) was formerly with a Fudan microelectronics-related institute.

⁴⁷⁷ Nasa Tsai (President of Grace Semiconductor), "China: An Emerging Centre for Semiconductor Manufacturing," *Future Fab International*, July 8, 2002. Yu, "China's I.C. Industry, the Status Quo and Future."

production equipment from the Netherlands, Sweden, Belgium, and Japan and commenced production in 2002.⁴⁷⁹

SMIC, headquartered in Shanghai but registered and incorporated in the Cayman Islands, was initially led by Richard Chang.⁴⁸⁰ Chang recruited a team of engineers and production managers from China, Taiwan, the U.S., Singapore, South Korea, and other countries. To attract both domestic and foreign experts, new recruits were offered stock options as well as an array of amenities on the SMIC campus including high quality employee apartments, an English-Chinese school for employees' children, and other services.⁴⁸¹

SMIC's initial funding is reported to have been US\$1.48 billion,⁴⁸² with US\$1 billion in equity finance and US\$480million in loans from Chinese banks.⁴⁸³ As a W.F.O.E., SMIC initially raised several rounds of international funding from sources such as Motorola, Goldman Sachs, and Walden.⁴⁸⁴ Wang suggests that funding from Chinese banks came only after raising international capital, but Richard Chang mentioned borrowing from Chinese

⁴⁷⁸ The Wassenaar Arrangement was a post-Cold War agreement that restricted high technology, dual-use exports to China.

⁴⁷⁹ PriceWaterhouseCoopers, "China's Impact on the Semiconductor Industry," 2004, page 31.

⁴⁸⁰ Zhu, *Wenji*, page 165. Around the same time, China's government also allowed the establishment of Grace Semiconductor Manufacturing Corporation (*Hongli Bandaoti Youxian Gongsi* 宏力半导体有限公司), which also had Taiwanese management. SMIC and Grace are often mentioned together, although SMIC was considered a national champion enterprise. See Chapter Five for more on Grace.

⁴⁸¹ Evelyn Iritani, "China on Road to Power in Chips," *Los Angeles Times*, October 28, 2002.

⁴⁸² Japer Moiseiwitsch, "Superfab," *Financial Technology Asia*, May 2001.

⁴⁸³ SMIC, "SMIC Annual Results 2004," accessed at http://www.smics.com/attachment/2011012017321517_en.pdf. Interview with Prof. Yang, June 8, 2009. Also, Mure Dickie, "Pioneering SMIC Leads the Chip Exodus to China," *Financial Times*, November 13, 2001.

⁴⁸⁴ Before going public, over forty percent of SMIC shares were held by the following investors: Motorola, Global Growth Fund and International Equity Income Fund, Beida Jade Bird Software System Company, Asia Pacific Associates III, Goldman Sachs, Platinum Creative Group Ltd., Integrated Silicon Solution, Inc., and Pacven Walden Management. See "SMIC Prospectus," March 11, 2004, accessed at www.smics.com/attachment/201101271459162_en.pdf.

banks before production had even commenced at SMIC. In October of 2001, Chang commented "The [Chinese] authorities said how much money we could borrow and from which Chinese banks."⁴⁸⁵ SMIC's initial US\$480 from Chinese banks is similar in size to Huahong's initial US\$500 million, but SMIC had far more capital than Huahong from international sources. After two years in production, in March of 2004, SMIC went public, raising another US\$1.017 billion and listing on the New York and Hong Kong stock exchanges.

Like Huahong-NEC, SMIC benefitted from preferential policies from China's central and local governments. Shanghai offered SMIC the standard incentives offered to high technology firms including, for example, a five year tax holiday and another five years at fifty percent of standard tax rates. SMIC was also granted a reprieve on tariffs and was required to pay only a small portion of China's 17 percent V.A.T.⁴⁸⁶ With locations in Shanghai as well as Beijing and Tianjin,⁴⁸⁷ SMIC was later asked by local government officials in Shenzhen, Chengdu, and Wuhan to work with these cities to manage semiconductor facilities. A Harvard Business School case study on this arrangement said: "[Richard] Chang was very committed to a strategy that leveraged the desire of cities within China, as supported by central government policies, to build clusters of high tech companies. By partnering with those cities to build new semiconductor fabrication facilities that SMIC would then operate under contract, [SMIC] could build scale without necessarily confronting immediate large

⁴⁸⁵ "New Plants Open on Fertile Ground," *Financial Times*, October 16, 2001. The article went on to say: "Mr. Chang has noticed another difference to doing business in China compared with Taiwan; he had had to employ eleven public relations officers to keep local officials informed, compared to just one in Taiwan."

⁴⁸⁶ Dickie, "Pioneering SMIC."

⁴⁸⁷ SMIC's Tianjin facility was purchased from Motorola, see Chapter Five.

capital outlays.”⁴⁸⁸ Chang referred to this type of partnering as a “reverse B.O.T.” model, where B.O.T. refers to the “build, operate, transfer” model. In the B.O.T. model, typically a private company builds and operates a civil infrastructure project, e.g., a transit system, and later transfers the system to a municipality. SMIC, however, partnered with Chengdu, Wuhan and Shenzhen to execute a “reverse B.O.T.” In the reverse B.O.T., the cities built semiconductor fabrication facilities, SMIC managed the facilities, and later the cities sold the facilities to SMIC. SMIC C.E.O. Richard Chang explained: “Initially the depreciation [on semiconductor facilities] is so high, the record for the large foundries so far has been that it is almost impossible to be profitable during the first seven years. So if we do a reverse B.O.T., it makes more sense.”⁴⁸⁹ This type of partnering allowed SMIC to expand its operations rapidly throughout China.

4.32 SMIC’s Results

SMIC made headlines in the global industry. In only its second year of production, SMIC was named a “Top Fab of the Year” in 2003 by *Semiconductor International*, a leading global industry journal.⁴⁹⁰ SMIC initially produced mostly memory chips (DRAM), but over the years the firm migrated to producing more complex logic chips. SMIC’s global clients included former clients of WSMC (which had merged into TSMC in 2000),⁴⁹¹ but SMIC also produced semiconductors for Chinese design houses. Indeed, as early as 2001, Chinese

⁴⁸⁸ Willy Shih, “Semiconductor Manufacturing International Corporation: ‘Reverse BOT’,” Harvard Business School (case study), January 2009, page 2.

⁴⁸⁹ Richard Chang quoted in Shih, “Reverse BOT,” page 7.

⁴⁹⁰ *Semiconductor International*, May, 2003.

⁴⁹¹ Kessler, “Capital Accumulation,” page 95-96.

design houses migrated to 0.18 μ m technology, in part due to SMIC's burgeoning capabilities.⁴⁹² SMIC began production in 2002 with 0.5 μ m technology, but had rapidly upgraded to 0.18 μ m. By 2006, SMIC's production represented 40 percent of all integrated circuit production in China. That year, SMIC held six percent of the global chip market, ranking third among all global foundries in terms of global market share. According to Richard Chang of SMIC, U.S. export controls and Taiwan restrictions against semiconductor investments in mainland China actually helped SMIC to capture more of China's domestic market in the early 2000s, as competing firms were somewhat stymied in setting up operations.⁴⁹³

Yet, these macro results must not obscure major problems that SMIC encountered, namely being unprofitable most years from 2003 and being the target of numerous lawsuits (detailed in Section 4.34.) Semiconductor fabrication facilities are commonly not profitable in their early years due to high capital costs and depreciation of equipment, but industry personnel have charged that SMIC was not well managed financially. Netherlands-based ASML is a leading global equipment supplier that worked regularly at SMIC's Chinese sites as a primary equipment and maintenance provider. Executives at ASML were critical of SMIC management. "[C.E.O. Richard] Chang wants more money [from the Chinese government] to expand, but he does not run the business well... SMIC fails due to too much government support, asset utilization problems, and slow implementation. If equipment breaks, SMIC will not pay the costs to fix it,"⁴⁹⁴ leading to low equipment utilization rates,

⁴⁹² S. Chen, G. Liu, V. Lee, J. Xie, "Rising to the Challenge: China's New Semiconductor Industry," *Future Fab International*, February 2, 2002.

⁴⁹³ Shih, "Reverse BOT."

⁴⁹⁴ Interviews with Fred Knijnenburg and Joseph Chen of ASML on April 11 and June 29, 2009 in Wuxi.

which are damning in the semiconductor industry. Morris Chang, founder of Taiwan's TSMC said "[Richard Chang] is basically a fab starter. He has a lot of expertise in building a fab. That was all he did at Texas Instruments. And basically that's what he did as WSMC. [Almost] as soon as he built the WSMC fab, it was sold to us [TSMC]. His experience does not encompass running a fab, much less making money from it. [Building a fab and running a fab] are quite different things."⁴⁹⁵

SMIC had succeeded in operating as a W.F.O.E. in China with international capital, management, talent, technology, and quality, but the migration to Mainland China of these assets – both tangible and intangible – was not without obstacles. At this juncture, we must consider SMIC's connections to Taiwan and Taiwan's TSMC.

4.33 Taiwan's Semiconductor Industry

As Chinese leaders sought to develop the semiconductor industry in China, they were well aware of the successful evolution of the semiconductor industry in Taiwan. Indeed, they looked upon Taiwan as something of a model for how to develop the industry in China.⁴⁹⁶ In Taiwan, the semiconductor industry received support from Taiwan's government and grew in large part through international funding and management. Starting from 1963, a number of U.S. companies established semiconductor operations in Taiwan, and in the 1960s and 1970s, Taiwan's government supported the semiconductor industry through new university courses, industry infrastructure, and by providing the capital to build an advanced

⁴⁹⁵ Bruce Einhorn and Morris Chang (interview script), "China's Fabless Appeal," *Businessweek*, September 22, 2002.

⁴⁹⁶ Chapter Six compares the history of the semiconductor industry in China to that of Japan, South Korea, and Taiwan more fully.

fabrication facility. This facility ultimately became an operational company in 1980, called United Microelectronics Corporation (UMC). UMC went on to become – and it remains – a leading global semiconductor company. Building on this, in 1987, the government of Taiwan invited Dr. Morris Chang, a Taiwan-born executive at U.S.-based Texas Instruments, to return to Taiwan. With investment from Netherlands-based Philips, Dr. Chang founded Taiwan Semiconductor Manufacturing Company (TSMC), which would originate and dominate the foundry model. At this writing, TSMC and UMC of Taiwan remain the world’s two largest semiconductor foundries. Through government support and international cooperation, the contemporary semiconductor industry in Taiwan became a major global player over the course of about 30 years, from the early 1960s to the early 1990s. According to a study by Rand, from the 1970s, “The Taiwanese government sought to foster the industry, though not to create a nationalized industry.[And] by the early 1990s, Taiwan was [technologically] only one year behind the global vanguard.”⁴⁹⁷

Despite Mainland China’s rapidly growing market for semiconductors in the 1990s, Taiwan’s semiconductor firms could not easily establish operations on the mainland. Taiwanese firms wanted to set up operations on the mainland in order to be closer to customers and to avoid import costs. However, due to political tensions between China and Taiwan, China’s government restricted foreign investment from Taiwan, and the government of Taiwan restricted investment in the semiconductor industry on the mainland. The government of Taiwan did not want to see its high technology, high value semiconductor industry migrate to the mainland. Taiwan’s leaders feared that if Taiwanese semiconductor

⁴⁹⁷ Rand National Defense Research Institute (J. Mulvenon, M. Chase, K. Pollpeter), “Shanghai-ed?: The Economic and Political Implications of the Flow of I.T. and Investment Across the Taiwan Strait,” 2004, pages

firms established fabrication facilities (foundries) in China, then Taiwanese design houses and P.A.T. firms would quickly follow to work with the foundries. In this way, Taiwan's whole semiconductor industry chain might migrate to the mainland.

Facing investment restrictions from their own government, TSMC, UMC and other Taiwanese firms lobbied to be allowed to invest in new operations on the mainland. Due in large part to this lobbying, in 2002, the Taiwanese government finally loosened restrictions on semiconductor investments in China.⁴⁹⁸ However, because of the growth in China's semiconductor market from the 1990s, certain individuals and groups from Taiwan had already begun to circuitously make semiconductor investments in mainland China even prior to Taiwan's relaxed regulations announced in 2002. Indeed, SMIC's origination in mainland China in the 2000-2001 period under a Taiwanese founder and C.E.O. signaled potentially illicit investments.

4.34 SMIC's Legal Disputes with Taiwan and TSMC

In the 2000s, the government of Taiwan and TSMC filed suits against Richard Chang and SMIC alleging illegal investments in mainland China as well as intellectual property theft by SMIC from TSMC. As we will see in Chapter Five, these lawsuits did not diminish Taiwanese firms' overall interest in expanding into mainland China, but they did cause both reputational and financial problems for SMIC.

As a citizen of Taiwan, Richard Chang was under Taiwan's restrictions on semiconductor investments in mainland China, and the government of Taiwan ultimately brought three lawsuits against Chang personally for illegal investments based on his work

⁴⁹⁸ Ibid. Dr. Chang's TSMC applied for permission to invest in Mainland China that same year, page 100.

with SMIC.⁴⁹⁹ In 2005, Taiwan's government fined Chang US\$155,000 and ordered him to withdraw his semiconductor-related investments in mainland China. Chang, however, did not pay the fine, and the Taiwanese government was not able to seize his assets because it could not prove that Chang was SMIC's "main investor."⁵⁰⁰ Following these legal disputes, Richard Chang renounced his Taiwanese citizenship in 2005.⁵⁰¹

In addition, SMIC faced several lawsuits from TSMC and ultimately had to pay over US\$450 million in financial and equity settlements. SMIC was first sued by TSMC in 2003 and 2004 for patent infringement and trade secret misappropriation.⁵⁰² Recall, Richard Chang sold WSMC to TSMC in 2000, but in that very same year, Richard Chang cofounded SMIC in mainland China. The overlap in timing raised questions. In 2003, TSMC accused SMIC of hiring more than 100 TSMC employees, obtaining trade secrets, and producing chips based on patented technology.⁵⁰³ Ultimately, TSMC won a settlement of US\$175 million from SMIC in 2005 for trade secret and patent violations. In 2006, TSMC and SMIC filed complaints and counter complaints, respectively, with SMIC alleging a global smear campaign by TSMC. In 2009, TSMC was awarded another US\$200 million in a case against SMIC. In that ruling,

⁴⁹⁹ Shih, "Reverse BOT."

⁵⁰⁰ "SMIC Founder and C.E.O. Richard Chang Resigns," *Taipei Times*, November 11, 2009.

⁵⁰¹ An outspoken Christian, Chang has said that his decision to go to Mainland China was more than just economic. "China is a good place in many aspects. The market is huge. Manufacturing costs are competitive. The pool of talent is also very good.But frankly, I was thinking about how I could share God's love with the Chinese more than how I could help the economy,"^{see} Evelyn Iritani, "China on Road to Power in Chips," *Los Angeles Times*, October 28, 2002. Many of the initial international team recruited to SMIC were ethnic-Chinese Christians, and the SMIC campus in Shanghai includes a church. Christianity was and remains a mainstay of SMIC's culture. As an example, the final page of a SMIC presentation titled "China I.C. and SMIC Progress" (presented October of 2004, by Samuel Wang, the President of SMIC Americas) was a biblical psalm: "You can make a difference. The joy of the Lord is your strength. Unless the Lord builds the house, its builders labor in vain..."

⁵⁰² "*TSMC v. SMIC*," 161 Cal. App. 4th 581, 74 Cal. Rptr. 3d 328, accessed online via LawLink in 2011.

⁵⁰³ Mure Dickie, "Taiwanese Chipmaker Files I.P. Protection Suit," *Financial Times*, December 23, 2003.

SMIC also had to issue TSMC approximately US\$90 million worth of shares and warrants.⁵⁰⁴

These settlements coupled with SMIC's lack of profitability led to Richard Chang's resignation from SMIC in 2009.

4.35 SMIC's Contributions to the Industry

SMIC itself achieved significant results, i.e., being the 3rd largest global foundry by 2006, but it also faced financial and legal challenges. Despite these mixed outcomes as a firm, SMIC arguably made positive contributions to the development of the overall semiconductor industry in China during its first five years in operation, 2002 to 2007. The two most important areas in which SMIC contributed to the industry are China's talent pool and international integration. As for the talent pool, SMIC created hundreds of high technology jobs and provided personnel with extensive formal training. And, according to former SMIC Chairman Wang Yangyuan, SMIC fostered possibly thousands of jobs in other organizations throughout the semiconductor value chain. Examples of SMIC's contributions include:⁵⁰⁵

- Jobs: Provided approximately 12,000 jobs at SMIC.
- Training and Support: Offered around 500 courses each year; funded continuing education and conference attendance; provided high quality housing, bilingual schooling, and other infrastructure for employees' families; and offered about 10 percent of SMIC's equity to employees.
- Advancing Technology: Hired hundreds of research and development staff, e.g., approximately 800 in 2007, leading to technological advances, such as SMIC's adoption of nano level process technology in 2005. Joined cooperative projects with Chinese universities and research institutes.

⁵⁰⁴ Don Clark, "SMIC's C.E.O. Resigns after TSMC Settlement," *Wall Street Journal*, November 11, 2009.

⁵⁰⁵ Wang and Wang, *Wo Guo Jichengdianlu Chanye*, pages 299-302.

- *Fostering the Industry Chain:* Cultivated the equipment, materials, design, and P.A.T. sectors. SMIC may have indirectly created 30,000 to 40,000 jobs throughout the industry value chain. For example, by 2007, forty percent of SMIC's revenues were from design houses, and more than a third of this forty percent was from domestic Chinese design houses.

In terms of international integration, SMIC created a China-based enterprise with international standards, using international (and domestic) sources for technology, capital, talent, and markets. Some examples include:⁵⁰⁶

- *Technology:* Developed technical partnerships with foreign companies, including Toshiba, Fujitsu, Chartered, IMEC, Infineon, Freescale, IBM, etc.
- *Capital:* In 2001, issued preferred stock and raised US\$1.1 billion; between 2001 and 2004 raised two rounds of private equity funding; in 2004, went public raising US\$1.8 billion; after 2004, got loans from international, as well as Chinese state owned banks.
- *Management and Talent:* Used international management practices and hired about 15 percent of its work force from overseas, e.g., Taiwan, the U.S., Singapore, South Korea and other nations. In 2005, SMIC had 8,342 employees of which 1,079 were from overseas. Over 100 were alleged to have been former Taiwan-based TSMC employees, and perhaps over 200 were from the U.S.⁵⁰⁷
- *Clients:* Maintained long term client relationships with foreign and domestic clients, including (by 2007) eight of ten of the largest global semiconductor companies.

At this writing, it is too soon to fully assess SMIC's role in the evolution of the semiconductor industry in China. However, since Richard Chang's resignation in 2009, SMIC has retained its position as the leading foundry in China (by revenue) as well as its unique identify as a W.F.O.E. national champion for China. SMIC's leadership and investors

⁵⁰⁶ Ibid., pages 302-304.

⁵⁰⁷ Henry Chesbrough, "Open Innovation in China," Presentation to the Stanford Program on Regions of Innovation and Entrepreneurship, 2005. Also, Monique Chu, "Controlling the Uncontrollable: Migration of Taiwanese Semiconductor Industry to China and Its Security Implications," presentation to European Association of Taiwan Studies, 2006, page 4 and footnote 12.

continue to be both international and Chinese. After Chang's departure in 2009, David Wang, a Taiwanese former Chairman of Huahong-NEC and a former executive at Applied Materials (a major U.S. semiconductor company), was named C.E.O. of SMIC. Two years later, Dr. Tzu-Yin Chiu, a former C.E.O. of Huahong-NEC, was named C.E.O. of SMIC. Dr. Chiu had held senior positions at Huahong, SMIC, and TSMC during his career, and he was educated and began his career in the U.S. at AT&T Bell Labs.⁵⁰⁸ As for investors, SMIC continued to have international shareholders, including TSMC, as well as significant investment from state owned Chinese organizations, primarily Datang, a major state owned enterprise group, and CIC, a Chinese sovereign wealth fund.⁵⁰⁹

4.4 State Led Development and National Champion Enterprises

Chapters Three and Four have examined the origins, nature, and evolution of China's national champion enterprises in the semiconductor industry, a critical high technology industry. This section considers state led development and state support for favored large enterprises, sometimes called national champions, in Japan, South Korea, Taiwan, and China

⁵⁰⁸ Mark Osbourne, "SMIC Appoints Huahong-NEC Executive as New C.E.O.," *Photovoltaics International*, August 2011.

⁵⁰⁹ Interview with Ye Tianchun, July 3, 2009, at the CAS Institute of Microelectronics in Beijing. Ye was the Director of the Microelectronics Institute in 2009 and a top advisor on national semiconductor industry policies. Chinese state-owned enterprise group Datang invested US\$171.8 million in SMIC in 2008 for a 16.6% interest in the company, per "SMIC Signs Cooperative Agreement With Datang," *TechSecurityChina*, January 12, 2009. In April of 2011, (CIC) China Investment Corp., China's sovereign wealth fund, agreed to invest \$250 million in SMIC, per SMIC, "SMIC to Receive Investment from CIC," April 19, 2011, as well as other industry sources.

itself. From this, we can consider the role of state led development and national champion enterprises in the semiconductor industry in China.⁵¹⁰

4.41 State Led Development and National Champions in East Asia

In late developing economies in the 20th century, states took specific measures to foster industrialization and economic growth.⁵¹¹ Alexander Gerschenkron's works in the 1950s and 1960s on Europe suggested that the relatively "backward" nations of Europe had a different development trajectory than already developed nations. In backward nations, the state had to intervene to compensate for the lack of technology, capital, and skills.⁵¹² In light of Japan's rapid development in the 1960s and 1970s and South Korea and Taiwan's in the 1980s and 1990s, scholars have sought to understand the state's role in industrialization in East Asia. As just one indicator of how rapidly these economies grew, according to Robert Wade's 1990 study, per capita gross national product rose by more than twenty times for Japan, South Korea, and Taiwan and by more than fifteen times for Hong Kong and Singapore in the 25 years between 1962 and 1986.⁵¹³ In each of these nations, the state used a

⁵¹⁰ Chapter Six (Conclusions) compares the development of the electronics and semiconductor industries in China with the development of these industries in Japan, South Korea, and Taiwan.

⁵¹¹ Late industrializers include not only the East Asian nations mentioned in this study but also Brazil, Turkey, India, Mexico, and perhaps others. That said, state support for industrialization is not entirely new in the 20th century. Britain, Germany and the U.S. all used certain protection policies during their initial periods of industrialization; for a discussion of this see Nolan, "Beyond Privatization," pages 177-178.

⁵¹² Alexander Gerschenkron, *Economic Backwardness in Historical Perspective* (Cambridge: Harvard University Press, 1962). Gerschenkron challenged the "generalization...[that] the history of advanced or established industrial countries traces out the road of development for the more backward countries." Instead, backward countries "showed considerable differences...with regard to the productive and organizational structures...These differences were to a considerable extent the result of application of institutional instruments for which there was little or no counterpart in an established industrial country." Backward states had to assist their industries in acquiring foreign technology and skills to foster capital intensive, large-scale production. See Gerschenkron's Introduction, pages 6-7.

⁵¹³ Robert Wade, *Governing the Market: Economic Theory and the Role of Government in East Asian Industrialization* (Princeton: Princeton University Press, 1990), Chapter Two.

number of interventions to foment growth, and scholars have thus examined the interplay between industrial policy and economic growth, i.e., “state led development,” including the state’s support of certain large enterprises.⁵¹⁴ Sometimes called national champions, these large enterprises were typically expected to become internationally competitive. In the last twenty years, China too has been the focus of numerous studies related to state led development. A brief review of influential works on state led development in Japan, South Korea, Taiwan, and China will enable us to consider how this industry specific study adds to or changes our understanding of state led development and national champion enterprises in China.

Chalmers Johnson’s 1982 *MITI and the Japanese Miracle* termed Japan a “developmental state,” owing to certain institutions and norms of Japan’s government. This developmental state had emerged ad hoc during the 20th century as a result of Japan’s late

⁵¹⁴ Not everyone is convinced that state led development was the primary cause of rapid growth in East Asia. The neoliberal, orthodox view challenges the results of industrial policies in East Asia, arguing instead that the rapidly developing nations of East Asia in the latter half of the 20th century “got the fundamentals right” and relied largely on market orientation and trade liberalization. The orthodox view typically identifies macroeconomic stability, market orientation, trade liberalization, entrepreneurialism, resource allocation, private ownership, and advances in human capital as the primary drivers of growth in East Asia and elsewhere. This view, sometimes called the Washington Consensus, voices much less support for state interventions and industrial policies, arguing the difficulty of proving causation between state interventions and growth. The World Bank’s 1993 *The East Asian Miracle: Economic Growth and Public Policy* took the orthodox position. The report analyzed eight Asian nations and identified macroeconomic stability, human resource development, capital accumulation and allocation, and market-friendly policies as the primary reasons for their economic growth. The report said “industrial policy has generally not been successful” (page 261), citing lower productivity growth rates in some targeted industries and market conforming outcomes, connoting that the industrial policies did not have significant effects beyond what would have occurred without state intervention. To the extent that state led development might have made contributions in East Asia, the orthodox view suggests that benefits were contingent, succeeding in some cases and failing in others. Generally, the orthodox view holds that business-government relations in East Asia have too often led to corruption and inefficiency, and that, since the late 1990s, East Asian nations (except perhaps China) are generally moving away from strong interventionist policies. Beyond East Asia, the neo-liberal perspective generally suggests that government interventions in industry and trade should be limited, where “interventions” might include restrictive tariffs or special requirements for foreign firms such as requiring foreign firms to offer certain export levels, technology transfer, R&D, joint ventures, local content purchasing, etc. See World Bank, *The East Asian Miracle: Economic Growth and Public Policy*, 1993 and Robert Wade, *Governing the Market: Economic Theory and the Role of Government in East Asian Industrialization* (Princeton: Princeton University Press, 1990 and 2003), pages xiii-xiv, xliii-xlv.

development relative to the West and the Japanese government's various efforts to promote economic growth. Japan's government and especially its central Ministry of International Trade and Industry (M.I.T.I.) fostered the growth of Japan's economy through industrial policy that influenced industries and large diversified business groups called *kereitsu*. Industrial policy utilized various "protective" tactics (e.g., tariffs, import restrictions, etc.) and "nurturing" tactics (e.g., low interest government funding, exclusion from import duties on critical equipment, industrial parks, etc.), as well as fostering oligopolistic competition between *kereitsu*.⁵¹⁵ Johnson argued that Japan's economy benefited from low cost exports (dating as early as the late 19th century with Japan's entry into the global textile trade), but the primary source of Japan's growth in the 1960s and 1970s was industrial investment in foreign technology, as planned and administered by M.I.T.I. Johnson described the Japanese state as having an explicitly developmental orientation as opposed to having a regulatory orientation, like the United States. Unlike the U.S. government, Japan's government and M.I.T.I. were concerned with which industries ought to exist, how they should be organized, and even how individual enterprises should operate.

Alice Amsden's 1989 *Asia's Next Giant: South Korea and Late Industrialization* argues that all late industrializers, and certainly South Korea, first and foremost were able to industrialize by *learning*, that is, "they industrialized by borrowing foreign technologies rather than by generating new products or processes, the hallmark of earlier industrializing nations."⁵¹⁶ This learning was explicitly technological (e.g., equipment and processes), but it

⁵¹⁵ Chalmers Johnson, *MITI and the Japanese Miracle: The Growth of Industrial Policy, 1925-1975* (Stanford: Stanford University Press, 1982).

⁵¹⁶ Alice Amsden, *Asia's Next Giant: South Korea and Late Industrialization* (New York: Oxford University Press, 1989), Introduction.

also entailed the rise of capable managers and a better-educated labor force. Amsden contrasts this learning-based development in South Korea with invention and innovation based development in Britain, Germany, and the U.S. in the first and second Industrial Revolutions of the late 18th and 19th centuries, respectively. In the first and second Industrial Revolutions, higher productivity was the result of newly invented (or innovated) technologies, processes, and products.

Amsden's thesis is that late developers could initially leverage low labor costs to grow their exports, but only state support would enable such a nation to move into more technologically advanced industries, which required more capital, but more importantly, more skills and knowledge, i.e., *learning*.⁵¹⁷ Korea was able to compete initially on low wages, but the low-wage-based light industries (textiles, clothing, etc.) that propelled growth in the 1960s in Korea were not able to independently foster the growth of more capital, technology, and skill intensive industries that Korea entered in the 1970s. Korea's Ministry of Trade and Industry and Economic Planning Board directed state subsidies to enable private Korean enterprises to compete in capital and technology intensive industries. State subsidies – predicated on strict performance standards – enabled large diversified Korean enterprises (conglomerates called *chaebols*)⁵¹⁸ to make productivity improvements and quality improvements to products that already existed in global markets.

Notably, Amsden explained that South Korea “got prices wrong,” in contrast to the theoretical market that “gets prices right” by balancing supply and demand. “Getting prices wrong” refers to state financial incentives and interventions to support industries and

⁵¹⁷ Amsden, *Asia's Next Giant*, page 63.

⁵¹⁸ Korea's *chaebols* include internationally known firms such as Samsung and Hyundai.

individual enterprises. State financial interventions addressed some of Korea's contradictory economic needs that were rooted in its relative economic backwardness. Some of the most important contradictions included the need for: 1) low interest rates to stimulate investment, but high interest rates to stimulate savings, 2) undervalued currency to support exports, but overvalued currency to minimize the cost of foreign debt and the cost of imported equipment and materials, and 3) protection for domestic industries, but free trade to get necessary imports and to export Korean-made goods.⁵¹⁹ To address these contradictory needs, the Korean government used state controlled banks and industrial policies to offer, for example, different interest rates for consumers versus investors and different exchange rates for exporters and importers. In this way, the state purposefully “got prices wrong” to stimulate industries, enterprises, and industrial learning, but these state supports were strictly dependent on the *chaebols*' performance and willingness to enter new industries.

Robert Wade's 1990 *Governing the Market: Economic Theory and the Role of Government in East Asian Industrialization* has much to say about the role of markets and the state in Japan and South Korea, but its main focus is Taiwan.⁵²⁰ In Taiwan, state officials were “not all knowing directors, but learning directors,” playing important roles in what Wade calls a “governed market.”⁵²¹ In Taiwan, state policies were intended to spur the transfer of resources away from lower productivity industries (lower technology, more labor intensive industries) into new, more productive industries often through state owned firms. The

⁵¹⁹ Amsden, *Asia's Next Giant*, page 13 and Chapter Six.

⁵²⁰ Wade, *Governing the Market: Economic Theory and the Role of Government in East Asian Industrialization* (Princeton: Princeton University Press, 1990 and 2003), Introduction to the 2003 Edition, page xvii. Another good source on Taiwan's economic history is Dwight Perkins, Li-min Hsueh, and Chen-kuo Hsu, *Industrialization and the State: The Changing Role of the Taiwan Government in the Economy, 1945-1998* (Cambridge: Harvard Institute for International Development, 2001.)

⁵²¹ Wade, *Governing the Market*, 2003, New Introduction to the 2003 Edition, page xvii.

island's policies changed over the years, supporting import substitution in the 1950s, export promotion in the 1960s, "secondary" import substitution (to benefit upstream, capital intensive industries) in the 1970s, and promotion of high technology in the 1980s. Taiwan was home to a number of dynamic small and medium sized firms that operated in part under market conditions, but Wade shows that Taiwan's government made sustained investments in upstream industries, such as plastics, electronics, steel, and shipbuilding, for which smaller firms did not have the technology and capital. Relative to Japan and South Korea, these industrial policies in Taiwan were less centralized, being carried out by a number of ministries and agencies.⁵²²

In Taiwan, a main thrust of state led development was to foster internationally competitive firms in higher productivity industries. This was sometimes called "picking winners."⁵²³ Enterprises in targeted industries, e.g., heavy industry and high technology, benefitted from state investments. Favored enterprises also benefited from import substitution policies (but not necessarily protection) and export promotion policies, which were assisted by an undervalued currency and export processing zones. Government policies also supported education, technology, and research and development programs, to support favored enterprises in new, encouraged industries. Further, Taiwan's government limited the degree to which foreign firms could take ownership in Taiwanese firms, but foreign investment was allowed, especially when it enabled favored Taiwanese firms to acquire foreign technology.

⁵²² Wade, *Governing the Market*, 1990, in particular Chapter Four covers how different heavy and higher technology industries were supported.

⁵²³ As of 2012, the largest Taiwanese global firms are firstly TSMC (semiconductors) and then Hon Hai Precision Industry (commonly known as Foxconn, the massive contract electronics manufacturer), Formosa Petrochemical, Chunghwa Telecom, and Formosa Plastics, see Nell Shen, "Five Taiwanese Companies Listed among World's 500 Largest," *Focus Taiwan*, July 21, 2012.

Indeed Taiwan's government actively supported and coordinated technology transfer programs with global firms, including by reducing taxes on imported equipment.

Other government policies also fostered selected industries. Foreign firms operating on the island were often required to source from local suppliers. Labor mobility was such that a number of Taiwan's relatively well-educated engineers were able to work at foreign affiliated firms and later leave to start new firms of their own. Taiwan's officials also employed informal "nudging" tactics, e.g., encouraging foreign firms to work with local firms in their industry or making strategic suggestions to Taiwanese firms.⁵²⁴ Taken together, Wade sees the state in Taiwan as having played a critical role in moving Taiwan into higher productivity industries and fostering economic growth.

These important studies by Johnson, Amsden, and Wade offer a wealth of both macro data and policy analyses of China's successful neighbors. These studies each essentially cover the entire modern economic history of a nation, as well as global economic history and economic theory, with many chapters on related matters such as "The Economic Bureaucracy" (Wade on Taiwan), and "The Boom in Education" (Amsden on Korea.) Perhaps because their scope is so broad, they necessarily devote less time to events in particular industries.⁵²⁵ Yet from these studies we see that in Japan, South Korea, and Taiwan, industries developed in the context of state led development, which consisted of various state interventions in trade, industrial policy setting, and state investments. These methods were directed at different industries over the decades and were often directed at supporting certain large enterprises,

⁵²⁴ Wade, *Governing the Market*, 2003, New Introduction to the 2003 Edition, page xxii.

⁵²⁵ Ibid., pages 79-108, and Amsden, *Asia's Next Giant*, pages 243-316. Surprisingly, Amsden covers more than five diverse industries in less than seventy pages, and Wade devotes less than thirty pages to a number of industries.

including government assistance for specific technology transfers from abroad. In China, officials looked to their neighbors' methods and accomplishments, as China was just one to two decades "behind" South Korea and Taiwan in its first two decades of reform and opening (1980s and 1990s.)

4.42 State Led Development and National Champions in China

As China sought to develop after 1978, vast state intervention was a pre-existing condition due to China's history of state ownership of enterprises, state led industrialization, and central planning. In the reform era, Chinese officials could not merely chose whether or not the state should intervene in any particular industry, because the state was already deeply involved in most industries. The question was *how* to reform China's bureaucratic-industrial complex. In the 1990s, Chinese officials saw the economic and social dislocations in former Soviet economies that were attempting relatively rapid privatization of the state owned sector before establishing supportive institutions (e.g., law, finance) and services (e.g., marketing, distribution). Chinese officials were also well aware of the contemporary economic histories of Japan, South Korea, and Taiwan, including these nations' promotion of selected large enterprises.

Considering the realities of China's economy and the experience of its successful East Asian neighbors, it was almost inevitable that Chinese leaders would proceed in the 1990s with some forms of state led development or, as it has been more recently dubbed for China, "state capitalism."⁵²⁶ China's leaders seem to have understood the historical role of large

⁵²⁶ Lin and Milhaupt, "We are the (National) Champions,": Understanding the Mechanisms of State Capitalism in China," *Columbia Law and Economics Working Paper*, Number 409, November, 2011.

enterprises in nations and industries around the world,⁵²⁷ and ultimately they sought to create a number of globally competitive large enterprise groups, as had their East Asian neighbors. In 1997 at China's 15th National Congress, President Jiang Zemin advocated that "The state owned sector must be in a dominant position in major industries and key areas that concern the life blood of the national economy..."⁵²⁸ Similarly, in 1998 State Council Vice Premier Wu Bangguo said:

"In reality, ...[history] shows that if a country has several group companies it will be assured of maintaining a certain market share and position in the international economic order. America, for example, relies on General Motors, Boeing, DuPont and a batch of other multinational companies. Japan relies on six large enterprise groups, and South Korea relies on ten large commercial groupings. ...Our nation's position in the international economic order will be to a large extent determined by the position of our nation's large enterprises and groups."⁵²⁹

While reforming and consolidating state owned enterprises across industries in the 1980s and 1990s, China's central government ultimately formed a national team (*guojia dui* 国家队) of over 100 large vertically-integrated enterprise groups (*qiye jituan* 企业集团) in selected industries.⁵³⁰ This was part of China's "grasp the large, let go of the small" approach (*zhua da fang xiao* 抓大放小) in which smaller state owned enterprises were "let go" while

⁵²⁷ Alfred Chandler identified large industrial enterprises as an underlying dynamic in modern industrial capitalism and the importance of the "visible hand" of enterprise management. Alfred Chandler, *The Visible Hand: The Managerial Revolution in America Business* (Cambridge: Harvard University Press, 1977) and *Scale and Scope* (Cambridge: Harvard University Press, 1990).

⁵²⁸ Quoted in Dyland Sutherland, "China's 'National Team' of Enterprise Groups: How Has It Performed?," University of Nottingham, China Policy Institute, Discussion Paper 23, 2007. Dylan quotes from *Selected Documents of the 15th CPC National Congress* (Beijing: New Star Publishing, 1997).

⁵²⁹ Wu Bangguo was an electrical engineer who studied at Qinghua University and worked in electronics prior to attaining high positions in government. Wu attended the early planning meetings for Project 909. He is quoted in Sutherland, "China's National Team." Sutherland's source is *Jingji Ribao*, August 1, 1998.

⁵³⁰ Lin and Milhaupt, "We are the (National) Champions," page 17. In 1987 the government legally defined the "business group." Fifty-seven groups were established in 1991 and another sixty-three in 1997.

larger enterprises were retained, consolidated, reorganized, and technologically upgraded, often through technology transfers from leading global firms. Broadly, the objectives in establishing large enterprise groups included economies of scale, specialization, and cross-enterprise collaboration, but the main priority was – and remains – to foster a group of internationally competitive enterprises to lead China’s integration in the world economy, to create, in effect, national champions.⁵³¹ From 2003, these enterprise groups have been overseen by China’s central State Owned Assets Supervision and Administration Commission (SASAC) under China’s State Council. The SASAC is the controlling shareholder in these groups.

Unlike Japan’s *keiresu* and Korea’s *chaebols*, China’s large enterprise groups have evolved not as diversified groups with member enterprises in different industries, but rather the groups have evolved over the years to be vertically integrated and typically (though not exclusively) operating *within particular industries*.⁵³² (According to Barry Naughton, these enterprise groups actually began as diversified,⁵³³ but over time they have become industry focused.) Here, vertical integration refers to the ownership structure of the enterprise groups. Higher level enterprises have ownership in lower level enterprises, but not vice versa, and member enterprises typically do not have horizontal ownership in other members.⁵³⁴ This use of “vertical integration” does not necessarily suggest that one enterprise or enterprise group

⁵³¹ Dylan Sutherland, *China’s Large Enterprises and the Challenge of Late Industrialization* (London: RoutledgeCurzon, 2003) and “China’s ‘National Team’.”

⁵³² Lin and Milhaupt, “We are the (National) Champions,” pages 13 and 18. In 1998, the Provisional Rules on Business Group Registration better defined the structure and entities of China’s business groups. For examples of these groups and their member enterprises, visit the enterprise group websites from www.sasac.gov.cn.

⁵³³ Barry Naughton, *Growing Out of the Plan* (Cambridge: Cambridge University Press, 1995), pages 299-301.

⁵³⁴ Lin and Milhaupt, “We are the (National) Champions,” page 24. In Japan and South Korea, horizontal cross-ownership among member enterprises was more common, even across industries.

conducts the full value-chain, i.e., R&D-production-distribution, although they may. China's first set of large enterprise groups was formed in 1991, and these were mostly in "backbone" industries such as power and construction. In 1997 officials opted to create a second set of large enterprise groups in industries including automotive, electronics, chemicals, and others, causing China's national team of large enterprise groups to eventually cover many if not most industries. Since, 1997, the list of national team members and the ownership and governance structures of these groups has continued to evolve.⁵³⁵

Because the 100 plus enterprise groups on China's national team each have numerous member enterprises, the total number of enterprises under the national team is in the tens of thousands.⁵³⁶ According to Lin and Milhaupt, China's large enterprise groups often consist of four key components: 1) a core holding company, 2) one or more publicly traded subsidiaries, 3) a finance company, and 4) a research institute.⁵³⁷ These large enterprise groups then own (in full or in part) or are linked with many enterprises in their industry, including state owned enterprises at the provincial and local levels. In recent years, China's state owned sector has been responsible for an increasing share of China's gross domestic product, and this has

⁵³⁵ Sutherland, *China's Large Enterprises*, pages 55-56. In setting policy for the large enterprise groups, Sutherland concluded that China "followed a 'groping for stones' approach, using trial and error, building upon more successful measures." He wrote: "Over the years [the 1980s, 1990s, and into the 2000s], a number of new policies was introduced and spread through an expanded number of trial business groups, including such measures as foreign trade rights, clarification of property rights within the core enterprises, the promotion of technology centres, and stock market listings."

⁵³⁶ These enterprises are now administered by China's State-owned Assets Supervision and Administration Commission (SASAC), under China's State Council. See www.sasac.gov.cn for a current list of the 100 plus large enterprise groups, listed in the Central Enterprises Directory (*yang qi minglu* 央企名录.)

⁵³⁷ Lin and Milhaupt, "We are the (National) Champions," page 14.

prompted renewed attention to China's still-being-defined "state capitalism" and the governance and ownership structures of China's large enterprise groups and their members.⁵³⁸

In China, state led development in the 1990s was primarily evident in the formation and ongoing innovations to large state owned enterprise groups as well as the use of centrally led five year plans, the setting of industrial policies, and extensive state control over industries considered important to national security including telecom, infrastructure industries, and banking. In the 1990s, Chinese officials did not tightly restrict foreign investment, but they definitely directed foreign investment to align with centrally led plans.⁵³⁹ Having defined the broad outlines of state led development in China, we can now consider state led development in the semiconductor industry in China, with special attention to the role of favored enterprises.⁵⁴⁰

4.43 China's Key and National Champion Semiconductor Enterprises

Chinese officials approached semiconductor industry development in the 1990s in ways that broadly reflected state led development in Japan, South Korea, and Taiwan. As in these nations, the Chinese government targeted the semiconductor (microelectronics) industry for support because it was a strategic, high productivity, high value, capital intensive industry

⁵³⁸ See for example Lin and Milhaupt, "We are the (National) Champions," page 13. According to SASAC data, the profits of China's large enterprise groups were greater in 2010 than those of the largest private firms in China, and by 2011 China had sixty-one firms in the Global Fortune 500, ranking China third behind the U.S. and Japan. Lin and Milhaupt use data from the *2010 SASAC Yearbook* and the *2010 China Enterprise Management Annual* to compare profits from 133 national champions and China's 500 largest privately owned enterprises, finding the former with three to four times the profits of the private enterprises, which could be due to low-cost government funding. See also U.S.-China Economic and Security Review Commission, "An Analysis of State Owned Enterprises and State Capitalism in China," 2011.

⁵³⁹ Nolan, "Beyond Privatization, pages 182-183.

⁵⁴⁰ Chapter Six specifically compares the overall development of the electronics and semiconductor industry in China with the development of these industries in Japan, South Korea, and Taiwan.

that officials believed needed state investment to advance. As was the case for strategic industries in Japan, South Korea, and Taiwan, China's policies and programs for the semiconductor industry were developed at the central level but also by industry planning organizations, in China's case, the Ministry of the Electronics Industry. As we saw for Huajing, Huahong-NEC and SMIC, municipal governments then augmented central government policies and programs.

Finally, as in other East Asian nations, China's central government officials selected specific large enterprises – in this case, Huajing, Huahong-NEC, and SMIC – as national champions. In developed countries in the 1990s, large enterprises were moving away from diversified holdings and were focusing on profitability and “core competencies,” but nonetheless, large enterprises remained technological and financial leaders across industries. China's decision to support certain large enterprises was thus aligned with the approach of its East Asian neighbors in recent decades, as well as the reality of ongoing leadership by large enterprises in the world's most advanced economies.⁵⁴¹

And yet, by looking at a particular industry and its enterprises, we see certain differences between the experiences in the semiconductor industry in China and state led development elsewhere. Huajing, Huahong-NEC, and SMIC were selected by the government to be national champions, and yet the phrase “picking winners” does not quite apply. Why? First of all, these were not existing enterprises, so Chinese officials were actually taking an approach in this high technology industry of establishing new enterprises rather than “picking” existing enterprises. Of Huajing, Huahong-NEC, and SMIC, only Huajing was based in an existing state owned enterprise (Wuxi's #742 Factory), and it was re-

⁵⁴¹ Nolan, “Beyond Privatization,” pages 175-177.

established as a “new” enterprise (Huajing) in 1989. Japan, Korea, and Taiwan also, in some cases, established new enterprises or significantly changed the operating capacity of existing enterprises through state investment for capital deepening and technological upgrading. Thus, the approach of the state creating (or supporting the creation of) new enterprises is not entirely unique to China. Yet, it bears mentioning that, in this particular high technology industry in the 1990s, China’s national champions were not “picked” from existing state owned enterprises (except Huajing) nor from existing private enterprises.

Returning to the notion of “picking winners,” these enterprises also were not necessarily established with the goal of being “winners” in terms of being internationally competitive. First and foremost, Chinese officials established Huajing, Huahong-NEC, and SMIC with the goal of advancing the technological level of a Chinese enterprise and of fostering the development of the full semiconductor industry chain in China. Officials did hope that each of these firms would, at least at their inception, be a technological leader among Chinese firms, but the larger goal was to advance the technological level of many firms in China, including state and non-state firms as well as foreign and domestic firms. In each case, officials believed that if one large scale, technologically advanced enterprise could operate in China, then other firms would have the confidence to establish operations in China’s admittedly imperfect business environment. In the case of SMIC, there was more of an expectation that the firm might eventually be quite internationally competitive, but the technology that SMIC initially sought to use was not global leading edge.⁵⁴² Finally, China’s emphasis in the 1990s on the manufacturing sector of the industry (via adoption of the

⁵⁴² SMIC initially sought eight inch production technology whereas global leading firms were already moving to twelve inch.

foundry model and the use of Sino-foreign joint ventures for export production) essentially placed China in a somewhat subordinate role in the global industry value chain, because in these production operations, the semiconductor designs typically did not originate in China.

Here, we must acknowledge an important reality that is often missing from frameworks that emphasize competition, winning, and leadership. Business case studies usually focus on leading firms, but the reality is that most firms are not leaders in their industries. Yet, firms can survive and contribute and attain positive results behind the vanguard. There can be much success in terms of learning, catch-up, innovation (in organization and business processes, if not technology), revenues, and even profits for firms that are not on the leading edge and are not “winners.” For the semiconductor industry in China, this study has assessed the contributions of the national champions, without exclusively asking whether they were “internationally competitive” or profitable or “winners.” In the semiconductor industry, China went from having an isolated, nationalized industry in the late 1980s to being very much a participant in the global industry by the 2000s. China’s national champions and key enterprises were not global leaders, but they made contributions in terms of retaining and gaining some market share for Chinese firms, training thousands of industry personnel, and integrating Chinese firms with the global industry. As a U.S. Semiconductor Industry Association report put it, China’s semiconductor industry was “primitive by Western standards through the mid 1980s” and had “historically proven unable to develop an internationally competitive semiconductor industry,” but after 2000, the industry in China “bore little resemblance to the technologically lagging industry” that existed into the 1990s.⁵⁴³ Arguably, China’s national champions and key enterprises were the site of

⁵⁴³ Semiconductor Industry Association, “China’s Emerging Semiconductor Industry,” page i and 23.

Chinese industry experience in the 1990s, and these experiences (often difficult, not “winning”) contributed to advances in the industry in the late 1990s and 2000s.

Unlike some state led development efforts in Japan and Korea, Chinese officials did not establish national champions Huajing, Huahong-NEC and SMIC to promote oligopolistic competition within China.⁵⁴⁴ Although each began production in earnest in the space of just three years from late 1999 to 2002, each enterprise took a different approach to serving the market. Huajing sought to serve China’s low end domestic market, Huahong-NEC initially sought to serve exports markets as well as the domestic market for I.C. cards, and SMIC sought to serve both foreign and domestic clients with relatively high end products. To produce for the market, Huajing, Huahong-NEC and SMIC each came to the Taiwan-originated foundry model by different routes. After years of struggling, Huajing ultimately leased part of its facilities in late 1997 to CSMC to be run as a foundry. Huahong-NEC migrated to the foundry model from the I.D.M. model in 2002, and SMIC (with Taiwanese managers) used the foundry model from its inception in 2000. Finally, in the sources used for this study, there was no mention of collusion between these three firms as well as China’s key semiconductor enterprises, although it is possible that collusion might have occurred.

Perhaps surprisingly, China’s key and national champion semiconductor enterprises were not all closely aligned with China’s national team of over 100 large enterprise groups. It is important to recall that China’s national team was established in the 1990s and 2000s, and

⁵⁴⁴ Into the 1990s, most major global semiconductor firms operated under the “integrated device manufacturer (I.D.M.)” business model. In an I.D.M., one vertically integrated company designs, fabricates (i.e., produces or manufactures), and packages/assembles/tests (P.A.T.) its own semiconductors, using its own foundry for fabrication. This foundry model was first developed in Taiwan in 1987 at the Taiwan Semiconductor Manufacturing Corporation (TSMC). The foundry model is in contrast to the I.D.M. model. Under the foundry model, a foundry leases its capacity to any number of customers. Customers design their semiconductors and then lease foundry capacity for fabrication. The foundry does not sell semiconductors into the market. That said, a company can have a foundry while also having other revenue streams.

its members have undergone acquisitions, consolidations, and other reorganizations in the intervening years. Thus, China's large enterprise groups are not the origin of important enterprises; most national team members are conglomerations of (mostly) pre-existing organizations, though these organizations may have been renamed. Huajing was eventually bought by national team member Huarun, but Huarun is somewhat unusual among China's national team in that it has member enterprises spanning many, diversified industries instead of being in just one industry. In the diverse Huarun enterprise group, China Resources Microelectronics (the present incarnation of Huajing) is not listed among Huarun's "strategic business units." Huahong-NEC, in contrast, is directly controlled by the China Electronics Corporation (CEC), a member of China's national team and a leader in electronics.⁵⁴⁵ Finally, SMIC's closest tie to China's national team is the Datang enterprise group's investment in SMIC. Datang is a state owned power generation enterprise group established in 2002. Datang did not invest in SMIC until 2008 at which time it took a 16.6 percent stake. Thus, SMIC's origins and early contributions were not under the auspices of China's national team.⁵⁴⁶ As of this writing, Datang's investment in SMIC has grown to over 20 percent, but SMIC is not included in Datang's list of primary member enterprises.

As for China's other key semiconductor enterprises (Shanghai Belling, ASMC, Shougang-NEC, and Huayue), Shanghai Belling is most directly linked to China's national team and has long been considered a leading electronics enterprise. Recall, Shanghai Belling had been in competition around 1989 with Huajing in Wuxi to be selected as the site for

⁵⁴⁵ CEC was established in 1989 as part of the restructuring of the former Ministry of Electronics Industry. It has been a member of the national team since 2000 and is now China's largest state owned "information technology" enterprise with sixty-one subsidiaries, including four semiconductor subsidiaries: Huahong, Huahong-NEC, Shanghai Belling, and China Integrated Circuit Design Group Corporation (CIDC, see Chapter Five.) CEC is administered by SASAC, see www.cec.com.cn.

⁵⁴⁶ "SMIC Signs Cooperative Agreement With Datang," *TechSecurityChina*, January 12, 2009.

Project 908. Shanghai Belling is a national team member in its own right, while also being listed by SASAC as a member enterprise of CEC, along with all the Huahong affiliated enterprises, as noted above. (Shanghai Belling and Huahong also have significant cross ownership in one another.) Shanghai Belling is a minority shareholder (five to six percent) since 1999 in another key semiconductor enterprise, ASMC. ASMC's other shareholders (with over ninety four percent ownership), however, are not directly members of China's national team.⁵⁴⁷ Huayue was another of China's key semiconductor enterprises, and CEC has been a shareholder in Huayue since the 1990s, but CEC currently does not list Huayue as a primary member enterprises. Finally, key enterprise Shougang-NEC is a subsidiary of NEC of Japan, and the Chinese partner, Shougang of Beijing, is a major steel enterprise group in China, but this steel group is not a direct member of China's national team. Thus, among China's national champion and key semiconductor enterprises, only Huahong-NEC and Shanghai Belling are directly tied to China's national team.⁵⁴⁸ Of course, as China's national team continues to evolve, it could become more directly influential in the semiconductor industry.

The three semiconductor national champions were not all strictly state owned enterprises and were not all directly tied to China's national team, but in each, this research has shown that the Chinese government was a major investor and government officials often

⁵⁴⁷ Access ASMC's capital structure at <http://www.asmc.com/en/en-aa-capitalstructure.html>.

⁵⁴⁸ For current information on links between the semiconductor enterprises and the national team, see SASAC at www.sasac.gov.cn for links to each of the 100 plus national team members. For the semiconductor enterprises, see 1) Huarun (English name China Resources) at www.crc.com.hk, 2) Huahong-NEC at www.cec.com.cn, 3) SMIC at www.smic.com, 4) Shanghai Bell at www.bmmc.net.cn, 5) Huayue at www.chmc.com.cn, 6) ASMC at www.asmc.com, and 7) Shougang-NEC at www.shougang.com.cn and www.nec.cn.

filled executive roles.⁵⁴⁹ Yet, the various government investors in each enterprise seem to have been less concerned with directly leading the enterprise – or trying to influence the industry – to enable their national champion to dominate in the industry. As we have seen, Huajing, Huahong-NEC and SMIC each had investments from different government-affiliated organizations (banks, ministries, cities, funds, etc.), but ultimately these different government-affiliated investors did not seem to speak with one voice. Government investments were coordinated at the founding of each enterprise, but over time, the investments changed hands with much negotiation. The overall impression from available sources and interviews is that government-affiliated investors were primarily concerned with getting their loans repaid or getting returns. Recall for example the ownership and investment changes at Huajing in Chapter Three. Huajing was passed from central ownership to (mostly) municipal ownership to the Huarun enterprise group. These changes were financially motivated, with the goal of recovering Huajing's debts and enabling the enterprise to survive, not necessarily to make Huajing more dominate in the industry.⁵⁵⁰ SMIC's Chinese government-affiliated investors also changed over the years (including state owned banks, the sovereign wealth fund CIC, and national team member Datang), and these government investors at times disagreed over the direction of the company. For example, at one point, CIC (China's major sovereign wealth

⁵⁴⁹ For example, Jiang Shoulei who had been with the Ministry of the Electronics Industry in the early 1980s became a Vice President at Huajing in late 1980s and later C.E.O. of Hongri, a sales affiliate of Huahong. Hu Qili was a former Minister of the Ministry of the Electronics Industry, and he was appointed Chairman of Huahong-NEC. Wang Yangyuan, Director of the Institute of Microelectronics at Peking University and CAS, was a founder and Chairman of SMIC. In the 2000s, a group of industry executives, many of whom were ethnic Chinese either from Taiwan, Singapore or Mainland China revolved through different leadership roles at Huahong-NEC and SMIC. For example, SMIC recently appointed Zhang Wenyi, a former chairman of Huahong and a former Vice-Minister for China's electronics industry, as its new Chairman.

⁵⁵⁰ In the course of these changes, the discussion was always about Huajing's debt not about Huajing's ability to maintain leadership as a national champion. Huajing had been considered a national champion from its inception in 1989-1990, but the enterprise seems to have fallen from official favor in the mid to late 1990s and early 2000s. Nonetheless, it survived, and today CRM is still considered a kind of national champion.

fund) did not want Datang to increase its stake in SMIC because officials at CIC feared that the global semiconductor industry would then perceive SMIC as a Chinese “state owned enterprise.”⁵⁵¹

Unlike in South Korea, where Amsden found that government subsidies to large enterprises were performance based, it is not at all clear that China’s semiconductor national champions were held to such standards. The accessible sources do not contain or even refer to concrete business plans or financial models for these firms’ expected revenues or profits. Sources do indicate an increased awareness among Chinese officials from Project 908 to 909 to SMIC that semiconductor enterprises needed to be profitable to sustain operations, and yet short term or even medium term profits seem to have been overshadowed by the primary goals of technological advance and global integration.⁵⁵² The leaders of Project 908, 909 and SMIC agreed that the Chinese government needed to invest in the semiconductor industry (due to Chinese enterprises being technologically behind and not having access to capital for capital intensive semiconductor facilities), but there seems to have been no model or demand for long term revenue, profitability, or innovation in these state owned or state supported enterprises.

China’s semiconductor national champions *were* similar to favored large enterprises in Japan, South Korea, and Taiwan in that the state directly facilitated their key technology

⁵⁵¹ Robin Kwong, “SMIC’s Future Unclear after Wang’s Resignation,” *Financial Times: Tech Hub*, July 18, 2011. Datang was (and is) a national team member, but its status as such has been threatened due to its size. It sought more control of SMIC to enlarge itself, in order to maintain its national team status and avoid being subsumed under another national team member. Yet, CIC (China’s major sovereign wealth fund) did not want Datang to have too large a stake in SMIC because it feared that the global semiconductor industry would perceive SMIC as a “state owned enterprise.”

⁵⁵² Even for leading global firms, new semiconductor fabrication facilities take years to become profitable. And more generally, while it is common for observers to focus on profitability, it bears mentioning that not all endeavors are profitable, whether they are investments in research, firms, products, etc. An unprofitable venture can serve as a learning experience and eventually lead to a more productive venture.

transfer agreements. Chinese officials directly negotiated for the transfer of second hand equipment in the 1980s for Wuxi's #742 Factory and continued this practice for each of the key and national champion semiconductor enterprises. Like elsewhere in East Asia, we have seen that Chinese officials exempted critical foreign semiconductor equipment imports from taxes, duties, and other import-related costs.

As for foreign ownership, it was indeed limited in Chinese semiconductor enterprises (as it had been, for example, in Taiwan), and foreign firms could not establish fully foreign owned subsidiaries in China.⁵⁵³ However, Chinese policies limiting foreign ownership were common across industries in China in the 1990s. In the semiconductor industry, Chinese officials sought to control foreign investment, but they simultaneously sought to allow more foreign ownership in the key enterprises (Sino-foreign joint ventures) and in the national champions. Typically, foreign firms were allowed less than fifty percent ownership in Chinese enterprises, but for example, in 1999 Huajing had just a forty-nine percent stake in the new CSMC-Huajing joint venture, and in key enterprise Shougang-NEC, Japan's NEC was able to increase its ownership to fifty-one percent by 2000.⁵⁵⁴ Each of these arrangements was uniquely negotiated, and recall that during this period foreign firms complained that "clear-cut transparent rules governing the terms of inward investment did not exist."⁵⁵⁵

Indeed, relative to favored large enterprises elsewhere in East Asia, China's semiconductor national champions had a surprising level of foreign ownership and management. Huajing was a pioneer in bringing in Taiwanese management and ownership.

⁵⁵³ Semiconductor Industry Association, "China's Emerging Semiconductor Industry," Figure 11, page 20-21, 26.

⁵⁵⁴ Michael Pecht, "Electronics Manufacturing Update" for the Office of Naval Research, 2000, page 37.

⁵⁵⁵ Semiconductor Industry Association, "China's Emerging Semiconductor Industry," page 26.

From there, Chinese officials leaned even more on foreign management and ownership, establishing Huahong-NEC from the start as a Sino-foreign joint venture, and then supporting SMIC, a wholly foreign owned, Taiwanese-led enterprise as a “Chinese” national champion.⁵⁵⁶

Chapter Five will address two additional similarities between the development of the semiconductor industry in China in the 1990s and state led development in Japan, South Korea, and Taiwan. In brief, these are: 1) industrial policies’ auxiliary support for targeted industries and 2) labor mobility resulting in new firm formation. In the 1990s, semiconductor personnel in China increasingly enjoyed labor mobility enabling them to move among state supported enterprises, Sino-foreign joint ventures, and foreign enterprises. Both Denis Simon and Robert Wade have shown that technical and managerial training in large firms coupled with labor mobility resulted in new firm formation in Taiwan.⁵⁵⁷ In the 1990s, some Chinese personnel began to leave larger semiconductor enterprises and form non-state firms, especially in the design, P.A.T., and distribution sectors of the industry. As for auxiliary support for targeted industries, industrial policies in Japan, South Korea, and Taiwan provided investments in research, industrial parks, and education, and this was true for the semiconductor industry in China as well.

In sum, China’s semiconductor national champions had some surprising characteristics relative to general conceptions of national champion enterprises in East Asia. China’s semiconductor national champions were newly established enterprises that were not

⁵⁵⁶ Chapter Six compares the development of the electronics and semiconductor industries in China to these industries’ development in Japan, Korea, and Taiwan. As for foreign ownership and management of favored semiconductor enterprises, we will see that Taiwan also relied extensively on foreign assistance.

⁵⁵⁷ Denis Simon, “Taiwan’s Emerging Technological Trajectory,” in *Taiwan: Beyond the Economic Miracle*, page 136.

necessarily expected to be “winners” but rather were operating behind the global industry vanguard. They were not a uniform group of enterprises established to foster domestic (or oligopolistic) competition. They were not all directly aligned with China’s national team, although government officials served in executive roles and the enterprises were recipients of state investments. Finally, the national champions had a high degree of foreign ownership and management.

Revealing the actual nature of these enterprises helps us to define state led development in China’s contemporary economic history. The true character and role of national champions are also important because the terms “state led development” and “national champions” have gained currency beyond academia. So called national champions can seem threatening or opaque to foreign observers, especially when they hail from a nation with a different type of government and legal system and with different ownership structures.

Here are just two examples of how foreign industry and government sources have represented state led development (or industrial policy) and national champion enterprises in the semiconductor industry in China. This first selection is from a 1997 U.S. government hearing before the House of Ways and Means Committee. The statements are from the President of the U.S. Semiconductor Industry Association.

“[China’s] Ministry of the Electronics Industry last spring announced the formation of Project 909...Huahong is a Ministry of the Electronics Industry owned company, and its chairman, Hu Qili, is Minister of the Ministry of the Electronics Industry.”⁵⁵⁸

“...There have been repeated reports that China’s Ministry of the Electronics Industry and its State Planning Commission have drafted electronics industrial

⁵⁵⁸ George Scalise (transcript), President of the Semiconductor Industry Association, “Hearing on the Future of US-China Trade Relations and Accession of China to the W.T.O.” (hearing before the Subcommittee on Trade of the Committee on Ways and Means), November 4, 1997.

policy to promote development of its domestic industry. However, this policy plan has not been issued publicly. ...While no details are currently available, earlier reports indicated that the electronics industrial policy could proscribe foreign majority ownership of semiconductor firms, establish export performance requirements for Sino-foreign joint ventures, and provide the basis for eventual displacement of foreign semiconductors.... The recent establishment of Project 909, in which...[NEC] has been granted a 28.6 percent share in a Sino-foreign joint venture in return for supplying the advanced technology...suggests a continuing Chinese Government focus on development of a domestic semiconductor production capability.”⁵⁵⁹

[China seeks to] “persuade foreign firms to invest in China and share their technology with Chinese firms through joint ventures... In return, suggestions are made that increased market access may be made available...”⁵⁶⁰

“...As a result of the continuing active government role...[there is] significant risk that ...state invested enterprises will be encouraged by Chinese officials to purchase from domestic suppliers. ...[There are] recent reports that, as the Chinese government moves out of many sectors, it will actually focus more attention on building up a select group of national champions in the electronics industry.”⁵⁶¹

Much like this report, in their relatively brief descriptions of Project 909, foreign industry and academic sources have incorrectly stated that the goal of Project 909 was “self sufficiency” aimed “to protect [China’s] large market from foreign domination,”⁵⁶² and “to end reliance on foreign [semiconductor] imports.”⁵⁶³ Further, foreign sources tend to emphasize the particular technology Project 909 sought (eight inch wafers and 0.5μm or less line width), leaving the

⁵⁵⁹ Ibid.

⁵⁶⁰ Ibid.

⁵⁶¹ Ibid.

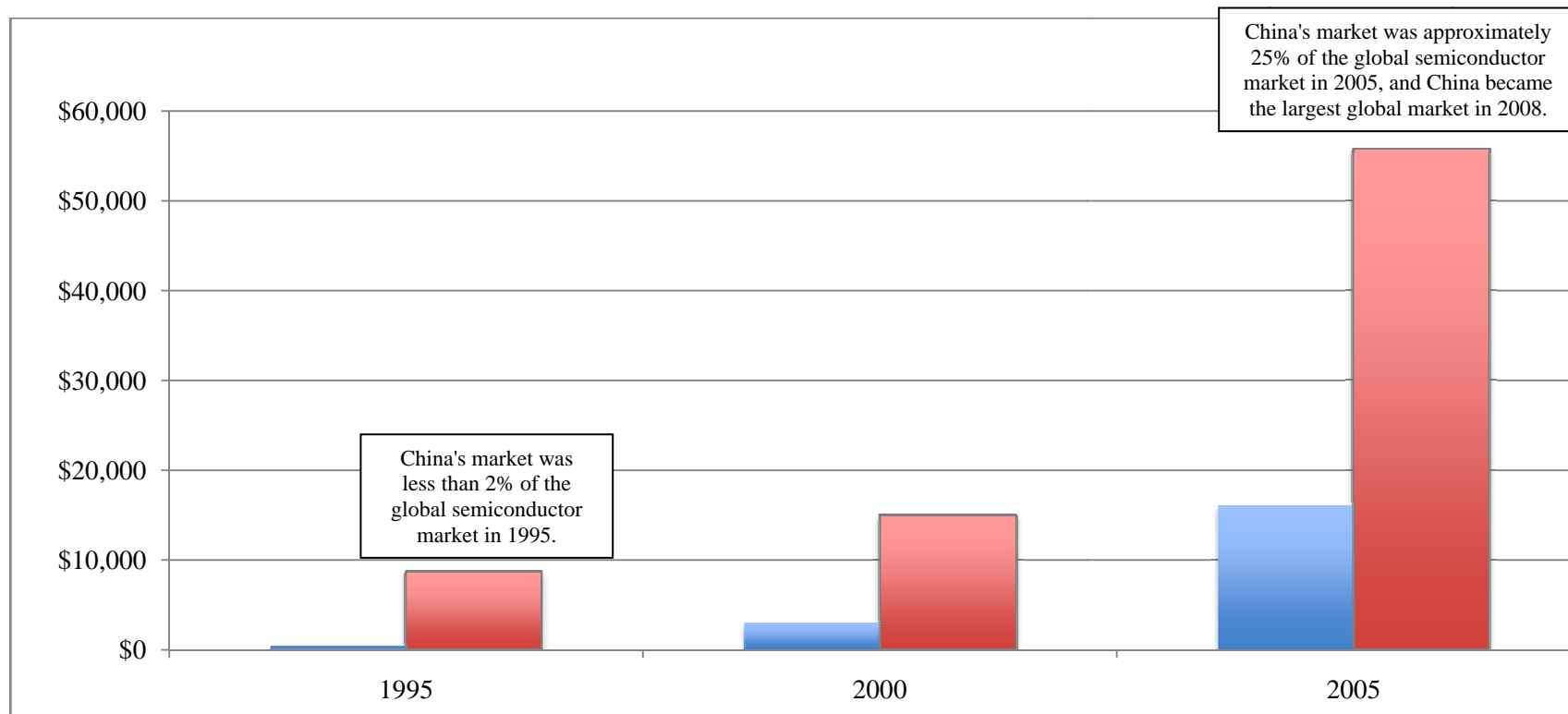
⁵⁶² Pecht, “Electronics Manufacturing Update,” page 26.

⁵⁶³ Michael Klaus, “Red Chips: Implications of the Semiconductor Industry’s Relocation to China,” *Asian Affairs, an American Review*, Winter 2003. This article is concerned with China’s growing power relative to the U.S. and Taiwan. It has a section entitled “Code Project 909: A Roadmap for Self-Sufficiency” which says “China is becoming less reliant on imported technology and is gaining control over every stage in the international semiconductor supply chain...[China’s] dedicated government support should fuel speculation that Project 909 is an insidious strategy to become self-sufficient...and facilitate military expansion.” iSupply, “Semiconductor Wafer Manufacturing in China,” page 4, put it more mildly saying that Project 909 intended “to reduce [semiconductor] imports.”

impression that Project 909 was primarily concerned with gaining a particular level of technology to ensure China's own ability to produce.

Yet, this research has shown that national champions Huajing, Huahong-NEC, and SMIC, as well as China's key enterprises, were not established with the goal of "self sufficiency," import substitution, or precluding foreign competitors in China, although indeed they were established to gain more share of China's domestic market. The goal was not for a particular firm (Huajing or Huahong-NEC or SMIC) to be so technologically dominant as to fully mitigate the need for imported semiconductors or the need for semiconductors made by foreign firms with operations in China. They were expected to be "leaders" in the industry only in the sense that at their inception they would be equipped with more advanced

Figure 8: China's Estimated Semiconductor Production (blue) and Market (red), in US\$ millions



This graph is constructed from the following sources:

1) PWC, "China's Impact on the Semiconductor Industry, 2004, 2006, and 2012," data sources include China Semiconductor Industry Association, CCID, and PwC analysis.

2) Wang Yangyuan and Wang Yongwen 王阳元 and 王永文, *Wo Guo Jichengdianlu Chanye Fazhan Zhilu: cong Xiaofei Daguo Zouxiang Chanye Qiangguo* 我国集成电路产业发展之路：从消费大国走向产业强国 (China's Integrated Circuit Industry Development Path: From a Big, Consuming Nation to a Strong, Industrial Nation), Kexue Chubanshe 科学出版社 (Science Press), 2008, page 123, per CSIA.

Note: The PWC analyses uses data from CSIA and CCID, both associated with China's Ministry of the Information Industries.

The data includes all enterprises operating in China, including foreign enterprises, not just Chinese owned or state owned enterprises.

technology, but technology acquisition at each of the national champions was meant to serve the larger purpose of fostering a globally integrated, diverse industry chain in China.

Further, this research did not find evidence that these national champions were expected to be leaders in China in terms of revenues, profits, or market share. Indeed, larger global semiconductor firms had already begun to operate in China in the 1990s, and Chinese officials were moving towards policies that would allow more access to global firms (addressed in Chapter Five.) Huajing, Huahong-NEC and SMIC were certainly not expected to dominate market *share*. In the 1990s, the vast majority of semiconductors used in China (perhaps eighty-five percent) were imported, and surely the majority would continue to be imported for the foreseeable future. Figure Eight (previous page) shows the wide gap between semiconductor production in China and semiconductor demand in China.

Finally, these enterprises were not expected to dominate particular “protected” sectors of China’s domestic semiconductor market. The major exception to this is China’s protection of its I.C. card market for the benefit of Huahong and its foreign partner. Essentially, Huahong offered potential foreign partners a guaranteed sector of China’s semiconductor market in exchange for partnership and technology. This quid pro quo, however, was not Project 909’s (Huahong’s) original plan. Rather, the decision by Chinese officials to protect the I.C. card market seems to have been a last-ditch effort to attract partners, given China’s undeveloped semiconductor industry, overall business environment, and poor results with Project 908. If Hu Qili’s account is accurate (and on this point, it may not be),⁵⁶⁴ foreign

⁵⁶⁴ While most of Hu’s records of Project 909 seem credible, this particular point raises questions. The use and production of I.C. cards in China affected various organizations and Chinese government priorities. Thus, it is difficult to know whether Huahong’s need to attract a partner was the sole reason why Chinese officials decided to protect this market.

companies were only willing to partner with Project 909 after the quid pro quo was offered, despite being in principal opposed to such arrangements. Foreign companies have lodged complaints against China in the semiconductor industry and in other industries for the quid pro quo of market access in exchange for technology transfer.⁵⁶⁵ This research, however, did not find examples of this quid pro quo actually being transacted, except in the case of Huahong-NEC. Yet, another possible case would be the Sino-foreign joint venture Shanghai Belling. Shanghai Belling (foreign partner Alcatel Bell of Belgium) may have been offered specific market segments, as this enterprise supplied telecom-related semiconductors as well as being the early provider of I.C.s for I.C. cards in China.⁵⁶⁶

Market protection was a common aspect of state led development in Japan, South Korea, and Taiwan with the state making financial interventions in international trade to protect or foster industries. In China, too, the key and national champion semiconductor enterprises operated under state interventions in trade. These interventions included export requirements for the Sino-foreign joint ventures and high tariffs on imported semiconductors, but providing protected market segments to foreign firms seems to have been limited, in practice.

To what extent did export requirements and high tariffs on imports succeed in protecting segments of China's semiconductor market? China's tariffs on semiconductors ranged from five to thirty percent, with more advanced semiconductors that could not be

⁵⁶⁵ Semiconductor Industry Association, "China's Emerging Semiconductor Industry," page 26. This claim was repeated in several industry articles, but without details.

⁵⁶⁶ Pecht, "Electronics Manufacturing Update," 2000, page 37.

made domestically enjoying lower tariffs in the five to ten percent range.⁵⁶⁷ Lower end semiconductors that could be produced domestically had higher tariffs, and thus the domestic products should have been somewhat protected. However, given that semiconductor demand grew rapidly in the 1990s and all the while perhaps eighty-five percent of semiconductors continued to be imported, it is difficult to argue that the official tariffs (which were often negotiated down) had a significant protectionist effect. Further, the higher tariffs on simple products resulted in significant smuggling of foreign made electronics into China through the late 1990s (see Section 4.26), resulting in the domestic market not being well protected. Chinese officials did establish export requirements on a one-off basis with foreign partners in Sino-foreign joint ventures to ensure that foreign producers in China did not come to monopolize China's market.⁵⁶⁸ In this way, the domestic market was perhaps in part protected, but the nature of the electronics supply chain was such that these export requirements probably had negligible affect. Electronics assemblers in China were required to use whichever semiconductor products were specified by the product designs. Designs often specified foreign, imported semiconductors even for low end semiconductors because Chinese semiconductors were believed to have inferior quality. Thus, even if a comparable semiconductor was available from a local Chinese enterprise and even if the low end foreign semiconductor was more expensive (due to high import tariffs on low end semiconductors), the assembler still had to use the more expensive import.

⁵⁶⁷ Semiconductor Industry Association, "China's Emerging Semiconductor Industry," page 26, from *Rules and Regulations for the Import and Export of Tariff of the PRC*, 1994.

⁵⁶⁸ Export requirements did not necessarily cover all of an enterprises' output. Export agreements were established for, for example, CSMC-Huajing, Huahong-NEC, and ASMC. Shougang-NEC was supplying China's domestic market but may have also been under export agreements for part of its production.

To be sure, state led development in China and elsewhere has included government subsidies, import substitution, and certain market and industry protections, which at times were disadvantageous to foreign competitors. Yet, this close examination of the semiconductor industry has shown that the reality of China's semiconductor policies and practices in the 1990s did not fully align with foreign observers' concerns.

4.44 Semiconductor National Champions and China's Policy Environment

Chapter Two, Section 2.43 considered "bottom up" influences in the 1980s reforms to China's semiconductor industry. Despite the seemingly top down, centralized nature of central planning and state owned industries, this research has shown that in the 1980s Chinese officials made a number of decisions and established new industry guidance mechanisms for the semiconductor industry based on bottom up input from semiconductor experts and leaders from around the country.

State led development and the use of national champions also seems to suggest top down influence. Indeed, Chapters Three and Four have shown that Huajing and Huahong-NEC were directly established and fostered through state plans and investment and SMIC was established with state support. In addition to this top down approach, this research suggests that the experiences of these enterprises resulted in bottom up influences in the industry. The experiences and obstacles of these national champions directly influenced officials' decisions for specific enterprises and policies for the broader semiconductor industry. As in Taiwan and Korea, Chinese officials were not all knowing but rather were learning from experience. We will see that one-off exceptions that officials made to support national champions (e.g., tax exemptions for imported equipment) fed into new industry policies in 2000. This section

highlights the experiences in the 1990s that directly influenced new policies in 2000 and beyond, which are covered in Chapter Five. Foreign observers have been critical of government “bureaucrats” holding executive positions in favored state supported enterprises in China,⁵⁶⁹ but in the semiconductor industry (most apparently at the key enterprises and Huahong-NEC), these dual roles seem to have enabled government officials to see and determine firsthand what policy and operational changes were needed in the industry.

Thus, in the semiconductor industry in China in the critical 1990s, the industry’s advances appear to have been both “state led” and “enterprise led.” That is, integration with the global industry brought issues to the fore, causing enterprise leaders and policy makers in China to respond with organizational changes and new policies. (This notion of enterprise led development is different than the theoretical “market led” development that tends to emphasize allocation of resources toward meeting market demands, export led development, market pricing, etc., in a stable macroeconomic environment.)⁵⁷⁰ The following discussion reveals enterprise led development through the experiences of Huajing, Huahong-NEC, and SMIC, and Chapter Five finds enterprise led development through foreign firms’ presence in China and through developments in the semiconductor P.A.T. and design sectors.

Government officials led the establishment of each of China’s key and national champions semiconductor enterprises between 1988 and 2000. Each was a unique case and each of the enterprises (except key enterprise Huayue) had an ownership form that differed from China’s state owned enterprises in the 1980s. The experience of negotiating,

⁵⁶⁹ Semiconductor Industry Association, “China’s Emerging Semiconductor Industry,” refers to the Chinese “bureaucrats” that were positioned as managers in the Sino-foreign joint ventures.

⁵⁷⁰ “Market led” development follows the orthodox view that advocates reliance on market orientation and trade liberalization, as well as macroeconomic stability, entrepreneurialism, resource allocation, private ownership, and advances in human capital.

establishing, and supporting these “one off” enterprises influenced Chinese officials as they sought to define new ownership and foreign investment policies for the broader semiconductor industry around 2000. The new policies are identified in Chapter Five, but here, let us consider three major enterprise led learning experiences of the 1990s, in terms of ownership and investment.

The key enterprises were formed by joining an existing Chinese state owned factory with a foreign partner to form a Sino-foreign joint venture, except in the case of Huayue. It is important to understand that these joint ventures were not merely small, experimental units imbedded within larger Chinese state owned enterprises. Rather, the joint ventures were the primary enterprise, attempting to operate in China’s evolving and inconsistent policy environment. The structures of the joint ventures varied, but as an example, let us consider ASMC. ASMC was founded in 1988 as a Sino-foreign joint venture between Shanghai’s #7 Radio Factory and Philips of the Netherlands. From 1988 to 1995, it was called Shanghai Philips Semiconductor Company. The joint venture did not continue with the work of the #7 Radio Factory. Instead, from its inception, the joint venture produced semiconductor products for export to Europe, based on designs and customers supplied by Philips. (ASMC was thus, in effect, China’s first semiconductor enterprise to adopt the foundry model.) ASMC did have Chinese state-affiliated investors (Bank of China, Shanghai Belling, China Orient Asset Management Corporation, and others over the years), but the new Shanghai Philips Semiconductor Company (now ASMC) was not just one part of a larger Chinese state owned enterprise.⁵⁷¹ Forming these enterprises and working with foreign partners on concerns and

⁵⁷¹ ASMC, *Jinian Gongsi Chengli 20 Zhounian: Shanghai Xianjin Bandaoti Zhizao Gufen Youxian Gongsi 纪念公司成立 20 周年：上海先进半导体制造制造有限公司 (20th Anniversary Memorial Book: ASMC)*, 2008.

obstacles ultimately influenced Chinese official's new policies for foreign investment in the semiconductor industry in 2000. As mentioned above, when these joint ventures were being established, foreign firms said that transparent rules for investment and trade did not exist.⁵⁷²

Another ownership-related learning experience involved the national champions. The ownership of the national champions shifted from state ownership (Huajing), to Sino-foreign joint venture (Huahong-NEC), to wholly foreign owned enterprise (SMIC.) This shift was not the result of a top down, state led plan, rather it was based on what was possible and desirable in each situation. Summarizing this shift, a Chinese semiconductor industry leader explained "There was no plan [for Huahong-NEC to follow Huajing, etc.] It was a complicated time."⁵⁷³

A third important learning experience in the 1990s that related to ownership and investment was China's opening to cooperation with Taiwan, first at Huajing and then through Taiwanese-led SMIC. Both of these arrangements served as stepping stones to later policies allowing Taiwanese investment on the mainland. These experiences also allowed Taiwanese semiconductor leaders and personnel to experiment with operations on the mainland (with investments often routed through Hong Kong) even before official changes to Taiwan's restrictions on such in 2003.⁵⁷⁴

Finally, in Huajing, Huahong-NEC, and SMIC, as well as the key enterprises, Chinese officials used certain tactics in the 1990s to enable technology imports, to attempt to partially

⁵⁷² Semiconductor Industry Association, "China's Emerging Semiconductor Industry," page 26.

⁵⁷³ Interview with Ye Tianchun, July 3, 2009, at the CAS Institute of Microelectronics in Beijing. Ye is the Director of the Microelectronics Institute and a top advisor on national semiconductor industry policies.

⁵⁷⁴ Semiconductor Industry Association, "China's Emerging Semiconductor Industry," page 68. Taiwanese investment in the mainland is addressed in Chapter Five. There are numerous articles and reports on Taiwanese investment in the mainland, see for example, *Taipei Times*, "Critics say China Policy Doesn't Address Real Needs" and "New Rules for Mainland Investment May Be Ignored," November 9, 2001.

protect the domestic market, to entice foreign partners, and to gain access to foreign capital.

New policies in 2000 would extend and standardize these practices. As we have seen, officials offered semiconductor enterprises tax holidays and exemptions and reductions on the high V.A.T.s for imported equipment, materials, and spare parts. China's import tariffs on semiconductors and semiconductor-related products in the 1990s were higher than those of other countries, but they were within the range of tariff levels for other industries in China.⁵⁷⁵

In the 1990s, there was not a special plan to impose particularly high tariffs for the semiconductor industry. Nonetheless, with relatively high tariffs for the semiconductor industry (by international standards), Chinese officials offered one-off tariff reduction measures to assist enterprises. In addition, in Shanghai's high technology parks and districts, officials also offered the opportunity to negotiate with the municipal government for the possibility of tax-free importation. Huahong-NEC and SMIC (located in Shanghai's new Pudong district), for example, received all the Pudong preferences made available to Sino-foreign joint ventures and high technology enterprises. In the 1990s, China's generally higher V.A.T. on imported semiconductors incited foreign firms to form joint ventures in order to produce in China; this tactic also influenced policy after 2000. Though foreigners objected based on W.T.O. rules,⁵⁷⁶ China announced a preferential V.A.T. for locally produced semiconductors in 2000, whether produced by domestic or foreign firms. Although the policy

⁵⁷⁵ Across industries in 1995, China's "average tariff" on imports was thirty-six percent. After 1995, as China began to seek entry to the World Trade Organization, China's average tariff level was reduced to twenty-three percent, per Nolan, "Beyond Privatization," pages 182-183.

⁵⁷⁶ Scalise, "US-China Trade Relations." In the mid 1980s, the US, Japan, and Canada agreed to eliminate tariffs on semiconductors. Later, in 1997, thirty-nine additional countries agreed to eliminate semiconductor tariffs through the Information Technology Agreement (ITA), an agreement under the W.T.O. to remove duties from information technology products. Later that same year China agreed to join the ITA, thus agreeing to (eventually) remove its semiconductor tariffs. This plan was disrupted, however, by China's announcement under its tenth five year plan (from 2001) of ongoing discriminatory tariffs for imported semiconductors.

was not implemented as late as 2003, it strongly fostered the relocation of global semiconductor fabrication to mainland China, which was well underway between 2000 and 2003.

Finally, this research has shown that Huahong-NEC's desire for foreign capital influenced China's 1998 *Guiding Catalog of Foreign Investment in Industry*, which added semiconductors to China's "encouraged" industries wherein foreign investments were likely to be approved. Further, in mid 1999, China's Ministry of Science and Technology confirmed that semiconductor enterprises could seek venture capital, a new source of funding for Chinese enterprises at that time.⁵⁷⁷ We will see these capital channels formalized in new policies for the semiconductor industry in 2000 and supported by statements in China's tenth five year plan (2001-2005).⁵⁷⁸

In the 1990s, the national champions and key enterprises were also the site of major enterprise led organizational, operational, and managerial changes. These changes were not instigated by top down policies for all semiconductor enterprises in China, rather, they occurred as enterprises in China took tentative steps to align with the global industry. These changes included the reorganization of enterprises by sector, e.g., establishing design, fabrication, and P.A.T. business units or companies, as we saw in Chapter Two at Huajing and in this chapter at Huahong. Creating these sector-based units effectively re-trained Chinese semiconductor personnel by changing internal and external business processes. Further, the adoption of the foundry model positioned Chinese enterprises as sites for global outsourcing, an important

⁵⁷⁷ Simon, "Critical Threshold."

⁵⁷⁸ *China's Tenth Five Year Plan*, Section 3.5.2.3: "Expand the number of financing channels, change from relying on bank loans to obtaining capital investment directly from overseas or local financial markets," from the Ministry of Information Industries' (MII) contribution to China's Tenth Five-Year Plan, translation accessed at United Nations Public Administration Network, www.unpan1.un.org/intradoc.

development. In Taiwan's 20th century economic history, Robert Wade described Taiwan's entry into the global semiconductor value chain by saying that 1961 was "a landmark year in the history of East Asia" because, in that year, foreign semiconductor firms began to outsource their semiconductor P.A.T. work to Taiwan, giving Taiwan a valuable role in the global industry. Wade said this was "the beginning of the corporate strategy that came to be called global manufacturing."⁵⁷⁹ By the time China adopted the foundry model in the 1990s (first, in effect, at ASMC, then in desperation at Huajing, and finally as a strategy at SMIC and Huahong), the global electronics industry had de-verticalized and electronic communications enabled "global production networks."⁵⁸⁰ (These networks obviously encompassed more than just production.) Finally, China's semiconductor enterprises brought in foreigners to act as General Managers and sales managers thus bringing new skills to enterprise management. Recall that CSMC-Huajing, Huahong-NEC, and SMIC all had foreign General Managers at their inception. With these changes and others, enterprises in China began to align with global industry practices.

⁵⁷⁹ Wade, *Governing the Market*, page 94.

⁵⁸⁰ See, for example, Chen and Xue, "Global Production Networks" or Dieter Ernst, "The New Mobility of Knowledge: Digital Information Systems and Global Flagship Networks," in *Digital Formations* (Princeton: Princeton University Press, 2005.)

Figure 7: Largest 15 Semiconductor Firms in China in 2003 by Revenue

Chinese enterprises in *italics*.

Note: These are the firms with highest revenues *operating* in China.

These are not the same as the largest semiconductor *suppliers* to the Chinese market because most of the semiconductors that meet China's market demand are imported.

Analysis:

Of the top 15 firms' revenue in 2003, "Chinese" firms constituted 47 percent.

The "Chinese" firms were a mix of ownership forms.

Rank	Headquarters	Name	Revenue in 2003 (US\$ million)	2003 Notes on "Chinese" Firms
1	US	Motorola	962	
2	<i>China/Cayman Islands/International</i>	SMIC	350	SMIC is a WFOE registered in the Cayman Islands.
3	Japan	Renesas	195	
4	<i>China/Japan</i>	Huahong-NEC	188	Huahong-NEC of Project 909 is a Sino-Foreign JV.
5	<i>China/US</i>	Leshan	149	LeShan has a JV with Motorola and provides mainly discrete devices.
6	Switzerland	Shenzhen Sai STMicroelectronics	125	
7	US	Intel	109	
8	<i>China</i>	Jianxin XinChao	108	XinChao is a state owned group.
9	<i>China/Netherlands</i>	ASMC	94	ASMC has a JV with Netherlands-based Philips and serves mainly as a foundry for Philips.
10	<i>China/Japan</i>	Nantong-Fujitsu	92	Nantong-Fujitsu is a Sino-foreign JV.
11	<i>China</i>	JCET	84	JCET is large state owned P.A.T. enterprise near Wuxi.
12	<i>China/Hong Kong</i>	China Resources Microelectronics/CSMC	77	CRM is a member of the CR enterprise group; it includes Huajing and CSMC of Project 908.
13	<i>China</i>	Datang	75	Datang is a state owned enterprise group in electronics-related industries.
14	Singapore	ChipPAC	73	
15	<i>China/Japan</i>	Shougang-NEC	68	Shougang-NEC is a Sino-foreign JV; Chinese partner is Beijing Shougang, a steel enterprise group.

Source: PWC, "China's Impact on the Semiconductor Industry, 2004," data sources include CSIA, CCID, and PwC analysis.

"Chinese" revenue:	1,285	47%
Other revenue:	1,464	53%
Total revenue:	2,749	100%

Figure 9: Largest 15 Semiconductor Firms in China in 2011 by Revenue

Chinese enterprises in *italics*.

Note: These are the firms with highest revenues *operating* in China. This is not the same as the largest semiconductor *suppliers* to the Chinese market because most of the semiconductors that meet China's market demand are imported.

Rank	Headquarters	Name	2011 Revenue US\$mm	2011 Notes on "Chinese" Firms
1	US	Intel	4,765	
2	Korea	Hynix	2,452	
3	<i>China/Cayman Islands/international</i>	SMIC	1,315	SMIC is a WFOE registered in the Cayman Islands.
4	US	Freescall	1,119	
5	<i>China</i>	HiSilicon (formerly with Huawei)	1,032	HiSilicon was formerly part of state-owned Huawei (telecomm), but is now a private, listed firm.
6	<i>China</i>	XinChao (JCET)	969	XinChao is a state owned group; it includes the large P.A.T. firm called JCET.
7	Korea	Samsung	838	
8	<i>China</i>	Spreadtrum	684	Spreadtrum was private from its inception.
9	<i>China/Japan</i>	Huahong	671	Huahong includes Huahong-NEC of Project 909, which is a Sino-foreign JV.
10	Taiwan	ASE	657	
11	Japan	Renesas	643	
12	<i>China/Hong Kong</i>	China Resources Microelectronics	631	CRM is a member of the CR enterprise group; it includes Huajing and CSMC of Project 908.
13	US	Cree Huizhou	631	
14	<i>China</i>	Nantong Huada	620	Nantong is a state owned group.
15	Japan	Panasonic	602	

Source: PwC, "China's Impact on the Semiconductor Industry, 2012 Update," data sources include CSIA, CCID, and PwC analysis.

"Chinese" revenue:	5,922	34%
Other revenue:	11,707	66%
Total revenue:	17,629	100%

Analysis: Of the top 15 firms' revenue in 2011, "Chinese" firms constituted 34 percent. The "Chinese" firms were a mix of ownership forms.

In each of the areas discussed above – ownership, financial incentives, and operations – the turbulent 1990s directly influenced China’s policy and business environment after 2000. The national champions and key enterprises may not have been internationally competitive in their technology and their financial results may have been mixed, but they bridged China’s isolated industry of the 1980s with the globally integrated industry of the post 2000 era. Through these enterprises, China was able to grow domestic production to (approximately) keep pace with the growth in the semiconductor market in China and to keep a foothold in its rapidly globalizing semiconductor industry, see Figures Seven and Nine (previous pages.) The enterprises created lasting global linkages, augmented China’s talent pool, and improved China’s policy and operating environment in the industry.

The industry and enterprise experiences of the 1990s affected the thinking of Chinese officials and semiconductor leaders. After three years with Huahong-NEC, Hu Qili reflected on China’s experiences in the 1990s, and he concluded that henceforth Chinese officials should focus their efforts on “creating a general environment which is suitable for the development of the semiconductor industry, providing preferential policies that are as good as those in the peripheral countries, simplifying examination and approval procedures, and encouraging foreign investment introduction and multi-channel financing...”⁵⁸¹ More specifically, a senior Chinese official at the Ministry of the Information Industries (the former Ministry of the Electronics Industry) said in 2000 that going forward the state should “refrain from the operation of [semiconductor] enterprises.”⁵⁸²

⁵⁸¹ Hu Qili, “Seize Opportunities to Develop China’s Semiconductor Industry,” *Renmin Ribao*, April 19, 2000 quoted in Semiconductor Industry Association, “China’s Emerging Semiconductor Industry,” page 37.

⁵⁸² Qu Weizhi, “How to Develop the Integrated Circuits Industry,” *Renmin Ribao*, May 15, 2000 quoted in Semiconductor Industry Association, “China’s Emerging Semiconductor Industry,” page 37.

This study's approach of examining a particular industry identifies the "how" of technological and economic advance in a high technology industry in China. In this chapter and Chapter Two, we saw Chinese officials supporting key and national champion enterprises in the 1990s. (At the same time, officials also supported research and design initiatives, covered in Chapter Five.) Yet, officials did not attempt to implement uniform, semiconductor-industry-wide policies in the 1990s, to try to guide all enterprises or trade. Rather, they learned from the experiences of enterprises for a period of about ten to fifteen years before implementing new policies for the industry after 2000. This enterprise led learning phase was one part of the "how" of technological and economic advance in this industry. Other aspects of global integration were also part of the "how," and these are covered further in Chapter Five. In her 1989 study of Korea, Alice Amsden made an important point about analyses of industrialization. She noted that nations' progression through the "stages of development" (from low skill, low capital activity to higher skill and capital intensive activity) has been credited to the work of entrepreneurs and spin-off firms. Amsden, however, carefully examined *how* Korea progressed through different stages of development, and she demonstrated that, particularly for capital and technology intensive industries, capital infusion and guidance by the state were critical.⁵⁸³ Wade's study of Taiwan also has much to offer about the "how" of technological and economic advance, from state financial interventions to culture to politics to economic planning bureaus and more. And indeed, in what he calls the "electrical and electronic goods" industries, there may have been an important period of enterprise led learning in Taiwan prior to the implementation of

⁵⁸³ Amsden, *Asia's Next Giant*, pages 243-247.

supportive industry-wide state policies. Wade recounts that in 1953 a Taiwanese electronics firm (Tatung) signed a technology transfer and training agreement with a Japanese firm. Ten years later, by 1963, seven electronics joint ventures between Taiwanese and foreign firms were in operation, and in the early 1960s a number of U.S. firms were investigating the possibility of cooperation with Taiwan. In 1962, Taiwan's government "revised the rules" for foreign investment, local content, and other matters affecting the industry. In the following two years "twenty-four U.S. firms rushed to make production agreements" in Taiwan. For this particular industry, Wade does not explicitly make the connection between the decade of learning (1953-1963) through joint ventures and the implementation of effective state policies (from 1962), but the implication is there.⁵⁸⁴

As we will see in Chapter Five, in the 1990s, China was a rapidly growing site for global electronic products production and assembly (i.e., televisions, telephones, DVD players, etc.), with numerous foreign firms already operating in China, including some semiconductor-related firms. In the 1990s, China's semiconductor-related research institutes and design organizations were also evolving, seeking to eventually commercial their designs. These 1990s trends, in addition to the experiences of China's key and national champion semiconductor enterprises, resulted in a notable degree of enterprise led development in this high technology industry.

⁵⁸⁴ Wade, *Governing the Market*, Chapter Four: State Led Industrialization, on electronics specifically, pages 93-94.

Chapter Five

Joining the Global Value Chain:

China's Growing Market, New Policies, and Emerging Design Sector

Chapter Five Contents

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In Chapters Three and Four, we saw the origins, challenges, and eventual contributions of China's key and national champion semiconductor enterprises in the 1990s. The existence and prioritization of these state-affiliated production enterprises suggests a degree of state led development in the industry, but Chapter Four showed that Chinese officials did not institute industry-wide, top-down policies to develop the industry until after 2000. For a period of ten to fifteen years in the late 1980s and 1990s, Chinese officials learned from the experiences of China's key and national champion enterprises as these enterprises established partnerships with leading global semiconductor firms. With these lessons in mind, officials implemented new policies for the whole industry after 2000. For this reason, Chapter Four suggested that the semiconductor industry in China evolved through both "state led" development and "enterprise led" development. This chapter will show that the policies enacted after 2000 supported a new era of growth, from the foundation developed in the 1990s.

Having addressed China's state-affiliated production enterprises in Chapter Four, this chapter considers other important ways in which the semiconductor industry in China in the 1990s and early 2000s increasingly integrated with the global semiconductor value chain. The industry in China underwent notable changes and growth from 1995 to 2000, and then entered a period of rapid growth after 2000. The chapter connects events and trends in the 1990s with the take off after 2000, which included a rapidly growing market for semiconductors in China, the arrival of more foreign semiconductor-related firms in China, and growth in semiconductor R&D and design work in China. Importantly, this chapter also covers the Chinese government's new policies for the industry after 2000, as well as other areas of policy that are often cited as influential to the semiconductor industry. Given the

dynamics of the industry in China in the 1990s and early 2000s, this chapter provides further evidence that this high technology industry advanced through a combination of state led development and enterprise led development.

Global semiconductor industry sources provided somewhat more coverage to the semiconductor industry in China from around 2000. Sources such as the U.S. Semiconductor Industry Association (SIA), global industry research firms such as iSupply, Gartner, and PriceWaterhouseCoopers (PwC), individual firms, and news sources increasingly recognized the growth of the industry in China and its integration with the global industry. For data on revenues, numbers of firms, etc., global sources usually used data from the China Semiconductor Industry Association (CSIA) and the China Center for Information Industry Development (CCID), which are the official Chinese sources for semiconductor industry data. Thus, most global industry analyses, in terms of data, correlated with Chinese sources and reports.

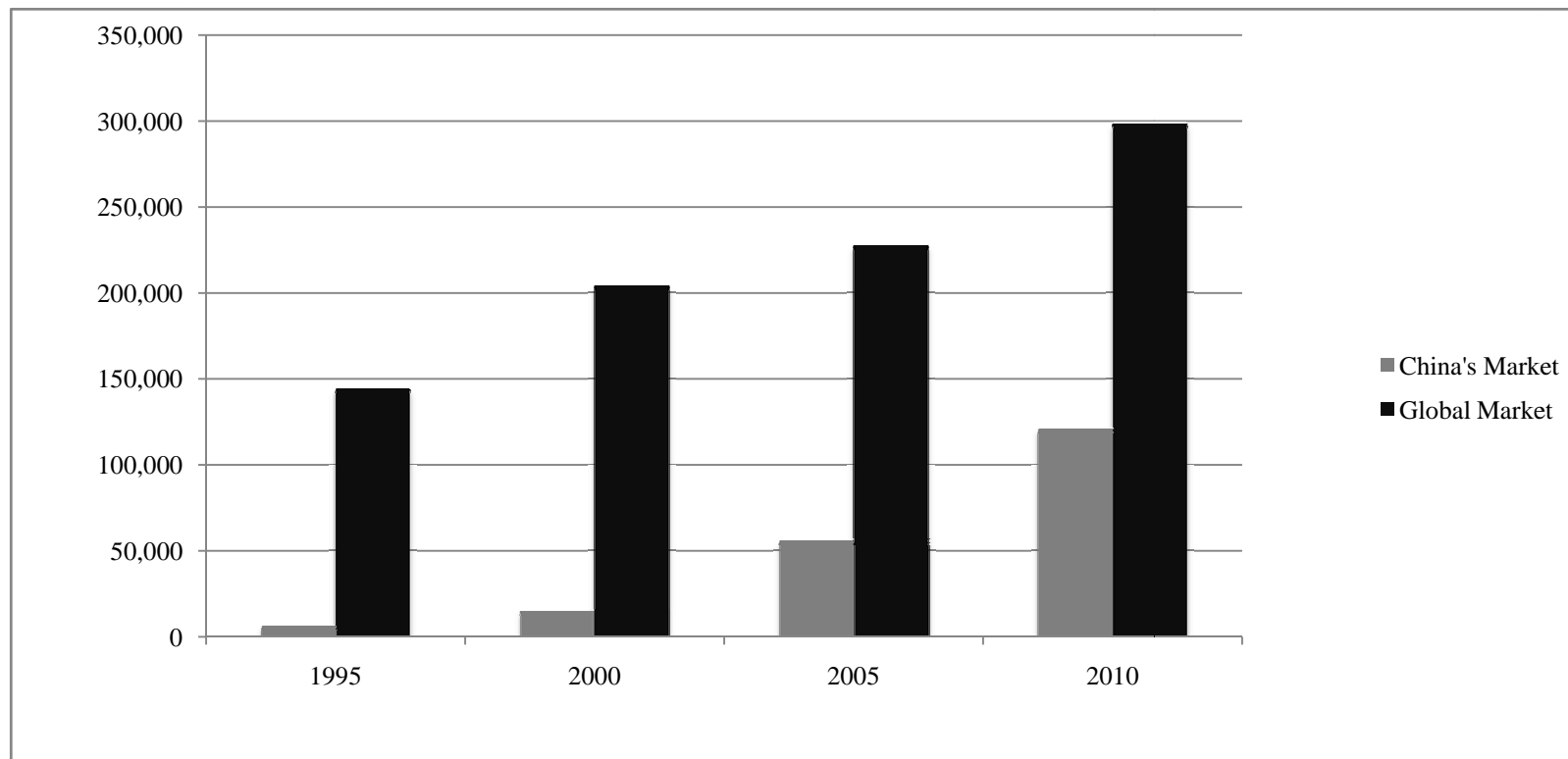
5.1 The “World’s Factory Floor” for Electronics

5.11 The Global Semiconductor Market and China

The market demand for semiconductors grew rapidly in China in the 1990s, due to the migration of global electronics manufacturing and assembly in China. From 2000, about two thirds of the market demand for semiconductors went into products that were ultimately exported, but China’s home market for electronics products (all of which required semiconductors) was also growing.⁵⁸⁵ In 1995, the market demand in China for semiconductors was only perhaps two to three percent of the global market, see Figure Ten,

⁵⁸⁵ PriceWaterhouseCoopers (PwC), “China’s Impact on the Semiconductor Industry,” 2004, page 21.

Figure 10: Semiconductor Market: China and Global, in US\$ Billions



Sources:

- 1) PWC, "China's Impact on the Semiconductor Industry, 2004, 2006, 2011 and 2012," data sources include China Semiconductor Industry Association, CCID, and PwC analysis.
- 2) Wang Yangyuan and Wang Yongwen 王阳元 and 王永文, *Wo Guo Jichengdianlu Chanye Fazhan Zhilu: cong Xiaofei Daguo Zouxian Chanye Qiangguo 我国集成电路产业发展之路：从消费大国走向产业强国* (China's Integrated Circuit Industry Development Path: From a Big, Consuming Nation to a Strong, Industrial Nation), Kexue Chubanshe 科学出版社 (Science Press), 2008, page 123, per CSIA

but China was the world's fastest *growing* market for semiconductors. Despite global downturns in the semiconductor industry in 1997 and 2001, China's market for semiconductors and semiconductor capital equipment both grew rapidly in the late 1990s and into the early 2000s. China's demand for semiconductors approximately tripled between 1995 and 2000. In the late 1990s, the U.S. Semiconductor Industry Association predicted that China would be the world's largest semiconductor market by 2010. Global electronics firms were creating much of the semiconductor demand in China, as these firms were increasingly manufacturing and assembling in China. By 2005, China was twenty five percent of the global semiconductor market, and surpassing the U.S. Semiconductor Industry Association's predictions, by 2008 China was already the world's largest market for semiconductors. In 2010, the market in China was more than forty percent of the total global market, per Figure Ten. With much of the global semiconductor market relocating to China, Chinese leaders set a goal of supplying thirty percent of the market demand in China during the tenth five year plan (2001-2005), and officials planned to continue to provide research and other auxiliary support and funding for the industry.⁵⁸⁶

Generally, as electronics products advanced in the 1990s, the relative value of semiconductors in such products rose. Electronics became less expensive to manufacture and

⁵⁸⁶ Hu Qili 胡启立, *Chao Daguimo Jichengdianlu Gongcheng Jishi 超大规模集成电路工程纪实 (Ultra Large Scale Integrated Circuit: Project Records)*, Beijing: Dianzi Gongye Chubanshe 电子工业出版社 (Electronics Industry Publishing House), 2006, page 149-151. Daryl Hatano of the U.S. Semiconductor Industry Association with the Office of the U.S. Trade Representative, in Jerry Mahoney, "China's Chip Challenge," *Electronics Business*, 2003. Precise numbers on China's semiconductor market and level of importation are difficult to identify in the 1990s because semiconductors are nested in other products and because of rampant smuggling (described in Chapter Four, Section 4.26.) However, Chinese and U.S. industry sources both indicate that smuggling was sufficiently curtailed between 1998 and 2002. This was due to China's anti-smuggling programs in 1998 and 1999 and through new Chinese policies implemented in January of 2002 that reduced tariffs on imported semiconductors.

assemble (due, in part, to low cost labor in China), and thus the value of semiconductors relative to the value of the products in which semiconductors were embedded rose, reaching in the range of twenty percent by 2000.⁵⁸⁷

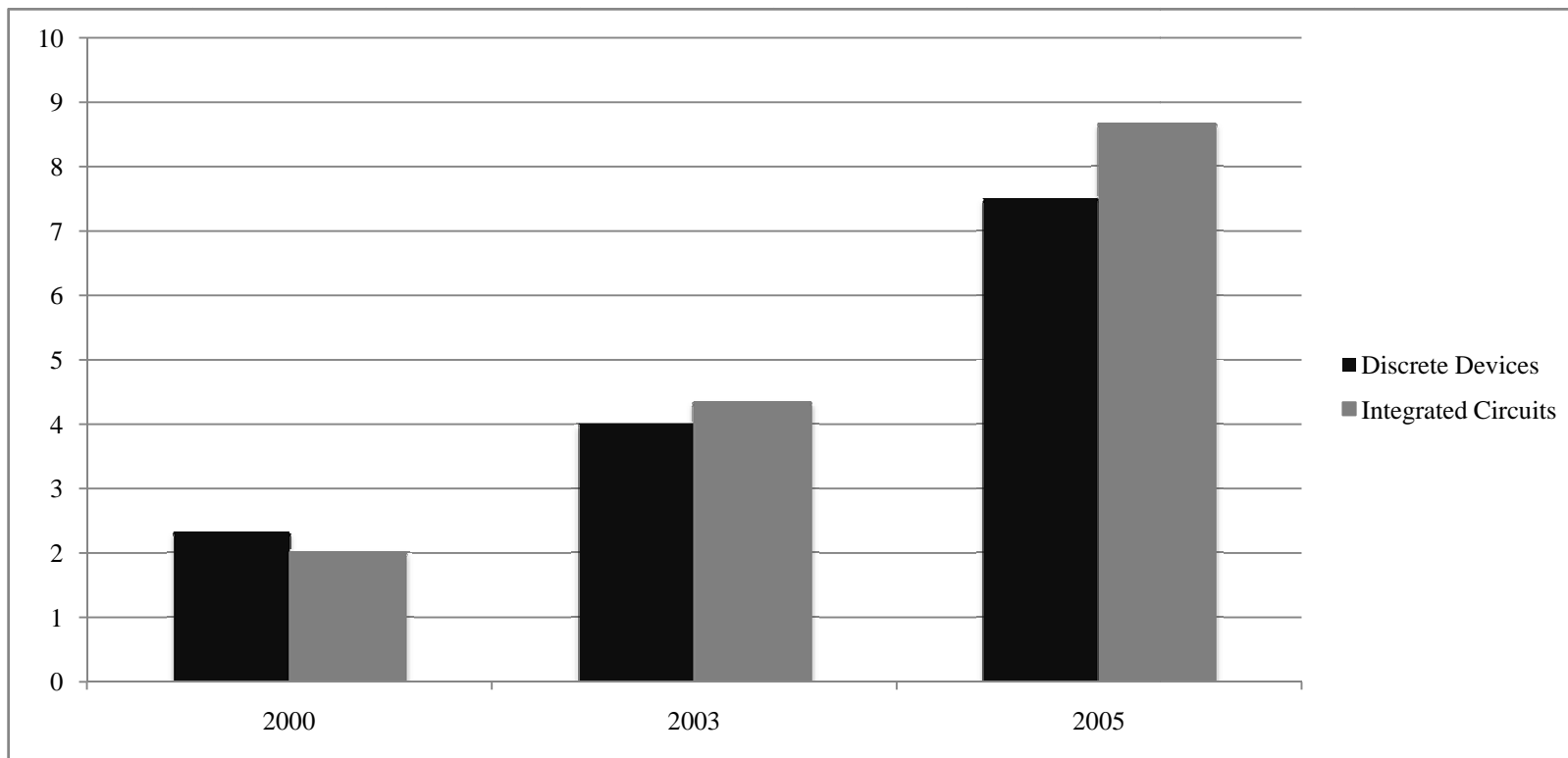
Despite the rise in semiconductors' value relative to that of electronics products, much of the market for semiconductors in China was for relatively low end semiconductors. The market for semiconductors can be broadly segmented between low-end discrete devices (e.g., transistors, diodes, resistors, capacitors) and higher value integrated circuits (I.C.s), which can have billions of discrete devices integrated on each chip. In the 1990s and early 2000s, although the dollar value of the market for I.C.s in China was about five times larger than the market for discrete devices, the market demand for I.C.s in China was mostly comprised of demand for relatively low tech I.C.s, those made with 0.4micron or larger process technology.⁵⁸⁸

Estimates of the percent of the semiconductor market demand in China that was met through imports in the 1990s and early 2000s typically range from eighty to ninety-five percent. As Chapters Two, Three, and Four have shown, semiconductor enterprises in China were mostly producing discrete devices in the 1990s, although their production of I.C.s was increasing. Indeed, more than half of semiconductor production revenues in China were for discrete devices until as late as 2003, when I.C. revenues finally began to surpass discrete device revenues, see Figure Eleven. Thus, production in China was geared more toward meeting the market for discrete devices, while most I.C.s had to be imported.

⁵⁸⁷ This held true for the leading categories of electronics products made in China including consumer electronics, telecomm products, and computers.

⁵⁸⁸ iSupply, "Semiconductor Wafer Manufacturing in China: A Panacea or a Global Investment Trap?," 2002, page 15.

Figure 11: Estimated Semiconductor Production in China in US\$ Billions



Source:

PWC, "China's Impact on the Semiconductor Industry, 2006," page 20, data sources include China Semiconductor Industry Association, CCID, and PwC analysis.

The following summarizes key aspects of China's growing semiconductor market in the late 1990s.

- Market demand was driven by global electronics firms, which were increasingly manufacturing and assembling in China due to low cost labor.
- Many of the semiconductors demanded in China were imported, approximately eighty five percent, although the semiconductors demanded in China were relatively low end at 0.4micron or greater process technology.
- Semiconductor production in China could only meet about fifteen percent of demand in China, and production in China was primarily lower end products.
- Approximately two-thirds of the semiconductors installed into electronics products in China were ultimately exported.

5.12 Global Semiconductor Firms Enter China

In the 1990s, although there was a growing market for semiconductors in China, there was not an ideal “marketplace” of semiconductor producing firms owing to China's history of central planning and state ownership of industries, lack of capital sources, non-transparent and inconsistent policy environment, and relatively small semiconductor talent base. Despite this environment, global firms were selling in China in the 1990s (that is, their semiconductors were being imported into China), and increasingly, global firms began to try to locate in China. These firms sought to establish operations in China because they believed that the market for semiconductors in China would continue to grow and China's policies would evolve.

Chapters Three and Four showed how five of the largest global semiconductor firms established significant partnerships or joint ventures in China in the 1990s as part of the

establishment of China's "key" and "national champion" semiconductor enterprises. To recap, these included:

- Alcatel's joint venture with China's Shanghai Belling (key enterprise)
- Philips' joint venture with China's ASMC (key enterprise)
- NEC's joint ventures with China's Shougang (key enterprise)
- NEC's joint venture with Huahong (national champion)
- AT&T-Lucent as Huajing's primary equipment partner for Project 908 (key enterprise and national champion)

As Chapter Four discussed, each of these major ventures was arranged on a one-off basis, despite being part of broad governmental plans for the semiconductor industry developed in the late 1980s (see Chapter Two.)

And yet, these important relationships were just a part of the migration of global semiconductor firms to China in the 1980s and 1990s. In addition to the firms above, other global semiconductor firms such as Texas Instruments, Toshiba, Fujitsu, Siemens, and Intel, began making notable semiconductor equipment sales in China and began establishing joint ventures and operations in China in the 1980s and 1990s, along with importing into (that is, selling semiconductors into) China. Figure Thirteen shows numerous examples of global firms' activities in China in the 1990s. Motorola is the company most commonly cited for having significant and early operations in China, and indeed Motorola invested over US\$3.4 billion in China.⁵⁸⁹ The Motorola's story, however, should not overshadow the reality that

⁵⁸⁹ IBS Center for Management Research, "Motorola in China," 2003, see www.icmrindia.org.

Figure 13: Examples of Global Semiconductor Firm Activity in China in the 1980s and 1990s

Year	Global Firm	Activity in China	Source
1984	Applied Materials	Began selling in China in 1984 and by 2000 had sites in Wuxi, Shanghai, Beijing and Tianjin.	21
1985	Hewlett-Packard	Established assembly (P.A.T.) operations with multiple Chinese partners from 1985.	7
From 1986	Fujitsu	Transferred technology to Nantong Huada for assembling logic chips; established JVs in Nanjing (1992), Jiangsu (1994), Xian (1995), Nantong (1997), and another Nanjing (1999.) Also established a research center with CAS in Beijing in 1994. Also operated a semiconductor assembly (P.A.T.) plant from 1999.	1
1986	Texas Instruments	Established first office in Beijing in 1986.	2
1991	Daw Technologies	Chinese government signed possibly the "single largest" semiconductor equipment purchase from Daw for Huajing, for clean room equipment.	3
1992	United States (various companies)	China sent three delegations to the U.S. to buy older, used semiconductor equipment.	4
1992	Motorola	Established Tianjin production facility for discrete devices and ICs, a wholly (Motorola) owned subsidiary.	5
1993	AMD	Opened a design office in Beijing.	7
1993	Diodes	Established production in China of discrete devices.	
1994	Toshiba	Established an assembly (P.A.T.) plant near Shanghai.	1
1994	Intel	Subcontracted P.A.T. work to Huajing for 386 chips; 1995, set up operations in Shanghai.	4
1994	Northern Telecom	Established joint venture with Shanghai government bodies to produce Ics; Norther was majority owner; the joint venture was to supply Northern's other China-based joint ventures. Northern set up four agreements and had locations in Beijing, Shanghai, and Guangzhou.	6

Figure 13, continued: Examples of Global Semiconductor Firm Activity in China in the 1980s and 1990s

Year	Global Firm	Activity in China	Source
1994	ITT	Formed joint venture with Zhejiang Connector Factory; ITT owned 51 percent of the joint venture.	8
1994	Toshiba	Established JV with Haujing to produce semiconductors. Toshiba owned 60 percent of the JV.	9
1994	U.S. Department of Commerce	The DOC along with three U.S. electronics-related trade associations established a U.S. Information Technology Office in Beijing.	10
1994	Microelectronic Packaging	Contracted with Chinese organizations to provide technology, training, and equipment for manufacturing (semiconductor) ceramic packaging.	12
1994	National Semiconductor	Signed agreement with Chinese government to provide semiconductor-related technologies to China.	13
1994	IBM	Supplied capital equipment and a major research contract to Beijing's Application Software Development Corp (associated with Qinghua University.)	19
1994	Hitachi	Established first China office in 1994; established an assembly (P.A.T.) site for DRAM in 1999.	20
By 1995	Sun Microsystems	Established a partnership with China-based Huasun.	19
1995	AlphaTec	Formed JV in Shanghai with Huaxu of the MEI for P.A.T.; Microchip Technologies (of Arizona) also participated in the venture.	11
1995	General Instruments	Received a business license to establish a semiconductor wholly foreign owned manufacturing facility in Tianjin.	14
1996	AT&T-Lucent	Established six JVs and two wholly foreign owned enterprises in China, with a total of 20,000 workers (also transferred primary technology to Huajing under Project 908.)	16
1996	Daw Technologies	Sold semiconductor equipment to Huajing, Huayue, and Chinese Design Institute No. 10.	18

Figure 13, continued: Examples of Global Semiconductor Firm Activity in China in the 1980s and 1990s

Year	Global Firm	Activity in China	Source
Before 1997	Siemens	Sold equipment to Huajing; established a production facility in Jiangsu Wuxi.	17
1997	Hitachi	Established a packing (P.A.T.) plant for DRAM.	1
1997	Bell Labs (the R&D unit of Lucent)	Built branches in Beijing and Shanghai and launched a joint lab with Shanghai Jiaotong Daxue.	16
1997	Matsushita	Provided technology to Wuxi Little Swan, a large electronics/semiconductor R&D firm.	17
Before 2000	Fairchild	Established manufacturing in China.	15

Sources:

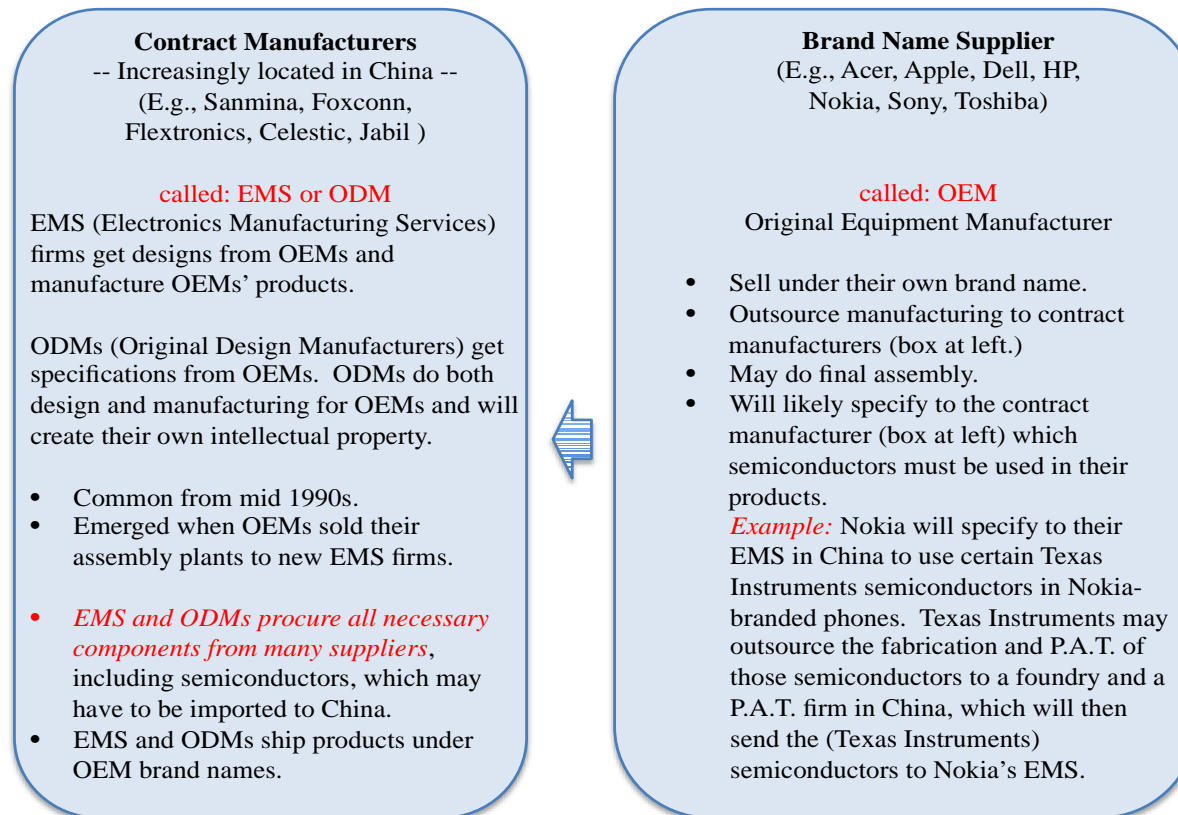
- 1) Jifu Wang, "China Huajing Electronics Group Corporation," unpublished business case study, 2000.
- 2) Texas Instruments, see article at http://www.ti.com/corp/docs/csr/news_community_ti_china.shtml.
- 3) *High Beam Research*, November 1992.
- 3) *High Beam Research*, "Daw Technologies," August 1, 1991.
- 4) *New York Times*, "Intel to Begin China Venture," March 26, 1994.
- 5) Bill Rumbler, "Motorola Building \$120million Factory in China," *Chicago Sun Times*, March 28, 1992.
- 6) *PR Newswire*, "Northern Telecom Announces Large Investment Program...in China," April 22, 1994.
- 7) Rebecca Smith, "China's Growing Market Lures U.S. Computer Chip Makers," *Tribune Business News*, April 3, 1994.
- 8) *PR Newswire*, "ITT Unit Forms JV with China's Largest Connector Company," April 12, 1994.
- 9) *New York Times*, "Toshiba in Chinese Deal," August 9, 1994.
- 10) *PR Newswire*, "U.S. Department of Commerce Awards First Ever Grant for U.S.-Beijing Information Technology Office," October 26, 1994.
- 11) *Business Wire*, "Alphatec Groups Forms JV in Shanghai, China," July 18, 1995
- 12) *Business Wire*, "Microelectronic Packaging Receives \$2million Contract from Chinese Government Electronics Concern," November 23, 1994.
- 13) *Business Wire*, "National Semiconductor and Chinese Government Sign Agreement...in China," December 22, 1994
- 14) *PR Newswire*, "General Instrument Corp. Division Receives Business License from PRC," May 25, 1995.
- 15) *Business Wire*, "Fairchild Semiconductor Completes Acquisition of QT Optoelectronics," May 30, 2000.
- 16) *Xinhua News Agency*, "Lucent Technologies' Investment Exceeds 100million," January 19, 1998.
- 17) *Washington Post*, "'Made in China' Takes Great Leap Forward," June 15, 1997.
- 18) *Business Wire*, "Daw Technologies Inc. Receives Approximately \$8billion in New Contracts," January 9, 1996.
- 19) Michael Zielenziger, "Pacific Rim: China Builds 'Brainpower Center'," *Tribune News Service*, November 1, 1995.
- 20) Hitachi, see article at <http://www.hitachi.com/about/corporate/history/1980.html>.
- 21) *Business Wire*, "Applied Materials Expands Global Presence to Better Serve Customers in Asia," May 8, 2001.

many global semiconductor firms began to establish operations in China in the 1980s and 1990s, and in the 1990s, Japanese semiconductor firms were actually the largest foreign presence in China. Prominent examples include Toshiba's equipment transfers to Huajing in 1980s and its plant near Shanghai from 1994, Hitachi in China from 1997, and Fujitsu with several locations in China in the 1990s. That said, these global firms did not contribute substantially to overall revenues in the semiconductor industry in China in the 1990s because many of these global firms' China-based activities were "offices," (lower value added) P.A.T. facilities, equipment sales, or arrangements to produce discrete devices, see Figure 13 above.

Global semiconductor and semiconductor-related firms increasingly desired to locate in China to be close to customers, where customers were mainly firms that were manufacturing or assembling electronics products and thus using semiconductors.⁵⁹⁰ In the 1990s, brand name original equipment manufacturers (i.e., O.E.M.s such as Apple, Toshiba, Nokia) began to use contract manufacturers (that is, outsourcing) for manufacturing and assembly. O.E.M.s would outsource to E.M.S. (electronics manufacturing service) firms or O.D.M. (original design manufacturers), which were increasingly located in China in the 1990s. Figure Twelve broadly defines the role of 1) global electronics firms, that is O.E.M.s, original equipment manufacturers, 2) electronic contract manufacturing firms called E.M.S. firms or O.D.M.s, and 3) semiconductor firms. For example, Chinese O.E.M. Panda may contract its manufacturing to O.D.M. Foxconn (also known as Hon Hai, Taiwan-owned but

⁵⁹⁰ *Asia Pulse News*, "Briefing," December 14, 1999. For example, by 1999, Jiangsu's Suzhou High Tech Development Zone already had some thirty foreign computer and electronics companies, including well-know foreign firms such as Seagate, Ericsson, and Philips. Electronics firms such as these all use semiconductors in their products.

Figure 12: The Global Electronics Supply Chain: OEMs and Contract Manufacturers



China-based), who may source semiconductors from Qualcomm of the U.S., who would own the fundamental I.P.

Global semiconductor firms' move to China was facilitated by the industry's transition from the vertically integrated I.D.M. business model, wherein one firm would do design, fabrication, and packaging/assembly/testing (P.A.T.), to a vertically disintegrated model, in which firms specialized in design or fabrication (foundries) or P.A.T. This trend was instigated by TSMC in Taiwan, which established the world's first foundry for outsourcing fabrication work in 1987. The availability of foundries then fostered the emergence of independent design firms. With foundries available, design firms could be successful without the high level of capital required to establish a foundry for their products; they could just outsource fabrication to foundries. Meanwhile, existing global I.D.M.s adopted a "fab-lite" strategy, which meant they were doing less fabrication themselves and outsourcing fabrication, when appropriate. The vertical disintegration of the semiconductor industry furthered the industry's relocation to China, because firms in both the P.A.T. sector and the foundry sector wanted to be close to customers.⁵⁹¹

5.12a The P.A.T. Sector

Semiconductor P.A.T. is technologically sophisticated relative to what might be called "packaging," "assembly," or "testing" in other industries. However, relative to the semiconductor design and fabrication sectors, the semiconductor P.A.T. sector is less capital

⁵⁹¹ SMIC, "Rising to the Challenge." In 2001, seventy percent of China's fabrication lines were still 3 and 4 inch lines, while the high-end semiconductor market was being met by 12 inch lines. U.S. export restrictions would not allow 12 inch production equipment to be sold into China, but European and Japanese suppliers would sell such equipment to China.

intensive, more labor intensive, requires fewer skills, and there is less concern about intellectual property protection. P.A.T. firms handle the final preparation of semiconductors before they go to the customer, so P.A.T. firms seek geographic proximity to customers such as E.M.S. firms and O.D.M.s. For all these reasons, P.A.T. firms increasingly sought to locate in China in the 1990s and 2000s.

Generally, the semiconductor P.A.T. sector was the first sector in the global semiconductor industry to undergo de-virtualization and locate in Asia. P.A.T. was traditionally done in house by the major global I.D.M.s, but as early as the 1960s, some I.D.M.s began to outsource their P.A.T. work to regions with lower labor costs. By 1980, perhaps eighty percent of the U.S. P.A.T. work was being done overseas, largely in Asia. Some overseas facilities were owned by global I.D.M.s and others were stand-alone P.A.T. firms or joint ventures. The semiconductor industry's de-verticalization in the 1990s (with the emergence of "fab-less" design houses and foundries) furthered the trend of stand-alone P.A.T. facilities.⁵⁹²

In the early 1990s, the P.A.T. sector in China consisted primarily of smaller Chinese facilities using 1980s technology. However, by 2000, non-Chinese firms already accounted for more than half of the revenues in the sector. Non-Chinese firms established operations in China in the 1990s due to the migration of global electronics manufacturing and assembly in China during that decade. At US\$1.61 billion, P.A.T. revenues in China in 2000 were already

⁵⁹² Wang Yangyuan and Wang Yongwen 王阳元 and 王永文, *Wo Guo Jichengdianlu Chanye Fazhan Zhilu: cong Xiaofei Daguo Zouxian Chanye Qiangguo* 我国集成电路产业发展之路：从消费大国走向产业强国 (China's Integrated Circuit Industry Development Path: From a Big, Consuming Nation to a Strong, Industrial Nation), Kexue Chubanshe 科学出版社 (Science Press), 2008, page 176.

more than twice the revenues of the semiconductor manufacturing sector in China, see Figure Seventeen ahead.⁵⁹³

From 2000, more global P.A.T. firms established operations in China either as wholly foreign owned enterprises or as joint ventures, and this influx caused China to become a leading global site for P.A.T. activity.⁵⁹⁴ By 2005, fifteen of the world's largest I.D.M.s had P.A.T. facilities in China, and many of the leading global P.A.T. firms had operations in China. This resulted in the P.A.T. sector being more globalized than the fabrication or design sectors, at that time.⁵⁹⁵ The P.A.T. work in China integrated the back end of the semiconductor value chain with the global industry and contributed to the notion of China as “the world's factory floor.”

The influx of P.A.T. activity, mainly in Jiangsu province in Wuxi, Suzhou, and Nantong, led P.A.T. revenues in China to multiply by 2.7 times by 2005, causing China's semiconductor industry to be significantly “unbalanced” in terms of the proportion of revenues accruing to the P.A.T. sector, as compared to the proportion of P.A.T. revenues in

⁵⁹³ Chen Ling and Lan Xue, “Global Production Networks,” *China and the World Economy*, Volume 18, Number 6, 2010.

⁵⁹⁴ Denis Simon wrote in 2000 that there were about 160 P.A.T. facilities in China, with about 60 being “major” facilities including wholly foreign owned enterprises and joint ventures. A 2004 PwC study said there were about 78 P.A.T. facilities in China in 2004, and of the 78, only 21 were firms that were headquartered in China. And, of the 78, “35 did not exist in 1999.” I attended a P.A.T. conference in Wuxi in 2009, and from the attendee list, it seemed that there well over 100 P.A.T. facilities in China by then. The conference participants were from a mix of mostly Asian countries, suggesting that many P.A.T. facilities in China had international management or ownership. See Denis Simon, “The Microelectronics Industry Crosses a Critical Threshold,” *The China Business Review*, 2001. PwC, “China's Impact,” 2004, pages 38-39. SMIC (S. Chen, G. Liu, V. Lee, J. Xie), “Rising to the Challenge: China's New Semiconductor Industry *Future Fab*, Feb 2, 2002. Leading global firms already with P.A.T. facilities in China by 2001, included Motorola, Philips, Panasonic, Fujitsu, and Alphatec, and by 2005, Intel, AMD, Samsung, and Hyundai were building P.A.T. facilities in China. Joint ventures included: Shougang NEC, Wuxi Huazhi, Mistubishi-Stone, Leshan-Pheonix, Nantong Fujitsu, and Shenzhen-SGS Thomson. Major P.A.T. firms in China by the early 2000s included: Amkor, ASAT Holdings, ASE, ChipMOS, Millinium Microtech, PSI Technologies, and STATSChipPac.

⁵⁹⁵ PwC, “China's Impact,” 2004, page 38. Chen, “Global Production,” page 123.

the global industry.⁵⁹⁶ This is not surprising, given China's low labor costs and the desire of P.A.T. firms to be close to customers. However, throughout the 2000s, P.A.T. revenues declined as a percentage of the industry, and the industry achieved better balance, see Figure Seventeen. According to the CEO of China's largest domestic P.A.T. enterprise (he was previously a General Manager of Huajing), despite the development of this sector, Chinese domestic P.A.T. enterprises were still about ten years behind global standards in the late 2000s, with their primary constraints being: capital, technical personnel, and competition from foreign firms that benefitted from government incentives in China. Chinese officials had not targeted the sector for support in the 1990s or through new policies around 2000 because the sector was considered lower-value-added and lower-technology, in terms of the semiconductor industry. The targeted sectors of the semiconductor industry were fabrication (manufacturing) and design.⁵⁹⁷

5.12b The Fabrication (Foundry) Sector

Global companies wanted to fabricate their semiconductors in China (by outsourcing to foundries) in order to be close to China's market and to avoid China's seventeen percent tariff on imported semiconductors. The V.A.T. for locally produced semiconductors was only three to six percent. (China's V.A.T. policy in the early 2000s is covered in Section 5.2

⁵⁹⁶ Interview with Yu Xiekang, General Manager of Jiangsu Changjiang Electronics Technology (JCET), June 2, 2009, JCET headquarters near Wuxi.

⁵⁹⁷ Yu Xiekang 于燮康, "Fengceye: Guimo Zhan I.C. Banbijiangshan Tongzhihua Jingzheng Jiaju 封测业：规模占 IC 半壁江山同质化竞争加剧 (The P.A.T. Sector: Half of the Nation's Integrated Circuit Industry)," *Zhongguo Dianzibao 中国电子报 (China Electronics News)*, May 12, 2009.

Figure 17: Semiconductor Production Revenues in China, by Sector (RMB100 million), excluding Discrete Devices

Year	2000	2001	2002	2003	2004	2005
Design	9.8	14.8	21.6	44.9	81.8	124.3
• Percent of industry	5	7	7	13	15	18
Fabrication (manufacturing)	48	27.7	33.6	60.5	180	232.9
• Percent of industry	26	14	14	17	33	33
Packaging, Assembly, Testing (P.A.T.)	128.4	161.1	213.3	246	283.5	344.9
• Percent of industry	69	79	79	70	52	49
Total	186.2	203.6	268.5	351.4	545.3	702.1

Source: National Bureau of Statistics, 2001-2005, shown in Chen Ling and Xue Lan, "Global Production Networks," *China and the World Economy*, Volume 18, Number 6, 2010, page 114, Table 1.

By 2004, a number of firms were offering foundry services in China, including:⁵⁹⁸ CSMC (Huajing's affiliate), Huahong-NEC, SMIC, ASMC, Hejian, TSMC, and Grace. Only four foreign I.D.M.'s had fabrication facilities in China by 2003, owing to the "fab-lite" trend. These four included: 1) NEC of Japan, which had partnered with Chinese national champion Huahong and was a partner in a key Chinese semiconductor enterprise Shougang-NEC, 2) Philips of the Netherlands, which had partnered with Chinese key enterprise ASMC, 3) ON Semiconductor of the United States, and 4) Rohm of Japan.⁵⁹⁹ While Taiwan's TSMC and UMC remained the world's largest foundries throughout the 2000s, foundry work increasingly migrated to China during that decade.

A common perception is that the fabrication sector took off in China after 2002, when Taiwan lifted investment restrictions on the semiconductor industry in Mainland China. This research, however, has shown that the increase in semiconductor production in China began prior to Taiwan's 2002 policy change, see Figure Six.⁶⁰⁰ (Taiwan's policies are discussed in Section 5.22.) That said, there was indeed an influx of Taiwan-related talent and investment to Mainland China from around 2000, particularly new foundries. These included Beijing's Huaxia Semiconductor Manufacturing (HSMC) which was a Sino-foreign joint venture with Taiwanese management and U.S. investment, as well as SMIC and Grace in 2000. SMIC and Grace are sometimes called "Taiwanese," due to their ties to Taiwan.⁶⁰¹ However, both are

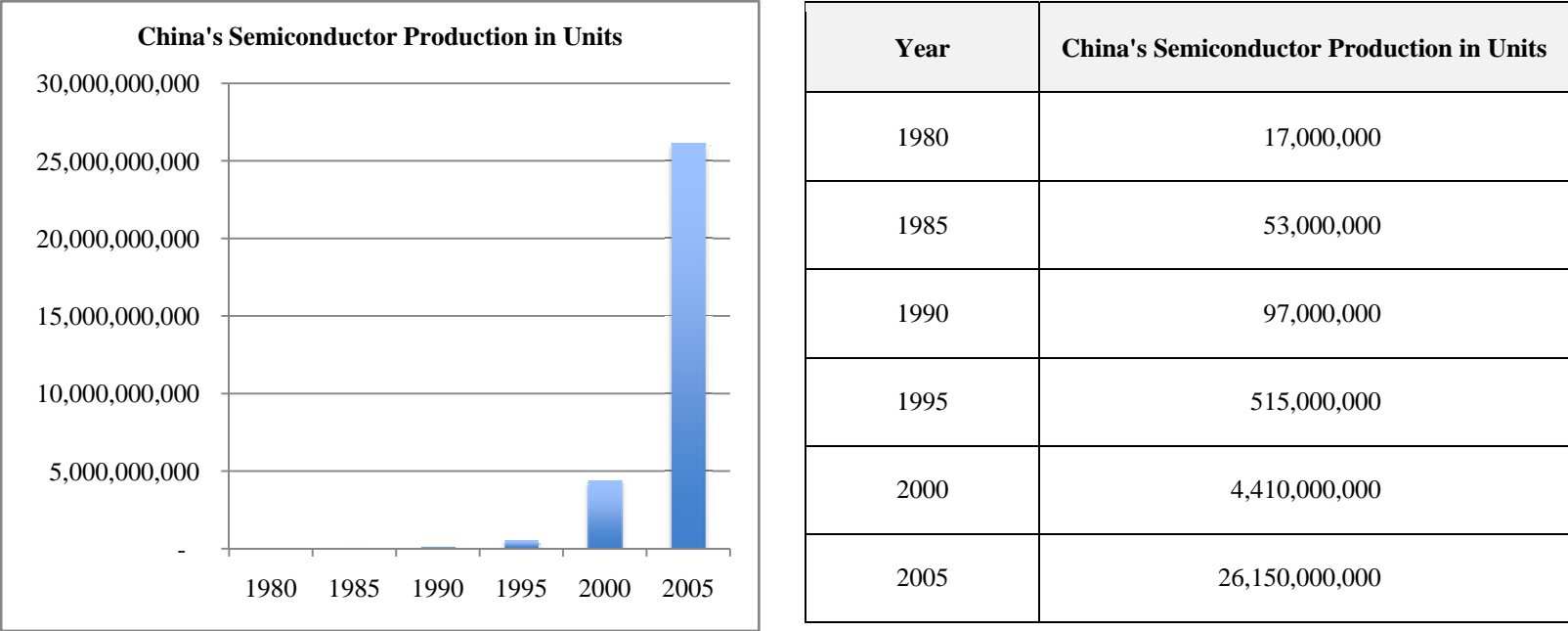
⁵⁹⁸ PwC, "China's Impact," 2004, page 35.

⁵⁹⁹ Motorola sold its Tianjin fabrication facility to SMIC in 2003.

⁶⁰⁰ Chen Ling, a professor at Qinghua University who studies the semiconductor industry, shows similar data regarding the take off in production in two documents, see Chen, "Global Production Networks," page 113 and Chen Ling, "Government Policy-making Capability," a presentation from Tsinghua University's Chinese Institute of Science and Technology Policy, November 30, 2010.

⁶⁰¹ SMIC and Grace both had executives from Taiwan and possible investments from Taiwan.

Figure 6: Semiconductor Production in China



This chart is compiled from the following sources:

1) Zhu Yiwei 朱贻伟, *Zhongguo Jichengdianlu Chanye Fazhan Lunshu Wenji 中国集成电路产业发展: (China's IC Industry Development: Collected Works)*, Beijing: Xinshidai 新时代出版社 (New Times Press), 2006, pages 127, 163 and 164.

2) Ling Chen and Lan Xue, "Global Production Networks," *China and the World Economy* (published by Chinese Academy of Social Sciences), Volume 18, Number 6, 2010, page 114. Chart footnotes: a) Chen and Xue, "Global Production Networks," this amount refers to investment in the five key enterprises (including Huajing) from 1985-1995.

Figure 7: Largest 15 Semiconductor Firms in China in 2003 by Revenue

Chinese enterprises in *italics*.

Note: These are the firms with highest revenues *operating* in China.

These are not the same as the largest semiconductor *suppliers* to the Chinese market because most of the semiconductors that meet China's market demand are imported.

Analysis:

Of the top 15 firms' revenue in 2003, "Chinese" firms constituted 47 percent.

The "Chinese" firms were a mix of ownership forms.

Rank	Headquarters	Name	Revenue in 2003 (US\$ million)	2003 Notes on "Chinese" Firms
1	US	Motorola	962	
2	<i>China/Cayman Islands/International</i>	SMIC	350	SMIC is a WFOE registered in the Cayman Islands.
3	Japan	Renesas	195	
4	<i>China/Japan</i>	Huahong-NEC	188	Huahong-NEC of Project 909 is a Sino-Foreign JV.
5	<i>China/US</i>	Leshan	149	LeShan has a JV with Motorola and provides mainly discrete devices.
6	Switzerland	Shenzhen Sai STMicroelectronics	125	
7	US	Intel	109	
8	<i>China</i>	Jianxin XinChao	108	XinChao is a state owned group.
9	<i>China/Netherlands</i>	ASMC	94	ASMC has a JV with Netherlands-based Philips and serves mainly as a foundry for Philips.
10	<i>China/Japan</i>	Nantong-Fujitsu	92	Nantong-Fujitsu is a Sino-foreign JV.
11	<i>China</i>	JCET	84	JCET is large state owned P.A.T. enterprise near Wuxi.
12	<i>China/Hong Kong</i>	China Resources Microelectronics/CSMC	77	CRM is a member of the CR enterprise group; it includes Huajing and CSMC of Project 908.
13	<i>China</i>	Datang	75	Datang is a state owned enterprise group in electronics-related industries.
14	Singapore	ChipPAC	73	
15	<i>China/Japan</i>	Shougang-NEC	68	Shougang-NEC is a Sino-foreign JV; Chinese partner is Beijing Shougang, a steel enterprise group.

Source: PWC, "China's Impact on the Semiconductor Industry, 2004," data sources include CSIA, CCID, and PwC analysis.

"Chinese" revenue:	1,285	47%
Other revenue:	1,464	53%
Total revenue:	2,749	100%

Figure 9: Largest 15 Semiconductor Firms in China in 2011 by Revenue

Chinese enterprises in *italics*.

Note: These are the firms with highest revenues *operating* in China. This is not the same as the largest semiconductor *suppliers* to the Chinese market because most of the semiconductors that meet China's market demand are imported.

Rank	Headquarters	Name	2011 Revenue US\$mm	2011 Notes on "Chinese" Firms
1	US	Intel	4,765	
2	Korea	Hynix	2,452	
3	<i>China/Cayman Islands/international</i>	SMIC	1,315	SMIC is a WFOE registered in the Cayman Islands.
4	US	Freescall	1,119	
5	<i>China</i>	HiSilicon (formerly with Huawei)	1,032	HiSilicon was formerly part of state-owned Huawei (telecomm), but is now a private, listed firm.
6	<i>China</i>	XinChao (JCET)	969	XinChao is a state owned group; it includes the large P.A.T. firm called JCET.
7	Korea	Samsung	838	
8	<i>China</i>	Spreadtrum	684	Spreadtrum was private from its inception.
9	<i>China/Japan</i>	Huahong	671	Huahong includes Huahong-NEC of Project 909, which is a Sino-foreign JV.
10	Taiwan	ASE	657	
11	Japan	Renesas	643	
12	<i>China/Hong Kong</i>	China Resources Microelectronics	631	CRM is a member of the CR enterprise group; it includes Huajing and CSMC of Project 908.
13	US	Cree Huizhou	631	
14	<i>China</i>	Nantong Huada	620	Nantong is a state owned group.
15	Japan	Panasonic	602	

Source: PWC, "China's Impact on the Semiconductor Industry, 2012 Update," data sources include CSIA, CCID, and PwC analysis.

"Chinese" revenue:	5,922	34%
Other revenue:	11,707	66%
Total revenue:	17,629	100%

Analysis: Of the top 15 firms' revenue in 2011, "Chinese" firms constituted 34 percent. The "Chinese" firms were a mix of ownership forms.

wholly foreign owned enterprises in China, and they are not registered nor headquartered in Taiwan.⁶⁰² Later in the 2000s, Taiwan's two largest foundries, TSMC and UMC, established operations in China.⁶⁰³ Despite this seeming shift in foundry capacity from Taiwan to Mainland China,⁶⁰⁴ Taiwanese firms did not dominate industry revenues in China in the 2000s, as shown in Figures Seven and Nine on the previous pages. (Recent twists in China-Taiwan semiconductor industry ties have garnered media attention. In 2009, Taiwan's UMC, the world's second largest foundry, bought China's Hejian foundry. Hejian had been established in Suzhou in 2001 allegedly with illegal investments tied to UMC of Taiwan. Thus, UMC's eventual purchase of Hejian is noteworthy. Also, in 2011, China's national champion Huahong merged with Taiwan-affiliated Grace.)⁶⁰⁵

5.12c Global Firms and China's Business Environment

Despite the integration of the semiconductor industry in China with the global industry during the 1990s and early 2000s, the Chinese government does not seem to have had national level plans for coordinating global semiconductor-related firms' entrance to China during

⁶⁰² Grace was established in Shanghai in 2000 as a pure foundry; it began production in 2003. Grace was founded as a wholly foreign owned enterprise, and it was a subsidiary of the Grace T.H.W. Group. Grace's co-founders were well connected. Winston Wong is eldest son of the former Chairman of Formosa Plastics of Taiwan, and Jiang Mianheng is the son of former Chinese President Jiang Zemin. Wong and Jiang met while studying in the U.S. Winston Wong initially served as president and CEO of Grace, but he was not an official investor due to investment restrictions imposed by Taiwan. By 2002, Nasa Tsai was President of Grace. Tsai got his doctorate at Stanford and worked at Fairchild and Intel in the U.S. before returning to Taiwan to co-found Mosel and Vitelic with Peter Chen. He and Chen also worked together in the late 1990s as founding executives of CSMC, affiliated with Huajing in Wuxi, see Chapter Three. See Chapter Four for SMIC's ties to Taiwan.

⁶⁰³ By 2013, Grace listed its significant shareholders as: Shanghai Alliance Investment, Cheung Kong Holdings and Hutchison Whampoa of Hong Kong, Silicon Storage Technology, Sanyo, and private equity firms GEMS and UCL Asia, see www.gracesemi.com, "Company Profile."

⁶⁰⁴ *Manufacturing and Technology News*, Volume 10, Number 15, August 4, 2003.

⁶⁰⁵ Hynix is 3rd largest memory maker in world, and about forty percent of its production was in Wuxi by 2008. Hynix was the largest employer in Wuxi in 2008.

Figure 13: Examples of Global Semiconductor Firm Activity in China in the 1980s and 1990s

Year	Global Firm	Activity in China	Source
1984	Applied Materials	Began selling in China in 1984 and by 2000 had sites in Wuxi, Shanghai, Beijing and Tianjin.	21
1985	Hewlett-Packard	Established assembly (P.A.T.) operations with multiple Chinese partners from 1985.	7
From 1986	Fujitsu	Transferred technology to Nantong Huada for assembling logic chips; established JVs in Nanjing (1992), Jiangsu (1994), Xian (1995), Nantong (1997), and another Nanjing (1999.) Also established a research center with CAS in Beijing in 1994. Also operated a semiconductor assembly (P.A.T.) plant from 1999.	1
1986	Texas Instruments	Established first office in Beijing in 1986.	2
1991	Daw Technologies	Chinese government signed possibly the "single largest" semiconductor equipment purchase from Daw for Huajing, for clean room equipment.	3
1992	United States (various companies)	China sent three delegations to the U.S. to buy older, used semiconductor equipment.	4
1992	Motorola	Established Tianjin production facility for discrete devices and ICs, a wholly (Motorola) owned subsidiary.	5
1993	AMD	Opened a design office in Beijing.	7
1993	Diodes	Established production in China of discrete devices.	
1994	Toshiba	Established an assembly (P.A.T.) plant near Shanghai.	1
1994	Intel	Subcontracted P.A.T. work to Huajing for 386 chips; 1995, set up operations in Shanghai.	4
1994	Northern Telecom	Established joint venture with Shanghai government bodies to produce Ics; Norther was majority owner; the joint venture was to supply Northern's other China-based joint ventures. Northern set up four agreements and had locations in Beijing, Shanghai, and Guangzhou.	6

Figure 13, continued: Examples of Global Semiconductor Firm Activity in China in the 1980s and 1990s

Year	Global Firm	Activity in China	Source
1994	ITT	Formed joint venture with Zhejiang Connector Factory; ITT owned 51 percent of the joint venture.	8
1994	Toshiba	Established JV with Haujing to produce semiconductors. Toshiba owned 60 percent of the JV.	9
1994	U.S. Department of Commerce	The DOC along with three U.S. electronics-related trade associations established a U.S. Information Technology Office in Beijing.	10
1994	Microelectronic Packaging	Contracted with Chinese organizations to provide technology, training, and equipment for manufacturing (semiconductor) ceramic packaging.	12
1994	National Semiconductor	Signed agreement with Chinese government to provide semiconductor-related technologies to China.	13
1994	IBM	Supplied capital equipment and a major research contract to Beijing's Application Software Development Corp (associated with Qinghua University.)	19
1994	Hitachi	Established first China office in 1994; established an assembly (P.A.T.) site for DRAM in 1999.	20
By 1995	Sun Microsystems	Established a partnership with China-based Huasun.	19
1995	AlphaTec	Formed JV in Shanghai with Huaxu of the MEI for P.A.T.; Microchip Technologies (of Arizona) also participated in the venture.	11
1995	General Instruments	Received a business license to establish a semiconductor wholly foreign owned manufacturing facility in Tianjin.	14
1996	AT&T-Lucent	Established six JVs and two wholly foreign owned enterprises in China, with a total of 20,000 workers (also transferred primary technology to Huajing under Project 908.)	16
1996	Daw Technologies	Sold semiconductor equipment to Huajing, Huayue, and Chinese Design Institute No. 10.	18

Figure 13, continued: Examples of Global Semiconductor Firm Activity in China in the 1980s and 1990s

Year	Global Firm	Activity in China	Source
Before 1997	Siemens	Sold equipment to Huajing; established a production facility in Jiangsu Wuxi.	17
1997	Hitachi	Established a packing (P.A.T.) plant for DRAM.	1
1997	Bell Labs (the R&D unit of Lucent)	Built branches in Beijing and Shanghai and launched a joint lab with Shanghai Jiaotong Daxue.	16
1997	Matsushita	Provided technology to Wuxi Little Swan, a large electronics/semiconductor R&D firm.	17
Before 2000	Fairchild	Established manufacturing in China.	15

Sources:

- 1) Jifu Wang, "China Huajing Electronics Group Corporation," unpublished business case study, 2000.
- 2) Texas Instruments, see article at http://www.ti.com/corp/docs/csr/news_community_ti_china.shtml.
- 3) *High Beam Research*, November 1992.
- 3) *High Beam Research*, "Daw Technologies," August 1, 1991.
- 4) *New York Times*, "Intel to Begin China Venture," March 26, 1994.
- 5) Bill Rumbler, "Motorola Building \$120million Factory in China," *Chicago Sun Times*, March 28, 1992.
- 6) *PR Newswire*, "Northern Telecom Announces Large Investment Program...in China," April 22, 1994.
- 7) Rebecca Smith, "China's Growing Market Lures U.S. Computer Chip Makers," *Tribune Business News*, April 3, 1994.
- 8) *PR Newswire*, "ITT Unit Forms JV with China's Largest Connector Company," April 12, 1994.
- 9) *New York Times*, "Toshiba in Chinese Deal," August 9, 1994.
- 10) *PR Newswire*, "U.S. Department of Commerce Awards First Ever Grant for U.S.-Beijing Information Technology Office," October 26, 1994.
- 11) *Business Wire*, "Alphatec Groups Forms JV in Shanghai, China," July 18, 1995
- 12) *Business Wire*, "Microelectronic Packaging Receives \$2million Contract from Chinese Government Electronics Concern," November 23, 1994.
- 13) *Business Wire*, "National Semiconductor and Chinese Government Sign Agreement...in China," December 22, 1994
- 14) *PR Newswire*, "General Instrument Corp. Division Receives Business License from PRC," May 25, 1995.
- 15) *Business Wire*, "Fairchild Semiconductor Completes Acquisition of QT Optoelectronics," May 30, 2000.
- 16) *Xinhua News Agency*, "Lucent Technologies' Investment Exceeds 100million," January 19, 1998.
- 17) *Washington Post*, "'Made in China' Takes Great Leap Forward," June 15, 1997.
- 18) *Business Wire*, "Daw Technologies Inc. Receives Approximately \$8billion in New Contracts," January 9, 1996.
- 19) Michael Zielenziger, "Pacific Rim: China Builds 'Brainpower Center'," *Tribune News Service*, November 1, 1995.
- 20) Hitachi, see article at <http://www.hitachi.com/about/corporate/history/1980.html>.
- 21) *Business Wire*, "Applied Materials Expands Global Presence to Better Serve Customers in Asia," May 8, 2001.

Figure 14: Examples of Global Firms' Major Activities in China in the Early 2000s

Year	Global Firm	Activity in China	Source
2000, 2001	Applied Materials	Re-enforced existing science funding and training center in cooperation with the Shanghai Science and Technology Commission	6
2000	Accord Advanced Technologies	Hired by Huajing-CSMC for "multi-million dollars" to refurbish equipment; AAT's first project in China	15
2000	AMD	Announced wholly owned subsidiary in Suzhou with US\$108 million investment	14
2000	Philips	Announced a wholly foreign owned P.A.T. operation in Dongguan	18
2000, 2001	SMIC (foreign owned, though considered "Chinese")	Established in 2000, began production in 2002.	
2000	Grace	Established in 2000, began production in 2003.	
2000	Motorola	US\$1.9 billion investment in a Tianjin IC fabrication and P.A.T. facility.	18
2001	Cirrus Logic	Signed a five year agreement with CSMC for CSMC to manufacture semiconductors for Cirrus	17
2001	Ericsson	Announced US\$5 billion investment in China from 2001-2006	2
2001	Nokia	Invested in a US\$1.2 billion project in Beijing	3
2001	Dell	Moved its Asia headquarters to China	4
2001	Alcatel	Moved its Asia Pacific headquarters to Shanghai	5
2001	Nelco Wuxi (part of Park Electromechanical Corporation)	Opened semiconductor materials facility in Wuxi	9
2002	ASML	Received a major order for multiple equipment products from Huajing	16
2002	Motorola	Announced US\$10 billion investment in China from 2002-2012	1
2002	KEC	Doubled Wuxi production	7

Figure 14, continued: Examples of Global Firms' Major Activities in China in the Early 2000s

Year	Global Firm	Activity in China	Source
2002	Texchem-Pack	Established a wholly foreign owned subsidiary in Wuxi to supply semiconductor firms	8
2002	Toshiba	Bought the Toshiba-Huajing P.A.T. joint venture and formed a wholly owned subsidiary called Toshiba Wuxi Semiconductor Company	10
2002	MEMSIC	Established P.A.T. facility in Wuxi	11
2002	TOWA	Established an equipment facility in Shanghai for P.A.T. firms	12

Sources:

- 1) www.motorola.com, noted in Nasa Tsai, President of Grace Semiconductor, "China: An Emerging Centre for Semiconductor Manufacturing," Future Fab International, Issue 13, July 8, 2002.
- 2) *China Computer News*, November 22, 2001, noted in Tsai, "China: An Emerging Centre..."
- 3) *People's Daily*, December 21, 2001, noted in Tsai, "China: An Emerging Centre..."
- 4) www.finance.lycos.com.cn, October 10, 2001, noted in Tsai, "China: An Emerging Centre..."
- 5) *Shanghai Computer News*, May 23, 2001, noted in Tsai, "China: An Emerging Centre..."
- 6) *Business Wire*, "Applied Materials Pledges Additional Funds...", May 5, 2000 and "Applied Materials Shanghai...", October 18, 2001.
- 7) *China Daily*, "In Brief," June 25, 2002
- 8) *Asia Pulse News*, "Malaysia's Texchem Resources to Set Up Unit in Wuxi," April 12, 2002.
- 9) *PR Newswire*, "Park Electrochemical Announces...", November 8, 2001
- 10) *Asia Info Services*, "Toshiba Expands Semiconductor...", July 11, 2002
- 11) *Sensor Business Digest*, "From the Editor: Market Opportunities Abound...", June 1, 2002
- 12) *Asia Info Services*, "TOWA Comes to Shanghai," November 26, 2002
- 14) Rand (James Mulvenon), "Shanghaied? The Economic and Political Implications...", July 2004, page 109.
- 15) *PR Newswire*, "Accord Advanced Technologies Announces...", June 21, 2000.
- 16) *Business Wire*, "ASML Increases Presence in China with Huajing...", December 3, 2002.
- 17) *Business Wire*, "Cirrus Logic Signs Five Year Foundry...", August 30, 2001.
- 18) Denis Simon, "The Microelectronics Industry Crosses a Critical Threshold," *China Business Review*, November-December 2001

those decades. The Sino-foreign partnerships in China's key enterprises and national champion enterprises were one-off projects, as shown in Chapter Four, and likewise, the entries of other foreign semiconductor firms to China in the 1990s and early 2000s appear to have been uncoordinated and handled on a case-by-case basis, see Figures Thirteen and Fourteen, previous pages. Neither Chinese nor foreign industry sources include references to governmental plans for coordinating foreign semiconductor firms' entry to China. China's new policies from around 2000 (see Section 5.2) fostered the industry but did not explicitly plan or coordinate the arrival of foreign firms. For example, these policies did not plan for a certain number of foreign firms to establish operations in China, they did not define what types of foreign semiconductor firms would be welcomed, they did not specify locations in China for foreign firms, etc.

That said, Chinese national and local plans clearly prioritized the semiconductor industry,⁶⁰⁶ leading officials to support foreign firms' efforts to enter China. However, in coordinating with various Chinese government authorities to establish contracts or operations in China,⁶⁰⁷ foreign executives complained about restrictions and ambiguities on ownership, production, and sales in China and the lack of coordination among Chinese government agencies. New entrants to China complained about China's "legal and political system" and governmental "policies and procedures," saying "business policies are often incomprehensible."⁶⁰⁸ In 1997, the U.S. Semiconductor Industry Association testified to the

⁶⁰⁶ China's eighth, ninth, and tenth five year plans (1990-2005) all prioritized microelectronics, as did the massive Project 909.

⁶⁰⁷ From 1992, the U.S. and China had had the U.S.-China Memorandum of Understanding on Market Access in place, under which China agreed to eliminate the use of import substitution policies.

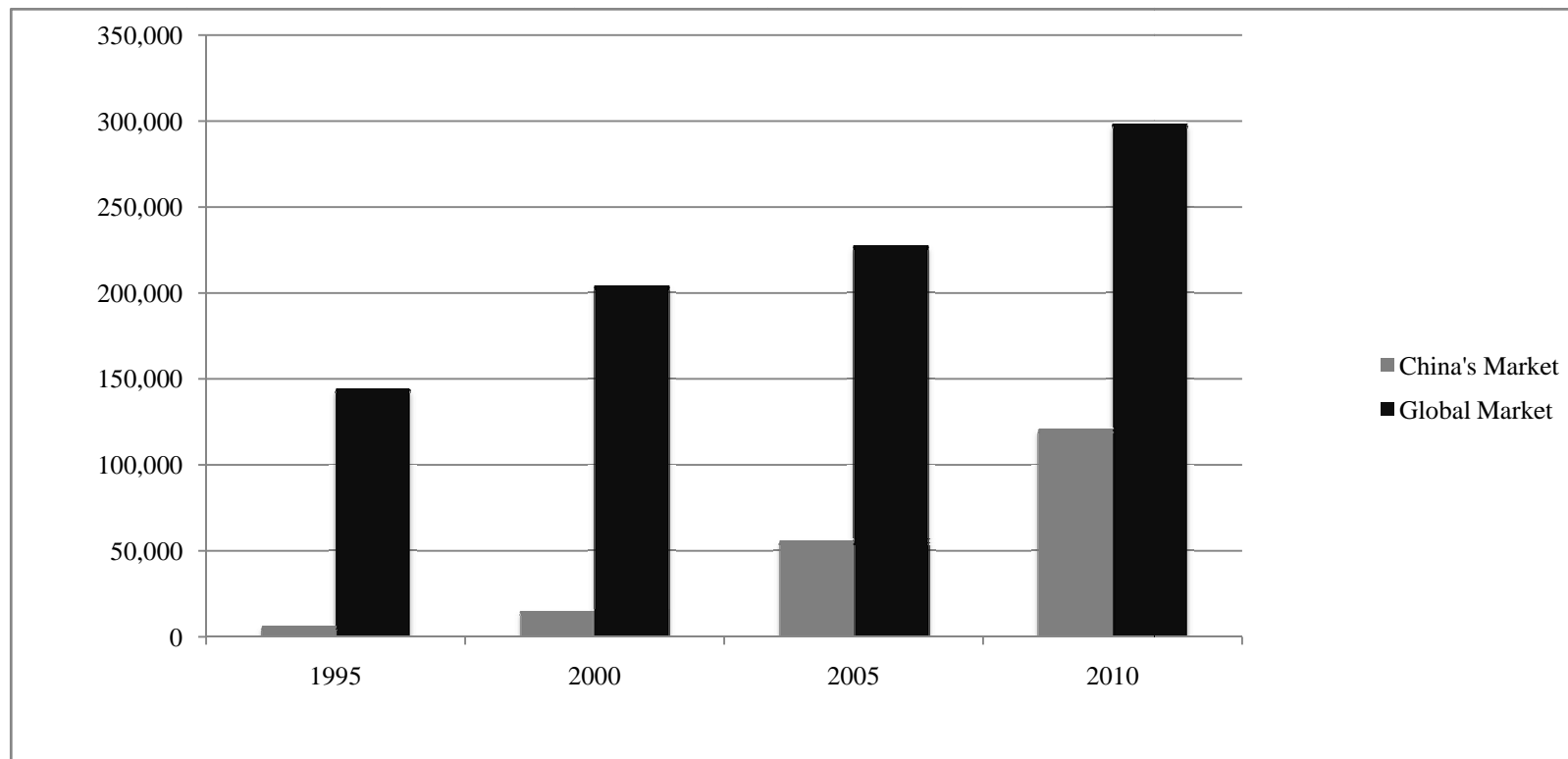
⁶⁰⁸ SMIC, "Rising to the Challenge."

U.S. Committee on Ways and Means' Subcommittee on Trade, outlining the specific problems of doing business in or with China.⁶⁰⁹ These included:

- *Policy Ambiguity:* Generally, China-based trade and business transactions were “fraught with anomalous, ever-changing, and non-transparent regulations.”
- *Investment and Market Restrictions:* 100 percent foreign ownership of manufacturing sites in China was allowed, but for electronics, all production had to be for export. However, each deal was individually negotiated. Commonly, in Sino-foreign joint ventures, the percentage of foreign ownership correlated with the percentage of export required, i.e., if a Sino-foreign joint venture had seventy percent foreign ownership, then seventy percent of production had to be for export. Export targets were not necessarily enforced, but the possibility existed that they might be retroactively enforced.
- *Trade Limitations:* Importation and exportation was limited to only those firms (including foreign-invested firms) designated by the Chinese government. Other firms operating in China had to conduct trade through designated firms. Foreign companies could not sell directly into China, and thus did not have direct access to the Chinese market; they had to sell through Chinese distributors.
- *Local Content Requirements:* There were also “localization” requirements for products made in China requiring that some percentage of parts and materials be made in China. These were not necessarily legal requirements, yet localization plans had to be filed with officials, firms could be audited for compliance, and the definition of “local” could vary. “Local” could include, for example, foreign-made components that were “localized” by having been imported through a Chinese distributor.
- *Chinese Firms' Advantage:* The SIA feared that China's state-invested enterprises would be pressured to purchase from domestic Chinese suppliers. China's state-invested enterprises were believed to “control a significant share” of the electronics-related products that are imported into or exported out of China and to “control a significant share” of China's electronics and computer industries. The SIA feared that, as Chinese leaders opted to disband or restructure many state owned enterprises, the Chinese government would actually become more involved in owning and controlling national champions in the high-priority electronics-semiconductor industry and would push state supported enterprises to purchase from Chinese suppliers, thus harming the prospects of global electronics and semiconductor firms in China.

⁶⁰⁹ George Scalise, President of the U.S. Semiconductor Industry Association, transcript, “Hearing with the U.S. Subcommittee on Trade of the Committee on Ways and Means: The Future of U.S.-China Trade Relations,” November 4, 1997.

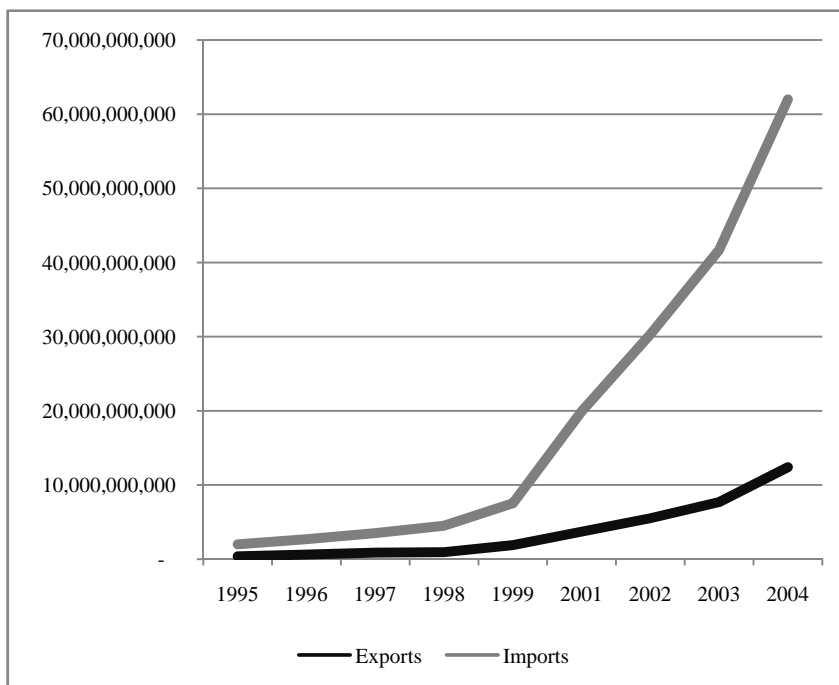
Figure 10: Semiconductor Market: China and Global, in US\$ Billions



Sources:

- 1) PWC, "China's Impact on the Semiconductor Industry, 2004, 2006, 2011 and 2012," data sources include China Semiconductor Industry Association, CCID, and PwC analysis.
- 2) Wang Yangyuan and Wang Yongwen 王阳元 and 王永文, *Wo Guo Jichengdianlu Chanye Fazhan Zhilu: cong Xiaofei Daguo Zouxian Chanye Qiangguo 我国集成电路产业发展之路：从消费大国走向产业强国* (China's Integrated Circuit Industry Development Path: From a Big, Consuming Nation to a Strong, Industrial Nation), Kexue Chubanshe 科学出版社 (Science Press), 2008, page 123, per CSIA

Figure 15: China's Imports and Exports of Semiconductors (I.C.s and Discrete Devices) in \$US

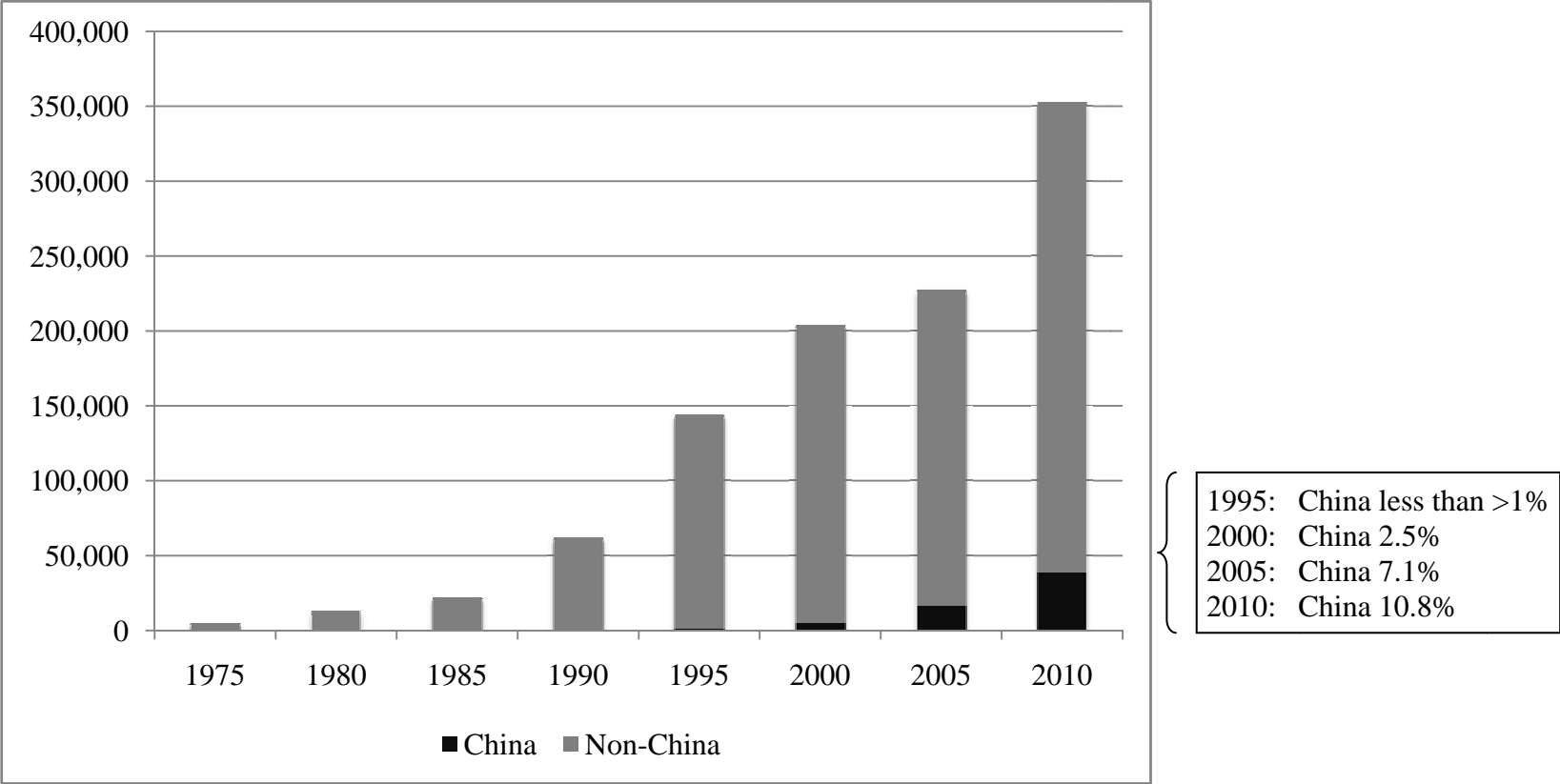


	Imports	Exports
1995	2,000,000,000	370,000,000
1996	2,700,000,000	600,000,000
1997	3,500,000,000	860,000,000
1998	4,500,000,000	940,000,000
1999	7,533,550,000	1,889,290,000
2001	19,900,000,000	3,700,000,000
2002	30,300,000,000	5,500,000,000
2003	41,700,000,000	7,700,000,000
2004	62,000,000,000	12,400,000,000

Sources:

- 1) 1995-1998 data from *China Electronics Industry Yearbook*, 1997 page 147, and 1999 page 211, shown in Michael Pecht, *China's Electronics Industry*, 1999, page 28.
- 2) 1999 data from Xu Xiaotian, Chief of Electronics Department, China's Ministry of Information Industry, cited in Michael Pecht, *China's Electronics Industry*, 1999, page 29.
- 3) 2001-2004 data from Taipei Times, cited in Michael Pecht, *China's Electronics Industry*, 2007, page 97..

Figure 19: Total Semiconductor Industry Production Revenues, US\$ Billions, Global vs. China



Sources:

1) PwC, "China's Impact on the Semiconductor Industry, 2004, 2006, and 2012," data sources include China Semiconductor Industry Association, CCID, and PwC analysis.

2) Wang Yangyuan and Wang Yongwen 王阳元 and 王永文, *Wo Guo Jichengdianlu Chanye Fazhan Zhilu: cong Xiaofei Daguo Zouxian Chanye Qiangguo 我国集成电路产业发展之路：从消费大国走向产业强国* (China's Integrated Circuit Industry Development Path: From a Big, Consuming Nation to a Strong, Industrial Nation), Kexue Chubanshe 科学出版社 (Science Press), 2008, page 123, per CSIA.

3) Author's analysis

In the 1990s, global enterprises entered China and worked with Chinese enterprises to instigate many Sino-foreign ventures, partnerships, and trade relationships. The global integration of the industry is evidenced by growth in: 1) the market for semiconductors in China, 2) the import and export values of semiconductors to and from China, and 3) the revenues of China-based semiconductor enterprises. See Figures Ten, Fifteen, and Nineteen, previous pages. Through all of this, Chinese officials were well aware of the growth in the semiconductor market and production, and they had been involved in establishing the Sino-foreign arrangements in China. Officials were thus well aware of the policy-related difficulties that semiconductor enterprises faced in China. These experiences led to what Chapter Four called “enterprise led learning,” and by 2000, Chinese officials were prepared to announce new, industry-wide policies to foster the semiconductor industry in China.

5.2 Changes in China’s Policy Environment, Circa 2000

“If we just engage in development behind closed doors, totally rely on ourselves in the aspects of talented people, funds, and technologies, and produce products only to serve and support ourselves, it is absolutely impossible to establish ourselves in the intense international competition. Therefore the strategic guiding principle for our developing the semiconductor industry should be basing the enterprises’ positions on the market, the technological development on international cooperation, the application of talented people on a global scale, and the investing and financing policies on international fund markets...

...Government must attach importance to creating a general environment which is suitable for the development of the semiconductor industry, providing preferential policies which are as good as those in the peripheral countries, simplifying examination and approval procedures, and encouraging foreign investment introduction and multi-channel financing....”

Hu Qili, (former) Minister of the Electronics Industry, 2000⁶¹⁰

In July of 2000, Chinese officials announced new policies that applied to both Chinese firms and foreign semiconductor firms operating in China. New policies were imperative because, as an official at the Ministry of Information Industry said “[China’s semiconductor industry] has remained rather weak and small in terms of its overall scale and has lagged relatively far behind in terms of its production technology development capability, product design and development capability, standards, and so on...”⁶¹¹ New semiconductor policies from 2000 are largely credited with ushering in an era of more rapid growth for the semiconductor industry in China, including the more technologically sophisticated design sector of the industry. With regard to these new semiconductor policies, an extensive U.S. Semiconductor Industry Association policy report noted that “With the exception of the auto industry – another Chinese government priority – no comparable sector specific measure has been issued by the [Chinese] government, a fact duly noted by national, regional, and local government officials.”⁶¹² The new semiconductor policies were announced prior to China’s entering the World Trade Organization (W.T.O.) in December of 2001, and the policies in

⁶¹⁰ Hu Qili “Seize Opportunities to Develop China’s Semiconductor Industry, *People’s Daily*, April 19, 2000, in Rand National Defense Research Institute (J. Mulvenon, M. Chase, K. Pollpeter), “Shanghai-ed?: The Economic and Political Implications of the Flow of I.T. and Investment Across the Taiwan Strait,” 2004, pages 103-104. Similarly, see Simon, “The Microelectronics Industry.” Simon recounts that the Ministry of the Information Industry Minister Wu Jichuan said that China’s semiconductor industry is a weak area that is critical to development. Minister Wu said that China must be careful not to waste money (due to the industry’s high capital costs) and must focus on not just production but the whole industry chain and on the domestic semiconductor market. Due to the limitations of China’s semiconductor industry, the Chinese government was willing to rely on the market and foreign investment to develop the industry. These comments were from September of 2001 at the National Integrated Circuit Work Conference and July of 2001 at a seminar on microelectronics and the information technology sector.

⁶¹¹ Qu Weizhi, “How to Develop the Integrated Circuits Industry,” *Renmin Ribao*, May 15, 2000 quoted in the U.S. Semiconductor Industry Association (SIA), “China’s Emerging Semiconductor Industry,” page 37.

⁶¹² U.S. Semiconductor Industry Association, prepared by Dewey Ballantine LLP, by T. Howell, B. Bartlett, W. Noellert, and R. Howe, “China’s Emerging Semiconductor Industry,” 2003, page 45.

part conflicted with W.T.O. agreements. Because of the W.T.O. conflicts, a (preferential) V.A.T. described in the new policies was ultimately changed, but not until April of 2005 when the W.T.O.-noncompliant V.A.T. had been in effect for several years. From the introduction of the policies in 2000 to 2005, the total revenues of the semiconductor industry in China increased by 377 percent, see Figure Seventeen. Revenues in the more technologically sophisticated design sector rose at a rate similar to the overall industry during this period. Thus, growth in the industry was not confined to the fabrication (manufacturing) sector or to the less technologically demanding assembly-packaging-testing (P.A.T.) sector of the industry.

Before delving into China's new domestic semiconductor policies in 2000, let us first address two international policy issues that were relevant to the development of the semiconductor industry in China leading up to 2000. These are Western export controls on dual-use technology to China and Taiwan's restrictions on semiconductor investments in China.

5.21 Western Export Restrictions

Semiconductor industry observers often suggest that Western export controls on semiconductor equipment to China hindered or blocked China's technological progress in the semiconductor industry, but this research has disputed such claims. Export controls on dual-

Figure 17: Semiconductor Production Revenues in China, by Sector (RMB100 million), excluding Discrete Devices

Year	2000	2001	2002	2003	2004	2005
Design	9.8	14.8	21.6	44.9	81.8	124.3
• Percent of industry	5	7	7	13	15	18
Fabrication (manufacturing)	48	27.7	33.6	60.5	180	232.9
• Percent of industry	26	14	14	17	33	33
Packaging, Assembly, Testing (P.A.T.)	128.4	161.1	213.3	246	283.5	344.9
• Percent of industry	69	79	79	70	52	49
Total	186.2	203.6	268.5	351.4	545.3	702.1

Source: National Bureau of Statistics, 2001-2005, shown in Chen Ling and Xue Lan, "Global Production Networks," *China and the World Economy*, Volume 18, Number 6, 2010, page 114, Table 1.

use technology to China were indeed part of CoCom restrictions until 1994 and the Wassenaar Arrangement after 1996.⁶¹³ However, interviews with Chinese industry leaders and the accounts of equipment imported to China in the 1980s, 1990s, and early 2000s suggest that export controls did not inhibit the importation of desired semiconductor production equipment to China, primarily because the equipment sought did not rise to the level of “export controlled” and because equipment that was restricted by U.S. suppliers could typically be purchased from European or Japanese suppliers.⁶¹⁴

⁶¹³ NATO organization CoCom (the COordinating COMmittee for Multilateral Export Controls, established in 1949) indeed limited high technology and dual use technology exports to China, the Soviet Union, and other Warsaw Pact countries. The role of CoCom was to set acceptable “technical specifications for dual-use items that were being considered for export” to China and Warsaw Pact countries. CoCom export controls remained in place until 1994. In 1996, 41 nations established the Wassenaar Arrangement on Export Controls for Conventional Arms and Dual-Use Goods and Technologies. Commonly known as the Wassenaar Arrangement, this arrangement was the post-Cold War successor to the CoCom. Wassenaar retained CoCom’s list of embargoed goods. Wassenaar Arrangement member nations include Russia and several eastern European nations, but not China. Wassenaar is not a formal treaty, and member countries can not compel other member countries to avoid controversial sales. Under the Wassenaar Arrangement, member countries voluntarily exchange information (on orders, sales, etc.) See Hanns-D. Jacobsen, “CoCom - The Coordinating Committee on Multilateral Export Controls (1st Draft),” *The Economics of the Cold War*, a conference at the Hamburg Institute for Social Research, September 2-4, 2009.

⁶¹⁴ These interviewees included: Teng Jingxin, Chief Engineer of Huarun, and Wang Guoping, CEO of Huarun, July 16, 2009, Wuxi, Huarun headquarters; Yu Zhongyu, President of China Semiconductor Industry Association, July 2, 2009, CSIA headquarters in Beijing; and Yu Xiekang, General Manager of Jiangsu Changjiang Electronics Technology, June 2, 2009, JCET headquarters. According to an interview with leading global equipment supplier ASML, (with Joseph Chen, June 29th of 2009 in Wuxi), in the 1990s, ASML could sell into China as long as they had “end user agreements,” which had to be signed by Chinese officials. Mr. Chen also gave examples of Chinese staff being able to maneuver around export controls. For example, in the 1990s, staff from China’s Institute 24 (affiliated with Huajing in the 1990s) wanted to buy equipment from the U.S., but they could not get visas, so they purchased from Freescale in the U.K. Also, when ASML sold equipment to a Chinese organization for a government project, ASML had to sell to the ostensibly “neutral” Fudan University to avoid export restrictions. See Chapter Three for Huajing’s importation of equipment from AT&T/Lucent in the mid to late 1990s. See Chapter Four for Huahong’s decision to partner with Japan’s NEC and a discussion of why this decision was not compelled by Western export controls, as is sometimes claimed. See Chapter Four for how SMIC maneuvered around export controls to import necessary equipment. Further, SMIC adopted a comprehensive Internal Compliance Program (I.C.P.) to comply with Western export control regulations. When the U.S. Department of Commerce enacted the Validated End User (VEU) program in 2007, SMIC was one of the initial participants. This program gave “validated” companies operating in China easier access to export controlled technology. These companies were authorized to purchase equipment without having to get individual export licenses for each piece of equipment, see Willy Shih, “SMIC: ‘Reverse BOT’,” Harvard Business School, January 6, 2009, page 4.

Confirming these findings, an extensive 2002 U.S. government study reported that Wassenaar export controls had been essentially ineffective in restricting relatively advanced semiconductor equipment from being exported to China. This study, “Export Controls: Rapid Advances in China’s Semiconductor Industry Underscore Need for Fundamental U.S. Policy Review,” concluded that “Wassenaar has not effected China’s ability to obtain semiconductor manufacturing equipment because the U.S. is the only member of this voluntary agreement that considers China’s acquisitions a cause for concern.”⁶¹⁵ In practice, the U.S. typically restricted sales of equipment to China if the equipment was less than two generations behind commercial state of the art. A “generation” in the semiconductor industry is usually about eighteen months to two years. Each generation employs smaller process technology, i.e., from 0.35microns to 0.25microns. U.S. regulations, however, did not stipulate exactly what technologies were restricted which have been because “commercial state of the art” is a moving target.

Generally, after the end of the Cold War, dual use technologies were less controlled and restricted. Global semiconductor industry leaders viewed semiconductor equipment as generic and widely available. Executives argued that restrictions were inappropriate and caused U.S. firms to lose sales to international competitors. According to the 2002 report, the U.S. generally approved exports of semiconductor equipment to China under the following -- somewhat surprising -- regulations:

“For the People’s Republic of China, the general licensing policy is to approve [license] applications, except for those items that would make direct and significant contributions to [warfare technologies.] Each application will be

⁶¹⁵ General Accounting Office (GAO), Report to the U.S. Senate, “Export Controls: Rapid Advances in China’s Semiconductor Industry Underscore Need for Fundamental Policy Review (GAO-02-620),” April 2002.

considered individually. Items may be approved even though they may contribute to Chinese military development or the end user or end use is military.”

Export Administration Regulations, Title 15,
Sections 742.4(a) and 742.4(b)(7)⁶¹⁶

Between 1997 and 2000, the U.S. only denied export licenses to 0.4 to 0.5 percent (in dollar value) of all semiconductor equipment destined for China, and, when not available from the U.S., China could purchase similar equipment from European or Japanese suppliers.⁶¹⁷ Similar to this study’s findings in Chapters Three and Four, the 2002 study reported that foreign semiconductor firms had been instrumental to the development of the industry in China and to enhancing the capabilities of the largest enterprises in China in the 1990s and early 2000s [*italics added below.*] Thus, the common refrain that Western export controls inhibited the semiconductor industry in China seems amply refuted by both Chinese and U.S. industry sources.

“Today (2002), China’s most advanced semiconductor manufacturing facilities can produce integrated circuits that are only one generation or less behind the current state of the art. Acquiring semiconductor technology and know how is a priority of the Chinese government. The country’s improvements in semiconductor manufacturing capability are the direct result of the involvement of Europe, Japan, and U.S. integrated circuit manufacturing in China, typically through *joint ventures or wholly foreign owned manufacturing facilities.* Currently China has eight major integrated circuit manufacturing facilities with substantial levels of foreign investment or ownership. The country’s rapid advances in this sector have integrated China into the global semiconductor industry, improved China’s commercial and defense industrial base, and created a potential new source of sophisticated integrated circuits for China’s industry and military. Fifteen years ago (1987), China was five generations behind the United States’ then-current commercial production capability.....”⁶¹⁸

⁶¹⁶ Ibid., page 24.

⁶¹⁷ Ibid., pages 17-19 and 27.

⁶¹⁸ Ibid., page 9. These “*eight major integrated circuit manufacturing facilities*” were four of China’s five key semiconductor enterprises, national champions Huahong-NEC and SMIC, and new arrival Grace, which was wholly foreign owned but headquartered and based in China as of 2000. The report does not say, but the eighth enterprise must refer to either Huaxia in Beijing or Hejian in Suzhou. Those two enterprises were under construction but not yet actually producing in 2002.

5.22 Taiwan's Policies on Semiconductor Investments in China

Taiwan's government had historically restricted most investments in Mainland China, but officials in Taiwan opted to lift many of these restrictions, including Taiwan's ban on semiconductor investments in Mainland China, in March of 2002. This was shortly after China and Taiwan joined the W.T.O., China in December of 2001, and Taiwan in January of 2002. Taiwan's 2002 policy change resulted from several pressures. First, executives of Taiwan's semiconductor firms, including Taiwan's two largest foundries, TSMC and UMC, lobbied extensively to be allowed to establish operations in China in order to be close to China's growing semiconductor market. In that same timeframe, the business environment in Taiwan had become less hospitable to the semiconductor industry owing to recent earthquakes and power outages, reductions in industry tax breaks, limited water and land at key technology parks, and rising incomes for engineers.⁶¹⁹ Second, the global recession in the early 2000s and Taiwan's domestic recession caused Taiwanese government leaders to seek expanded economic exchanges with Mainland China. Finally, the W.T.O. forbade most trade and investment restrictions among member countries.⁶²⁰

Taiwan's March 2002 policy allowed Taiwanese semiconductor firms to invest in or establish eight inch (or less) semiconductor manufacturing operations in Mainland China, if they first upgraded their operations in Taiwan to twelve inch production, which was leading edge technology at that time. In turn, the Taiwanese government committed to increase its support for the semiconductor industry in Taiwan, through increased funding for research and

⁶¹⁹ Japer Moiseiwitsch, "Superfab *Financial Technology Asia*, May 2001.

⁶²⁰ Professor Chyan Yang and Shiu-Wan Hung, "Taiwan's Dilemma Across the Straight: Lifting the Ban on Semiconductor Investment in China," *Asian Survey*, July/August 2003.

semiconductor-related infrastructure, in order to keep the most advanced elements of Taiwan's semiconductor industry on the island. Taiwan's government also pledged to investigate existing allegations of illicit Taiwanese investment in the semiconductor industry on the Mainland, most notably at SMIC, as discussed in Chapter Four. In 2002, Taiwan was the world's fourth largest semiconductor industry, behind the U.S., Japan, and South Korea, and the industry was considered a crown jewel of Taiwan's electronics industry. Thus, the decision to allow certain semiconductor activity and investment on the Mainland was debated by Taiwan's leaders and its business community for nine months, from August 2001 until April 2002, due to fears by some constituents that semiconductor migration to the mainland would "hollow out" Taiwan's electronics industry and create an exodus of Taiwanese semiconductor professionals to the Mainland.⁶²¹ The new regulations for the semiconductor industry were part of a broader set of economic regulations devised by Taiwan's new Economic Development Advisory Conference (E.D.A.C.) in 2001. The E.D.A.C.'s proposed approach to Taiwan-China trade was called "active opening, effective management," and it sought to open more cross-Strait trade, but with mechanisms to ensure fair taxation, risk management, and transparency.⁶²²

The semiconductor industry was actually following much of the rest of the electronics industry in terms of migrating from Taiwan to Mainland China. As discussed in Section 5.12, much of the lower-value added segments of the broader electronics industry, i.e., firms that manufacture and assemble electronics products (E.M.S. firms and O.D.M.s), had migrated to Mainland China in the 1990s for low cost labor and land, including many Taiwanese owned

⁶²¹ For a longer discussion of Taiwanese officials' and the Taiwanese business community's concerns about regulations toward China, see Rand, "Shanghai-ed," pages 30-41.

⁶²² Yang and Hung, "Taiwan's Dilemma."

or invested firms. Through these electronics-related ventures, Taiwanese semiconductor leaders were familiar with the electronics and semiconductor industries in China. A study by the Rand National Security Research Division found that by 2000 China was already manufacturing more information technology hardware than Taiwan (by revenue), and in 2002, Taiwan-invested companies produced more than seventy percent of the electronics products made in China.⁶²³ Taiwan had always restricted investments in the mainland, and from 1996, Taiwan enacted the “no haste, be patient” policy, which capped Taiwanese investment in the Mainland at US\$50million and forbid Taiwanese investors and firms from manufacturing a list of over one hundred information technology products in Mainland China. At US\$50 million, the cap certainly enabled many productive investments on the Mainland, and Taiwanese investors also routed money through third countries to skirt the cap. By 2002, estimates of the total amount of Taiwanese investment in Mainland China ranged from US\$30 billion to US\$100 billion.⁶²⁴ Thus, Taiwan’s new policies allowing eight inch or less semiconductor investments in China were additive to existing Taiwanese electronics investments in Mainland China.

The integration of the semiconductor industry across Taiwan and China occurred primarily through: 1) circuitous investments on the Mainland from Taiwan prior to 2000, 2) open investment from Taiwan after Taiwan’s new 2002 semiconductor policies, and 3) the vertical dis-integration of the global semiconductor industry beginning in the 1990s and gaining momentum after 2000. In this research, we have seen that prior to Taiwan’s

⁶²³ Rand, “Shanghai-ed,” page xiii.

⁶²⁴ CRS Report for Congress, International Trade and Finance: Foreign Affairs, Defense, and Trade Division, “Taiwan’s Accession to the W.T.O. and Its Economic Relations with the United States and China,” May 16, 2003.

semiconductor-specific policy changes in March of 2002, Taiwanese were already active leaders or investors in several of the largest semiconductor enterprises in Mainland China including CSMC (affiliated with Huajing), SMIC, Grace, and allegedly at China's Hejian in Suzhou, established in 2000.⁶²⁵ Immediately after Taiwan's new policy in 2002, Taiwan's giant TSMC foundry also announced plans to establish operations in Mainland China. Other China-Taiwan integration followed, including the migration of smaller Taiwanese firms and industry professionals to the Mainland.

5.23 China's Document 18 and Entry to the W.T.O.

Prior to Taiwan's 2002 policy changes discussed above, officials in Mainland China announced several new policies for the semiconductor industry in mid 2000. These changes reflected the Chinese government's ongoing commitment to the semiconductor industry as well as officials' understanding of the specific needs of semiconductor firms in China. China's Ministry of the Information Industry, with input from overseas Chinese, scholars, and foreign advisors, drafted the most influential semiconductor-related policy document of this period, Document 18.⁶²⁶ Importantly, the document concluded by saying that "enterprises

⁶²⁵ CSMC was established in Hong Kong in 1997, but its leadership team was Taiwanese. SMIC's relationship with Taiwan is discussed in detail in Chapter Four. Grace was established in Shanghai in 2000 as a wholly foreign owned enterprise. One of Grace's co-founders was Winston Wong, eldest son of the former Chairman of Formosa Plastics of Taiwan. Winston Wong initially served as president and CEO of Grace, and by 2002, Nasa Tsai of Taiwan was President of Grace. Tsai got his doctorate at Stanford and worked at Fairchild and Intel in the U.S. before returning to Taiwan to co-found Mosel and Vitelic with Peter Chen. He and Chen also worked together in the late 1990s as founding executives of CSMC, affiliated with Huajing in Wuxi, see Chapter Three. From its inception in 2001, China's Hejian was rumored to have grey investment from Taiwan's UMC, and ultimately, Taiwan's UMC bought Hejian in 2009.

⁶²⁶ Chen Ling at the U.S.-China Science and Technology Forum, "Government Policy-making Capability: A Case Study on China's Semiconductor Industrial Policy Process," Chinese Institute of Science and Technology Policy at Tsinghua University, November 30, 2010, unpublished.

established in China, regardless of the nature of ownership, can enjoy these policies.”⁶²⁷ Thus, China’s new policies for the semiconductor industry were not designed to benefit only “Chinese” companies or China’s state supported enterprises, but rather to support the development of the global industry in China. That said, the policies did support the industry *in China*, meaning that the policies incited companies (of whatever ownership form) to locate *in China*. One particular policy (the V.A.T. policy) would provoke the U.S. Semiconductor Industry Association to press Chinese officials for changes, based on W.T.O. commitments. Nonetheless, the offending policy was in effect from 2000 to 2005, a period of rapid growth that built on the existing industry from the 1990s. Document 18 did not resolve issues around intellectual property protection and financial repatriation, but its effects were significant.

On June 24 of 2000, the State Council published Document 18 called “Several Policies to Encourage the Software and Integrated Circuit Industries.”⁶²⁸ One of the most influential and controversial aspects of Document 18 was its V.A.T. policy that gave semiconductor manufacturers located in China a substantial rebate on the V.A.T. This caused imported semiconductors to be relatively more expensive than semiconductors produced in China. This policy had two effects, both of which were positive for the industry’s

⁶²⁷ See article 52: “Fan zai Zhongguo jingnei sheli de....qiye, bu fen suoyouzhi xingzhi, junke xiangshou ben zhengce 凡在我国境内设立的.....企业, 不分所有制性质, 均可享受本政策 (Enterprises established in China, regardless of the nature of their ownership, all can enjoy this policy)” of “18 Hao Wenjian: Guli Ruanjian Chanye he Jichengdianlu Chanye Fazhan de Ruogan Zhengce 18 号文件：鼓励软件产业和集成电路产业发展的若干政策 (Document 18: Some Policies to Encourage the Software and Integrated Circuit Industries).” This document is available from the Chinese Electronics Standardization Institute (*Zhongguo Dianzi Jishu Biaojunhua Yanjiusuo* 中国电子技术标准化研究所) at www.chinasoftware.com.cn/calling_info_detail.asp?id=47.

⁶²⁸ Wang and Wang, *Wo Guo Jichengdianlu Chanye*, page 331.

development in China. First, it gave domestic producers such the key Sino-foreign joint ventures and China's national champion enterprises a cost advantage over foreign competitors. At the same time, the V.A.T. policy encouraged foreign firms to establish operations in China in order to benefit from the V.A.T. rebate available to producers located in China. (The V.A.T. policy is discussed further below.) The V.A.T. policy, however, was just one of many policies established via Document 18.

Around the time that Document 18 was released in 2000, global industry personnel were interested in Document 18's potential effects on semiconductor manufacturing. After all, China seemed to be in the midst of a massive build up of foundry capacity, and there was a question as to whether China would overtake Taiwan as the leading global site for foundries. However, Document 18 targeted both the semiconductor industry and the software industry. In addition to the important closing article mentioned above that said all semiconductor companies, regardless of ownership form, could utilize Document 18's policies, there was another important closing article. Article 51 of Document 18 declared that semiconductor design firms could enjoy all of Document 18's policies that targeted the software industry, as semiconductor design firms are similar to software firms.⁶²⁹ These new policies for the semiconductor design sector would help move the semiconductor industry in China up the global value chain. Document 18's potential effects on the semiconductor manufacturing sector were more apparent because China had already made strides in the manufacturing sector and because the manufacturing sector is so capital intensive. Foundry operations are

⁶²⁹ See Article 51: Jichengdianlu sheji ye shitong ruanjian chanye, shiyong ruanjian chanye youguan zhengce 集成电路设计业视同软件产业，适用软件产业有关政策 (Integrated circuit design companies will be regarded as the software industry, and they can apply the policies relating to the software industry) of "18 Hao Wenjian."

necessarily large-scale, highly visible undertakings. New design firms (commonly called “design houses”), on the other hand, are often small, low-capital endeavors that “fly under the radar” for some time before achieving results. Thus, Document 18’s effects on the design sector were less evident, in the short term. This section deals primarily with Document 18’s effects on the manufacturing sector, and Section 5.3 below addresses the development of the semiconductor design sector in China, both before and after Document 18.

Document 18 actually refers to three documents. The initial Document 18 was promulgated in July of 2000. The document was followed by Letter 51, a document from the State Council issued in 2001 confirming Document 18 and offering additional supportive policies for the software and semiconductor industries. Document 18 was then revised with input from Letter 51.⁶³⁰ As a central level document, Document 18 calls on other central, provincial, and local governmental agencies to develop policies and procedures to implement Document 18’s policies. The following summarizes the final policies of Document 18 for the semiconductor industry, particularly for manufacturing.⁶³¹

Easing the Formation of New Firms and Overseas Branches:

- New Sino-foreign joint ventures, new wholly foreign owned firms, and new Chinese firms will be approved by the relevant Chinese governmental departments.

⁶³⁰ Guowuyuan Guo Ban Han (2001) 51 Hao: Guowuyuan Bangongting guanyu Jinyibu Wanshan Ruanjian Chanye he Jichengdianlu Chanye Fazhan Zhengce youguan Wenti de Fu Han 国务院, 国办函 (2001) 51 号: 国务院办公厅 ▪ 于进一 ▪ 完善软件产业和集成电路产业发展政策有 ▪ 问题的 ▪ 函 (State Council, State Office (2001) Letter 51: State Council’s Office Reply Regarding Issues to Further Improve Software and Integrated Circuit Industry Development.)

⁶³¹ “18 Hao Wenjian (Document 18)” Article 12. Document 18 and Letter 51 from the State Council instruct other governmental departments, agencies, etc., to implement the necessary processes and regulations in order to enact the policies of Document 18 and Letter 51.

- Enterprises will get approval to establish branches in Hong Kong and Macao.
- Enterprises will get approval to establish overseas trading companies or representative offices, if they meet one of the following conditions:
 - Annual import/export volume is more than US\$500,000 and growth rate is 30 percent over the previous three years.
 - Sales revenue in first two years of operation exceeds \$US40 million and taxes were paid.

Clarifying and Decreasing Taxation

- When new enterprises are approved, the tax department will simultaneously provide information on enterprise taxation.
- If an enterprise's total tax burden is beyond six percent of revenues, then the amount over six percent will be rebated. The rebated amount must be invested in research or expanded production. [NOTE: This created the "preferential" V.A.T. policy. China-based firms got the 17 percent V.A.T. rebated to bring their total tax burden to six percent.]
- The Catalog for the Guidance of Foreign Investment in Industries will list semiconductor production equipment and related technology as exempt from import duties and import V.A.T.
- If domestically (Chinese) designed semiconductors must be produced overseas due to lack of production capability in China, then those semiconductors can be imported to China with a preferential tariff rate.
- Enterprises can fully depreciate their capital equipment in three years.

Encouraging Foreign Investment and Trade

- If a foreign firm invests more than US\$1 billion in Chinese operations or invests in 0.25micron production technology (or better) in China, then that firm will have:
 - A refund of the seventeen percent V.A.T., to bring the total tax burden to six percent, and the rebated amount must be re-invested in China.⁶³²
 - A lower tax rate of fifteen percent.⁶³³

⁶³² The fifteen percent tax rate was part of the tenth five year plan (2001-2005) and was not included explicitly Document 18.

⁶³³ The V.A.T. rebate was part of the tenth five year plan (2001-2005) and was not included explicitly in Document 18.

- No customs duties nor import V.A.T. on imported materials or other consumables.
 - Special procedures for expedited customs clearance.
 - A special foreign exchange account for its profits to avoid foreign-exchange rate risks.
 - Five year corporate income tax holiday, beginning in the first year of profitability, and another five years taxation at fifty percent.
 - [NOTE: In practice, firms did not have to meet this investment or technology threshold in order to get the benefits.]
- If a production firm exports more than US\$50 million annually and if a design firm exports more than US\$5 million annually, then they will have special import/export processes to expedite security, clearance, customs, inspection, etc.

Creating More Capital Availability

- China's government will set up venture capital pools for semiconductor firms. Along with this, the tenth five year plan said the government will "change from relying on [government] bank loans to obtaining capital investment directly from overseas or local financial markets."⁶³⁴

Protecting Intellectual Property

- China's government will protect the intellectual property of semiconductor-related designs and products.

Notably, Document 18's "policy" to protect intellectual property was written in very abbreviated form and offered no specifics about how intellectual property would be protected. However, in April of 2001 the State Council promulgated new regulations specifically to protect semiconductor designs, to be enforced by China's State Intellectual Property Office. China's protection of intellectual property is discussed in Section 5.4 below.

Document 18's policy on intellectual property was insubstantial, but otherwise, Document 18 was reinforced by other national policies around 2000. China's tenth five year

⁶³⁴ Tenth five year plan, Section 3.5.2.3, quoted in SIA, "China's Emerging," page 46.

plan (2001-2005) included investments in critical high technology industries and projects, including semiconductors. The plan called for US\$120 billion in investments in the semiconductor industry between 2001 and 2005, or approximately US\$24 billion annually.⁶³⁵ For comparison, China's official annual defense budget was US\$14.6 billion in 2000 and US\$29.9 billion in 2005.⁶³⁶ The goal was for domestic production to meet thirty percent of the domestic market by 2005. (With fast growth of the global semiconductor industry in this timeframe, China's "thirty percent" goal was still not met by 2011.) Also, Chinese officials increased semiconductor research funding through China's existing 863 Plan, and the "Guiding Catalog for Foreign Investment in Industry" further encouraged semiconductor investments via an August 2000 update.⁶³⁷ Finally, semiconductor firms were eligible for China's national "Two + Three" plan, which offered a two year corporate tax exemption from the first profitable year and a fifty percent tax reduction for the following three years.

Document 18 was also reinforced by local policies. Shanghai and Beijing, the two most popular destinations for foreign semiconductor firms, promulgated follow up documents to Document 18,⁶³⁸ as well as offering local incentives. Shanghai offered the "Five-Five"

⁶³⁵ *Zhonghua Renmin Gongheguo Xinxi Chanye Bu Zonghe Guihua Si Bian* 中华人民共和国信息产业部综合规划司编 (PRC Ministry of Information Industry Comprehensive Planning Yearbook), "Zhongguo Xinxi Chanye Shiwu Fazhan Guihua 中国信息产业十五发展规划 (10th Five Year Plan of China's Information Industry)" (Beijing: Renmin Youdian Chubanshe 北京: 人民邮电出版社 [Beijing: Post and Telecommunications Publishing House], 2001), pages 33-42, summarized in Rand, "Shanghai-ed," pages 104-106.

⁶³⁶ China's actual defense expenditures may have been much higher. These figures are from GlobalSecurity, a U.S.-based, non-governmental organization.

⁶³⁷ Simon, "Microelectronics." The tenth five year plan called for investments in a national research and development center, a design firm with the goal of RMB100 million in revenue, six to ten fabrication facilities (with six to twelve inch production lines and 0.35 to 0.13micron technology), and five to six packaging-assembly-testing plants.

⁶³⁸ In support of Document 18, Beijing issued "Jing Zheng Fa [2001] 4 Hao: Guanyu Guanche Guowuyuan Guli

plan, which included a total tax holiday for five years for manufacturers and a fifty percent discount for the following five years, along with other incentives. Beijing offered incentives including the “Shanghai + One” plan, which promised to exceed any incentives offered by Shanghai by one year. Beijing also offered relocation packages for semiconductor executives and grants to offset project costs.⁶³⁹

Global semiconductor leaders generally welcomed Document 18 and its related policies as they demonstrated Chinese officials’ desire to offer clarity, consistency, and support to domestic and foreign enterprises. That said, Document 18’s implementation was called “chaotic” by one Chinese official, although it “achieved its primary goals.”⁶⁴⁰ The goal of providing a preferential V.A.T.-related tax policy for China-based producers, however, displeased foreign semiconductor executives from the start. In China, the V.A.T. was collected by sellers at the point of sale and remitted to China’s tax authorities. Foreign firms manufacturing in China qualified for China’s preferential domestic rebate on the seventeen percent V.A.T., to bring their total tax burden down to six percent. This policy was “improved” in September of 2001 to bring the total tax burden down to three percent for semiconductors that were both designed and manufactured in China.⁶⁴¹ Under this policy, imported semiconductors were more expensive than those manufactured in China because

Ruanjian Chanye he Jichengdianlu Chanye Fazhan Ruogan Zhengce de Shishi Yijian 京政发 [2001] 4号: 于贯彻国务院鼓励软件产业和集成电路产业发展若干政策的实施意见 (Beijing Circular [2001] Number 4: Measures for Implementing the State Council 'Policies for Encouraging the Development of Software and Integrated Circuit Industries')” accessible at http://govfile.beijing.gov.cn/Govfile/front/content/12001004_0.html.

⁶³⁹ “Beijing to Foster Semiconductor Business,” *People’s Daily*, June 17, 2003. Rand, “Shanghai-ed,” page xix. Moiseiwitsch, “Superfab.”

⁶⁴⁰ SIA, “China’s Emerging,” page 47, per an interview with a Chinese Ministry of Information official in 2002.

⁶⁴¹ Liu Baijia, “China’s Semiconductor Sector Shake Up,” *People’s Daily*, September 8, 2004.

makers of imported semiconductors had to pay a one to twelve percent import tariff,⁶⁴² as well as the V.A.T. of seventeen percent.⁶⁴³ This gave firms manufacturing in China (whether domestic or foreign) a sizable cost advantage over firms manufacturing overseas, and thus incited foreign firms to locate in China.⁶⁴⁴

The semiconductor V.A.T. also compelled semiconductor firms to use the “Hong Kong turnaround,” a cost-evasion tactic used by many industries in China. In the semiconductor industry, “unfinished” products that were imported to China were not charged a V.A.T. To avoid China’s V.A.T., semiconductor manufacturers in China would export unfinished silicon wafers to Hong Kong. As an export, the wafer would not be charged a V.A.T. Then, a China-based P.A.T. facility would import the unfinished wafers from Hong Kong for final processing. Because the imported wafers were “unfinished” products, they were not charged a V.A.T.⁶⁴⁵

Chinese officials eliminated the tariffs (ranging from one to twelve percent) on imported semiconductors in January of 2002 as part of its W.T.O. commitments, but the preferential V.A.T. remained in place from 2000 until 2005. During this time, semiconductor revenues in China increased by almost 400 percent, from US\$4.3 billion to US\$16.1 billion. Semiconductor leaders in the U.S. Japan, and Europe compelled the U.S. House of

⁶⁴² Different sources describe this tariff as ranging from one to twelve percent. The range is not surprising given the inconsistency in China’s policies and one-off negotiations between individual firms and officials, as described in Chapter Four. It seems that around three percent may have been common for tariffs. See Moiseiwitsch, “Superfab,” which cites a one to three percent tariff. Also, Simon, “Microelectronics,” which cites a six to ten percent tariff. The SIA cites a six to twelve percent tariff, see Hatano of the SIA, statement to the Congressional-Executive Commission on China, “Is China Playing by the Rules?”

⁶⁴³ Hatano of the SIA, statement to the Congressional-Executive Commission on China, “Is China Playing by the Rules?”

⁶⁴⁴ Wang and Wang, *Wo Guo Jichengdianlu Chanye*, pages 347-349.

⁶⁴⁵ PwC, “China’s Impact,” 2004.

Representatives, the World Semiconductor Council, and the Office of the U.S. Trade Representative to launch complaints against China. Finally, in March of 2004, the U.S. filed a formal complaint through the W.T.O., followed by Japan and Europe. After this, on July 9th of 2004, China agreed to eliminate the preferential V.A.T. through a U.S.-China agreement, and the formal W.T.O. complaint was withdrawn. The preferential V.A.T. then expired in April of 2005.⁶⁴⁶

China's new policies for -- and investments in -- the semiconductor industry from 2000 were primarily articulated in Document 18 and China's tenth five year plan, but the global integration of the semiconductor industry in China was also fostered by China's entry to the W.T.O. in December of 2001. Since the early 1990s, the U.S. Semiconductor Industry Association had been sending delegations to China and advising Chinese leaders on possible benefits of "opening" the industry. In a November 1997 summit between U.S. President Bill Clinton and China's President Jiang Zemin, Chinese officials agreed to eventually join the Information Technology Agreement (I.T.A.), a W.T.O. agreement among over forty nations (as of 2013, over seventy nations) that eliminated tariffs on semiconductors and other information technology products. China's became an official member of the I.T.A. in April of 2003, but it was due to the I.T.A. that Chinese officials eliminated semiconductor tariffs in January of 2002.⁶⁴⁷ Also, in November of 1999, the U.S. and China had signed a bilateral trade agreement in anticipation of China joining the W.T.O. The 1999 agreement included several U.S. Semiconductor Industry Association demands including: "elimination of tariffs

⁶⁴⁶ Hatano of the SIA, statement to the Congressional-Executive Commission on China, "Is China Playing by the Rules?"

⁶⁴⁷ Scalise of the SIA, transcript, "Hearing with the U.S. Subcommittee on Trade of the Committee on Ways and Means; Hatano of the SIA, statement to the Congressional-Executive Commission on China, "Is China Playing by the Rules?"

by 2002..., de-politicization of buying decisions by [China's state supported enterprises], trading and distribution rights for foreign firms, removal of technology-transfer and export requirements as a condition for market access or foreign investment, adequate protection of intellectual property rights, and continued permission for the U.S. to use anti-dumping methodology in trade disputes with China.”⁶⁴⁸

Following the 1997 and 1999 agreements, China officially joined the W.T.O. in December of 2001 and enacted laws and regulations to improve transparency and consistency in China. In the early 2000s, Chinese officials also committed to allowing W.T.O. members to review Chinese trade-related regulations before new regulations were implemented and enforced. Officials further agreed to establish one official “journal” for all Chinese trade-related regulations, measures, etc., and they considered posting the journal on the web, in English.⁶⁴⁹ China also enacted a new “Government Procurement Law” in January of 2003.⁶⁵⁰ This complex law attempted to create greater transparency around the purchasing decisions of government agencies and state supported enterprises.⁶⁵¹

⁶⁴⁸ The White House Office of Public Liaison, “November 17, 1999 Summary of U.S.-China Bilateral W.T.O. Agreement,” accessible via www.uschina.org/public/991115a.html; also, Simon, “Microelectronics,” page 8.

⁶⁴⁹ Hatano of the SIA, statement to the Congressional-Executive Commission on China, “Is China Playing by the Rules?” I have not been able to identify this (proposed) all-in-one English language website.

⁶⁵⁰ “The Government Procurement Law of the People's Republic of China, Order of the President No. 68,” accessible in English translation at http://www.gov.cn/english/laws/2005-10/08/content_75023.htm.

⁶⁵¹ “Purchases of goods or services by these state-owned and state-invested enterprises do not constitute ‘government procurement’ and thus are subject to W.T.O. rules” see The White House Office of Public Liaison, “November 17, 1999 Summary of U.S.-China Bilateral W.T.O. Agreement.” Foreigners complained that the procurement law said Chinese government agencies must purchase products with fifty percent local content, but “local content” had several definitions, so, for example, foreign products imported by a Chinese distributor could be considered “local.” For an analysis of the Government Procurement Law, see the Commission of the European Communities’ “E.U. China Trade Sustainability Impact Assessment: Government Procurement, Horizontal Study,” August of 2008.

Despite Document 18, the U.S.-China 1999 agreement, China's W.T.O. entry, and W.T.O.-related policy changes, foreign semiconductor leaders were still voicing complaints about China's policies in 2003. In particular, the preferential V.A.T. was still an issue, foreign firms still faced "local content" requirements in China, policies and the bureaucracy in China remained opaque, and intellectual property was not adequately protected.⁶⁵²

Nonetheless, foreign and Chinese firms continued to expand in China after 2000, with semiconductor firms receiving the tax and other incentives discussed above. An industry survey by PriceWaterhouseCoopers in 2004 found that "foreign [semiconductor] organizations operating in China indicate that [national and local government] incentives have been consistently delivered as promised."⁶⁵³ However, Chinese officials did not simply allow foreign firms to establish operations in China and dominate China's huge semiconductor market. One semiconductor executive said "depending on the agreement you make [with the Chinese government,] they usually allow you to sell into China up to half of your output."⁶⁵⁴

At this writing in 2013, Document 18 is still considered a turning point in the semiconductor in China, and in fact, the document was renewed and re-issued in 2011 with additional supportive policies. The policies in Document 18 offered four primary areas of support: 1) easing firm formation, 2) clarifying and decreasing taxation, 3) encouraging

⁶⁵² Hatano of the SIA, statement to the Congressional-Executive Commission on China, "Is China Playing by the Rules?" Profit repatriation was also (and remains) an issue, although larger global firms seem to the financial wherewithal and accounting expertise to abide this frustration. In 2001, Winston Wong of Grace, a major new semiconductor foundry in Shanghai, said: "Of course China is a foreign exchange controlled country. But there are certain procedures to go through to get your money out. In our experience, the procedures are tedious but...we are always able to legally get the money out," see Moiseiwitsch, "Superfab." See Deloitte, "Finding a Smooth Path to Repatriate Cash and Profits from China," online at www.transactionservices.citigroup.com.

⁶⁵³ PwC, "China's Impact," 2004, page 16s and 35.

⁶⁵⁴ Ben Lee, Vice President of Asia Pacific at Altera, in Moiseiwitsch, "Superfab."

foreign investment and trade, and 4) protecting intellectual property. Should Document 18 and the follow-on policies enacted by relevant agencies and localities be viewed as “state led” development? Certainly, the V.A.T.-related tax policy favored producers located in China, and aligned with Document 18, China’s tenth five year plan called for substantial governmental investments in the semiconductor industry. These conjure state led development, as it is commonly understood, as discussed in Chapter Four. That said, other than the V.A.T.-related preferential tax policy, the other policies of Document 18 were open to forms of any ownership type and were geared toward creating a more consistent and functional business environment. Document 18 did not create any state investments in particular enterprises, although funding from the tenth five year plan did. On balance, China’s new policies for the semiconductor industry from around 2000 can be interpreted as having elements of state led development, but as being largely geared toward creating a better context for the industry, in order to allow enterprises to develop.

5.3 Moving Up the Global Value Chain: R&D and Design

For China, to advance in the semiconductor design sector would signal “moving up the global value chain” and not merely being “the world’s factory floor.” Design is the most technologically demanding sector in the industry, in terms of the human capital needed. In the global semiconductor industry, only about six percent of personnel in the P.A.T. sector and about twenty-four percent of personnel in the fabrication sector are degreed engineers, however, in the design sector, the percentage of personnel with four-year degrees jumps to

about eighty five percent.⁶⁵⁵ In design, human capital is key, and it is not just education, it is practical experience and also managerial and marketing experience, and of course, the ability to create and manage intellectual property.

China emergence in the global industry was first in manufacturing and P.A.T., but less visible in the 1990s were Chinese semiconductor leaders' efforts to improve design capabilities and the infrastructure for design work in China. Somewhat like the manufacturing sector, Chinese officials made plans and investments in the design sector in the 1990s and 2000s. The sector was enhanced by talent cultivated in the 1990s through investments in design-oriented bases, projects, and organizations. The sector was also enabled by the ability of Chinese fabrication facilities to take "outside" orders in the 1990s; that is, fabrication facilities could produce not only for their own sales or for the central plan, but they could serve as "outsourced" manufacturing for other enterprises or design houses. Then, policies around 2000 created a better operating environment for the design sector. Finally, modularization and standardization in the semiconductor industry and the ease of electronic communication among firms (due to the Internet) fostered the design sector around the world. All these factors contributed to rapid growth of the design sector in China in the 2000s, despite China's still insufficient protection of intellectual property.

The development of the design sector in China in the 1990s does not lend itself as easily to measurement by revenues. Progress in the design sector does not necessarily translate into revenues in the short term. Thus, this section examines the investments and activities in the sector from the 1990s, policy changes around 2000, and finally the not

⁶⁵⁵ Wang and Wang, *Wo Guo Jichengdianlu Chanye*, pages 176-177, table 4.5, using statistics from a Gartner industry survey.

insignificant results realized in the 2000s, when design sector revenues grew from US\$0.13 billion in 2000 to US\$1.52 billion in 2005.

This section concludes with a discussion of how intellectual property protection, or lack therefore, may have influenced this sector. In the 1990s and 2000s, foreign investment in the design sector in China was likely constrained by lack of intellectual property protection. That said, foreign firms did establish design operations in China from the 1990s, and there is no way to measure how much more foreign investment might have arrived had I.P. protection been more robust. Also, several realities mitigate the notion that lack of I.P. protection was a primary determinant – or deterrent – in the level of foreign design activity in China. First, firms tend to keep their leading edge design work in their home country in order to preserve their I.P. and their technological advantage. Second, there were many obstacles to doing business in China in the 1990s, manufacturing and P.A.T. were only beginning to ramp up, and thus the industry was not yet a natural site for advanced global design activity. Finally, China was not home to vast numbers of cutting-edge design talent, so in terms of human capital resources, China was not an obvious geographic choice for design activity. Thus, China's lack of I.P. protection was not the only factor against foreign investment in design in China in the 1990s and into the 2000s. (I.P. is discussed further in Section 5.34 below.)

5.31 State Investments in Design, 1990s and early 2000s

From the 1980s, Chinese leaders prioritized semiconductor design along with manufacturing, although efforts to promote design took different forms than those to promote manufacturing. The approaches that Chinese officials primarily used to foster design included establishing various semiconductor “bases,” funding specific research and design projects,

and by supporting certain semiconductor design organizations. In Chapter two, we saw that Chinese officials established a number of new central-level “industry guidance mechanisms” (see Section 2.43c) for the semiconductor industry in the mid to late 1980s, when officials were in the midst of restructuring and reforming the formerly centrally planned industry. These guidance mechanisms promoted design bases and created processes whereby expert committees could prioritize and fund design projects, based on competitive proposals from design organizations. Further, Chapter Four noted that Chinese leaders supported specific semiconductor design organizations, several of which were funded as part of Project 908 and 909. At the national level, China’s Ministry of the Information Industry (the M.I.I., formerly the Ministry of the Electronics Industry), the Chinese Academy of Science (C.A.S.), and the Ministry of Science and Technology (M.O.S.T.) led most semiconductor-related policy making and investment decisions, but municipal and provincial bodies made their own semiconductor-related investments as well as coordinating with national investments, as we will see in this section. The various government-supported efforts were intended to cultivate human resources and design capabilities and to create processes and organizations that would foster the design sector. Then, from the late 1990s, alongside these government-supported bases, projects, and organizations, many new revenue-generating design houses emerged.

5.31a Design Bases

From 1983, Chinese leaders pursued a strategy of geographically clustering semiconductor activity. This approach was not unique to the semiconductor industry. Chinese officials were well aware of the benefits of industrial clustering from experiences of other nations, such as Silicon Valley and Route 128 in the U.S. and Hsinchu Science and

Industrial Park in Taiwan.⁶⁵⁶ These and other clusters had high quality and mobile technical specialists, a culture of meritocracy and risk-taking, local universities, professional service providers (law, accounting, etc.), capital sources (especially venture capital), and business-friendly policies.⁶⁵⁷ The synergies among these factors are credited with fostering innovation and business development. Thus, Chinese leaders attempted to create clusters for various industries and activities in China. In the semiconductor industry, officials pursued clustering in order to reap the benefits of coordination and knowledge sharing among semiconductor experts and organizations and to offer preferential policies and infrastructure to design organizations in the clusters. The various efforts at clustering included design “bases,” research and design centers, and talent cultivation “bases” within universities.

Following the examples from the U.S., Japan, South Korea, and Taiwan, China’s semiconductor leaders’ first broad notion for restructuring the industry in the 1980s was to establish “Two Bases and One Point” (see Section 2.43b.) The initial intention was for the South Base to cover Shanghai, Jiangsu and Zhejiang and the North Base to cover Beijing, Tianjin, and Shenyang. The Point was to be the city of Xian. The intention of this policy was to cluster semiconductor activity in the hope of fomenting the emergence of a full semiconductor industry value chain in the North Base, the South Base, and Xian. This was in contrast to the geographically dispersed character of the industry in China in the 1980s. The Two Bases, One Point concept remained influential in the 1980s, 1990s, and 2000s. Ultimately, Wuxi (home of Huajing and Project 908) was designated the “National Southern

⁶⁵⁶ AnnaLee Saxenian, *Regional Advantage: Culture and Competition in Silicon Valley and Route 128* (Cambridge: Harvard University Press, 1994.)

⁶⁵⁷ Cong Cao, “Zhongguancun and China’s High Tech Parks in Transition,” *Asian Survey*, September-October, 2004.

Microelectronics Industrial Base” in 1989. Shanghai also established two important spaces for microelectronic activity, first the “Caohejing Microelectronic Industrial Zone” in 1984 (now known as the “Caohejing Hi-Tech Park”) and the “Zhangjiang Hi-Tech Park” in 1992 in Pudong, which was (and is) in part identified as an “integrated circuit industry base.” The Zhangjiang Hi-Tech Park was (and remains) home to both Huahong and SMIC. In the north, Beijing did not officially establish the “Northern Microelectronics Industry Base” until 2000. As we have seen in Chapters Three and Four, more production-related semiconductor activity in the 1990s was located in the Wuxi-Shanghai corridor. Beijing was viewed as less appropriate for semiconductor production than Shanghai/Jiangsu/Zhejiang, due to the prevalence of sand storms in the north, but Beijing was conducive to design work due to its proximity to the Chinese Academy of Science, Tsinghua, and various technology organizations both in and out of the semiconductor industry. The Northern Microelectronics Industry Base now consists of the “North Microelectronic Technology Research and Development Base” and the “North Microelectronic Production Base,” both in the vicinity of Beijing.⁶⁵⁸

In addition to these larger sites, China’s Ministry of Science and Technology worked with municipal governments to establish seven “national integrated circuit design bases” in the following seven cities: Wuxi, Shanghai, Beijing, Shenzhen, Xian, Hangzhou, and Chengdu. (The Wuxi National Integrated Circuit Design Base, “WXICC,” was the host for

⁶⁵⁸ There are thousands of technology parks, industrial bases, high technology zones, etc. in China. This chapter covers only the leading semiconductor-related bases. To identify China’s many parks, zones, bases, etc., see “SPICA Directory Profiles for China” at www.spica-directory.net. For an analysis of the effectiveness of these clusters, see Haiyang Zhang and Tetsushi Sonobe, “Development of Science and Technology Parks in China, 1988 - 2008,” *Economics: The Open-Access Journal*, Volume 5, 2011. On Beijing’s most famous and largest technology park, Zhongguancun, see Yu Zhou, *The Inside Story of China's High-Tech Industry: Making Silicon Valley in Beijing* (Lanham: Rowman and Littlefield, 2008.)

this research.) A design base was also established in Hong Kong, and thus these bases were known as the “7 + 1” program. These bases, established in 2000 and 2001, offered young design firms office space, training programs, talent/hiring programs, inter-firm introductions, tax and other subsidies, and technical infrastructure such as E.D.A. tools for designing semiconductors and access to I.P. libraries. The management teams at the bases also solicited overseas Chinese to return to China and invest in design firms or relocate existing overseas firms to China. Each base had a management staff that provided start up firms with these services and worked to attract semiconductor-related firms across the value chain to their region. By 2008, each base had dozens of mostly small semiconductor design-related firms on site. Between 2001 and 2007, these bases offered various training opportunities to over 12,000 personnel and attracted over 1,000 overseas Chinese, in various capacities.⁶⁵⁹

⁶⁵⁹ Wang and Wang, *Wo Guo Jichengdianlu Chanye*, page 356, author’s visits. There is a large body of literature on industrial and technological clusters. In Franco Malerba and Stefano Breschi, editors, *Clusters, Networks, and Innovation* (Oxford: Oxford University Press, 2006), Chapter One gives an overview of the literature and arguments. Primarily the arguments in favor of clustering hinge on: shared knowledge, user-producer proximity, mobility of human capital, flexible firm formation (and disbanding), business-government-academic networks, entrepreneurial culture, availability of service industries and capital, heterogeneous experiences of human capital, and sectoral differences. Douglas Fuller and Cao Cong have questioned the effectiveness of China’s technology bases. See Fuller, “Importing Institutions to Enhance Performance: Foreign Finance and China’s I.C. Firms,” M.I.T. Dissertation, Political Science, 2005, page 34-36, and Cong Cao, “Zhongguancun.” Fuller argues that the bases are an attempt by the Chinese government to “pick winners” and that not all firms in the bases are sufficiently innovative. Cong concurs with the lack of innovation, citing poor technical skills, unclear ownership, lack of capital, and other problems. In my view, it is difficult to know how many of the firms and individuals on such bases ultimately achieve some kind of success. The effects of the bases are not just the revenues and products achieved on site. One of Fuller’s interviewees mentioned that the technology park “did enough by providing preferential policies...without any cushion from the state, the founders would have been hard put to come back to China to set up shop...” Similarly, I found that bases were important for their “one stop shopping” aspect. That is, bases helped new firms to connect with the right agencies, apply for subsidies, source accounting help, etc., in addition to serving as tech hubs. In the West, there are very few “break out” technological successes among new firms, and the fact that tech bases in China are not replete with obvious technology success stories does not prove that the bases are ineffective. Much progress is gradual as people and firms evolve. In the U.S., businesspeople seek out technology parks because start-up firms really do want the infrastructure and synergies, and local governments in the U.S. and U.S. universities provide such parks, despite clear proof of success. Like much infrastructure, effects may be long term.

As human capital is the primary prerequisite for semiconductor design, from 2001, China's Ministry of Science and Technology, via the 863 Project, established sixteen national "integrated circuit talent cultivation bases" to enhance design capabilities at leading Chinese universities. These university bases hired overseas semiconductor experts and increased semiconductor-related courses and degrees. Meanwhile, through the 1990s and 2000s, universities and technical schools throughout China were increasing semiconductor-related courses, as well as other electronics and information-related courses. Prior to 1995, most semiconductor design at universities was done at Fudan University in Shanghai and Tsinghua University in Beijing. Leading schools also sought funding through the Ministry of Education's national Project 211 or Project 985.⁶⁶⁰

In addition, from the late 1990s, university leaders also coordinated with industry leaders to establish joint research programs to train young engineers. As just two examples, in the city of Xian, Xidian University partnered with global semiconductor firm Infineon to establish Xian's "national integrated circuit talent cultivation base." Infineon also provided scholarships and training labs for both Xidian University and Xian Jiaotong University. In Shanghai, Fudan University and Shanghai Jiaotong University established partnerships with Huahong and global semiconductor giant AMD. By 2000, AMD had invested US\$2 million in an arrangement with Shanghai's Science and Technology Commission for research and development projects and scholarships. There were many other partnerships between universities, the talent and design "bases," and companies, all geared toward enhancing China's pool of semiconductor design talent, especially from the late 1990s. Nonetheless, in

⁶⁶⁰ Projects 211 and 985 served many fields and industries. For more on these national projects, see China's Ministry of Education at www.moe.gov.cn.

the 2000s, funding for Chinese university research was not as closely tied to industry research as it is in the West.⁶⁶¹

5.31b Research and Project Funding

In addition to the bases described above, central officials established several sources in the 1980s that provided project funding for semiconductor-related research and design. These sources remained in operation in the early 2000s, although by then, some industry leaders believed that that “turn around time” between applying for project grants and actually putting funds to use was too long, relative to fast-pace of semiconductor technological change. The four primary sources for project funding (also mentioned in Chapter Two) included:

1. *Electronics Annual Fund*: From 1986, the State Council offered the Ministry of the Electronics Industry (later called the Ministry of the Information Industry) an annual fund for research projects, some of which were specific to semiconductors. These project funds were distributed to enterprises and other organizations. From 1986 to 2006, the M.E.I. fund allocated RMB3.9 billion for research projects. Local governments (particularly in Shanghai) augmented this funding with RMB15.6 billion between 2000 and 2004. These funds likely supported both design and other sectors of the industry.

2. *National Engineering Research Centers*: From 1985, the Chinese Academy of Science began establishing National Engineering Research Centers. By 1996, there were

⁶⁶¹ Moiseiwitsch, “Superfab,” per Michael Pecht. Professor Pecht has extensive experience with electronics industry academic research and China’s electronics industry.

seventy such centers; of these, the thirty-four devoted to semiconductor and electronics-related research received RMB1.7 billion in funding.⁶⁶²

3. I.C.C.A.D. and I.C.C.A.T. Specialist Committees: From 1985, the State Council directed the State Planning Commission's Science and Technology Division to emphasize semiconductor capabilities. Central-level I.C.C.A.D. and I.C.C.A.T. specialist committees were established to guide and allocate funding for semiconductor-related research and development programs and projects. From 1990, these committees introduced a new "rolling" mechanism for project proposals, investment, and testing. In this system, every four months, new projects are proposed and potentially funded. The progress of funded projects is checked at regular intervals.⁶⁶³ (This program was still in place as of 2008.) From about 1983 to 2000, the I.C.C.A.D. and I.C.C.A.T. committees allocated RMB1.2 billion.

4. 863 Program I.C. Specialist Project: From 1986, the "I.C. Specialist Project" was established as part of the broader, national 863 Program, a.k.a. The National High Technology R&D Program. In the 863 Program, expert committees in Beijing establish research priorities, and organizations apply (compete) for funding to pursue advances in specific technological areas. If awarded funding, the expert committee periodically checks project milestones. The 863 Program is under the Ministry of Science and Technology. From 2000 to 2004, the 863 Program invested RMB700 million in semiconductor-related projects.⁶⁶⁴

5.31c Design Organizations

⁶⁶² Wang and Wang, *Wo Guo Jichengdianlu Chanye*, page 332.

⁶⁶³ Ibid., 331-332.

⁶⁶⁴ Ibid., page 333.

From the late 1980s and through the early 2000s, China's central level officials also opted to provide government funding directly to major, new semiconductor design organizations. These were in addition to China's existing leading semiconductor-related design institutes: the Chinese Academy of Science Institute of Microelectronics, Institute of Semiconductors, Institute of Software, Institute of Metallurgy, and the National Engineering Center for A.S.I.C. Design. The most prominent of the new organizations are listed below, and each remains in operation as of this writing.

China I.C. Design Center (CIDC): In 1986, Chinese semiconductor industry leaders established China's first significant (state owned) design house. Around 2000, CIDC had 180 staff members, and sixty percent had worked or studied abroad. This organization was restructured in 2002 under the China Electronics Group (one of China's largest enterprise groups) with the new name Huada Electronic Design Company.⁶⁶⁵

908-Related Design Organizations: From 1989, Project 908 funds were intended to support not only Huajing and its #1424 research institute, but also a number of enterprises across the semiconductor industry chain. 908 funding was delayed, as addressed in Chapter Three, but finally in 1998, the central government made 908 funds available to support Huajing as well as nine design centers.⁶⁶⁶ (With little information about Project 908 publicly available, the identity of these nine design centers is not clear.)

909-Related Design Organizations: Like Project 908, Chinese officials intended for Project 909 funding to support design as well as manufacturing. Project 909, under Huahong,

⁶⁶⁵ In 2011, Huada was ranked by revenue as the 17th largest indigenous Chinese semiconductor enterprise, excluding foundries and P.A.T. enterprises, per PwC, "China's Impact," 2012.

⁶⁶⁶ In 2011, the combined revenues of the design organizations originally affiliated (or still affiliated) with Huajing ranked 10th among the revenues of the largest indigenous Chinese semiconductor enterprises, excluding foundries and P.A.T. enterprises, per PwC, "China's Impact," 2012.

eventually provided funding for: the Beijing Huahong IC Design Company; the Shanghai Huahong IC Design Company; and the Shanghai Huahong Jitong Smart Card System Company; as well as other design-related endeavors.⁶⁶⁷

The Shanghai I.C. R&D Center Consortium (ICRD): In 2002, the Shanghai municipal government, in cooperation with Huahong, established this “open platform” consortium to support semiconductor design work throughout China. This non-profit consortium has a team of advanced semiconductor experts (thirty percent hold Ph.Ds.), and the ICRD team works with enterprises, universities, and institutes to provide technical support and technology transfer and to share intellectual property.

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Despite the state investments covered in Sections 5.31a, 5.31b, and 5.31c above, the design sector in China did not take off in terms of revenues until after 2000, and even then, the sector was small relative to the revenues of the manufacturing and P.A.T. sectors. As was discussed in Chapter Four, Chinese officials purposely targeted the manufacturing sector for initial large investments, believing that manufacturing was an area where China could use borrowed technology to master manufacturing and eventually advance the broader industry.<sup>668</sup> However, officials’ decisions to invest in design bases, design research, and design organizations, as outlined above, all helped to cultivate design talent in China leading up to 2000.

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<sup>667</sup> See Chapter Four, Section 4.25 on Huahong’s I.P. agreements with foreign firms and its in-house I.P. development. In 2011, the combined revenues of Beijing Huahong I.C. Design Company and the Shanghai Huahong I.C. Design Company ranked 12<sup>th</sup> among indigenous Chinese semiconductor enterprises, excluding foundries and P.A.T. enterprises, per PwC, “China’s Impact,” 2012.

<sup>668</sup> Alice Amsden in *Asia’s Next Giant* (Oxford: Oxford University Press, 1989) has argued that late industrializers tend to first focus on the “shop floor” when competing “on the basis of borrowed technology.”

The sources available for this study did not reveal China's total governmental investment in the semiconductor design sector in the 1990s and early 2000s. Indeed, because semiconductor-related expenditures were disaggregated throughout the economy, it is likely that a figure exclusive to the semiconductor design sector does not exist. However, some high level estimates and comparisons are shown below. The list below is only to provide points of comparison; there were of course many other semiconductor-related investments in manufacturing, design, and other sectors of the industry. Nonetheless, these examples suggest that Chinese officials highly prioritized microelectronics.

Estimates in US\$ billions:

|                |                                                                        |
|----------------|------------------------------------------------------------------------|
| 7.6 billion:   | Annual official military budget, 1995 <sup>669</sup>                   |
| 14.6 billion:  | Annual official military budget, 2000                                  |
| 29.9 billion:  | Annual official military budget, 2005                                  |
| 14.2 billion:  | Annual electronics investments, 1996-2000 <sup>670</sup>               |
| 24 billion:    | Annual semiconductor investments, 2001-2005                            |
| 1+ billion:    | Project 909, 1996-2000                                                 |
| ~ 0.7 billion: | Research projects in Section 5.31b, over 15 to 20 years <sup>671</sup> |

### 5.32 New Design-related Policies, Circa 2000

As in other sectors of the semiconductor industry, new policies in 2000 correlated with rapid growth in the semiconductor design sector, one of the worlds most – if not the most –

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<sup>669</sup> Official military budgets from GlobalSecurity, a U.S.-based, non-governmental organization. However, the Stockholm International Peace Research Institute estimates that China's total military-related expenditures may be almost three times higher than the reported budgets.

<sup>670</sup> Simon, "Microelectronics."

<sup>671</sup> This rough estimate is from Section 5.31b. In RMB billion,  $(3.9 \times 0.5) + 1.7 + 1.2 + 0.7 = 5.55$ . Then,  $5.55 / 8 = 0.7$ , to convert to US\$ billion. For the Electronics Annual Fund, the 3.9 is multiplied by 0.5 because the fund was not specific to semiconductors. The overall estimate is very rough, due to these projects covering different years and the investment data being complete. Nonetheless, it suggests an order of magnitude.

influential technological sectors. In 2000, Document 18 offered a number of supportive policies to the industry, and the semiconductor design sector was entitled to all software policies because design houses are similar to software firms. The following summarizes the most important benefits from Document 18 for semiconductor design houses.

*Taxation and Exports Benefits:*

- Design firms will get the seventeen percent V.A.T. on their sales rebated to effect an overall tax rate of three percent.<sup>672</sup>
- Design firms will get a preferential income tax rate.<sup>673</sup>
- Design firms will be exempted from customs and import V.A.T. for equipment and technology.<sup>674</sup>
- Design firms will get approval to export and certain benefits related to exportation.<sup>675</sup>

*Capital Provision:*

- The government will establish venture capital funds<sup>676</sup> and will allow and support design firms in seeking foreign investment.<sup>677</sup>

*Infrastructure Support:*

- The government will provide support and funding for design-related infrastructure needs and will fund design incubation centers (these were the “7+1” design bases.)<sup>678</sup>
- The government will fund R&D centers to allow firms, research institutes, and universities to collaborate on semiconductor design initiatives.<sup>679</sup>

*Human Resource and Firm Encouragement:*

- The government will provide funding for:<sup>680</sup>
  - Attracting global human resources, by offering funds to set up companies with preferential policies.

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<sup>672</sup> “18 Hao Wenjian (Document 18),” Article 5.

<sup>673</sup> Ibid., Chapter on Tax Policy.

<sup>674</sup> Ibid., Chapter on Tax Policy, Article 8.

<sup>675</sup> Ibid., Chapter Five.

<sup>676</sup> Ibid., Chapter Two, Article A.

<sup>677</sup> Ibid., Chapter Two.

<sup>678</sup> Ibid., Chapter 2, Article B

<sup>679</sup> Ibid., Chap on Industrial Technology Policy, Article 11.

<sup>680</sup> Ibid., Chapter Seven.

- Hiring foreign experts and providing family subsidies to attract high-end experts (e.g., housing, tuition, etc.)
- The government will provide funding for:<sup>681</sup>
  - Expanded course offerings and advanced degree programs in universities
  - Vocational training, re-education, and distance learning for adult learners
  - Study abroad options
- Design firms can set wages, total income, and equity shares as they wish to encourage top contributors.<sup>682</sup>
- Design firm experts will be granted approval to attend international conferences, meetings, etc.<sup>683</sup>

Government Procurement:

- Government procurement will purchase domestic software, if it is of equal (or better) quality and price relative to foreign products.<sup>684</sup>

### 5.33 The Design Sector Proliferates

In the supportive policy context described above, the design sector in China changed and grew rapidly from 2000. Between 2000 and 2005, design revenues in China, including both foreign and domestic firms, increased by approximately 11.7 times, from US\$0.13 billion in 2000 to US\$1.52 billion in 2005. The number of design firms expanded from 98 firms in 2000 to 479 firms in 2005. From around 2003, the number of firms began to level, as individual firms grew in size.<sup>685</sup> Figure Eighteen shows the growth in design sector revenues and firms in China.

Despite this growth, by 2005, the design sector in China as a percent of total industry revenues was somewhat small (ten percent), relative to the design sector in the global industry

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<sup>681</sup> Ibid.

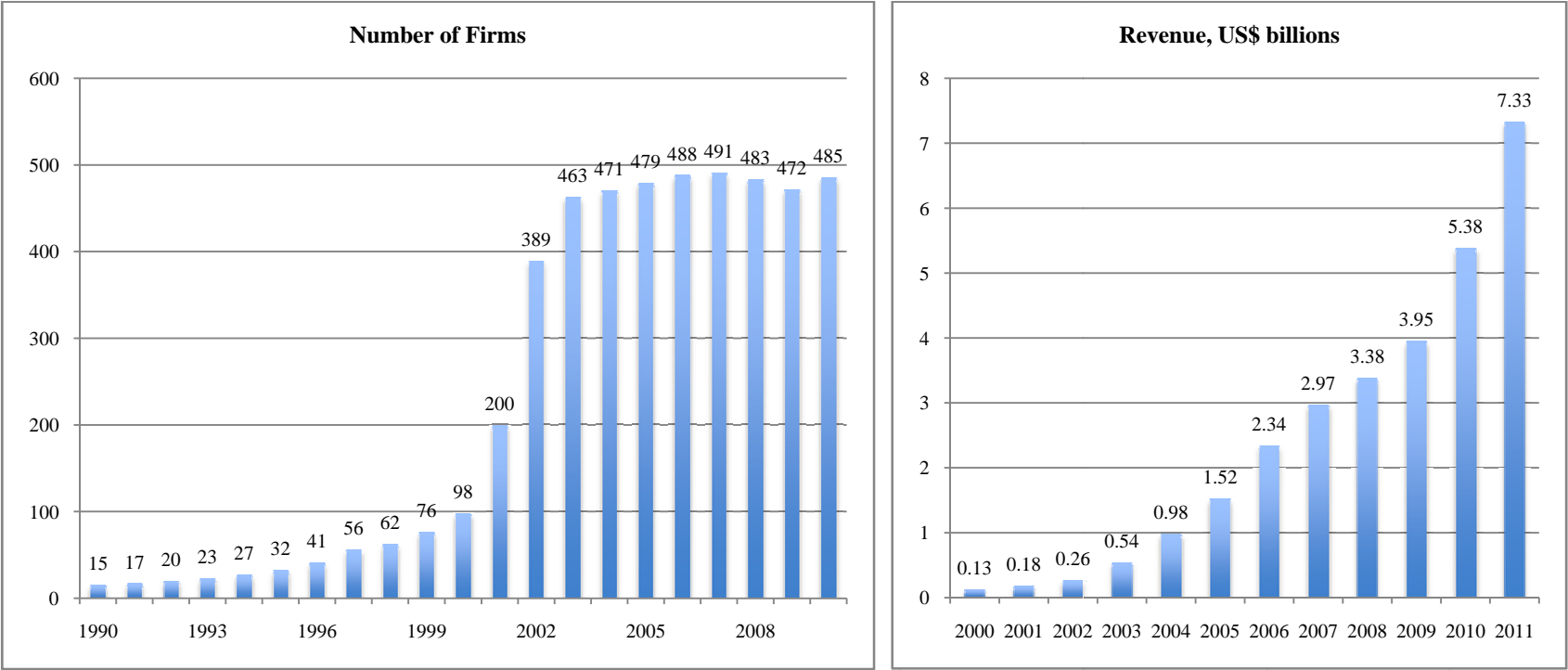
<sup>682</sup> Ibid., Chapter Six, Articles 18-20.

<sup>683</sup> Ibid.

<sup>684</sup> Ibid., Chapter Eight, Article 25.

<sup>685</sup> PwC, “China’s Impact,” 2012, Figure 17, data from CCID.

**Figure 18: Semiconductor Design in China, Revenue Growth and Firm Growth**



Source: PwC, "China's Impact on the Semiconductor Industry," 2012, page 3.2, data from C.C.I.D. and C.S.I.A..

(sixteen percent.)<sup>686</sup> At the same time, the proportion of revenues from (low-end) P.A.T. activity in China was high, placing China relatively lower on the global value chain. However, during that decade, design was the fastest growing sector in the industry, with the proportion of revenues from design increasing each year. By 2011, design was sixteen percent of the industry in China, similar to the global industry.

The talent pool for semiconductor design also expanded rapidly from 2000, although questions about the quality of talent lingered. The number of design sector employees was perhaps only 2,500 in 2000 but this grew to 20,000 in 2005.<sup>687</sup> For comparison, in the early 2000s, there were perhaps 300,000 to 400,000 such designers in Silicon Valley.<sup>688</sup> The number of design personnel expanded along with revenues and firms in the early 2000s, but both Chinese and foreign observers noted that the quality of Chinese designers was not at international levels. Industry executives said that less than half of the semiconductor designers in China were “capable.”<sup>689</sup> From the mid 1980s, the first big wave of mainland students had gone abroad for advanced degrees, many in engineering and science, and many of these advanced students opted to remain abroad for better career opportunities. After the

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<sup>686</sup> Data from PwC, “China’s Impact,” 2007, pages 43-44, and author’s analysis of revenues for the following sectors: I.D.M., design, foundry, and P.A.T.

<sup>687</sup> Interview with Yu Zhongyu, President of China Semiconductor Industry Association, July 2, 2009, CSIA headquarters in Beijing. iSupply noted that China was graduating about 400 “semiconductor design engineers” annually in the early 2000s. However, the growth in the number of employees in the design sector is not just a matter of new graduates. Experienced personnel can also move into the design sector. A person may move from being, for example, a manager in a foundry (likely with a technical background) to working in a design organization. Also, a number of academic fields provide appropriate background for pursuing work in semiconductor design, i.e. electrical engineering, computer science, materials science, chemical engineering, industrial engineering, software engineering, computer-electrical engineering, etc. I do not know what “semiconductor design engineers” covers, in terms of academic disciplines. My educated guess is that the annual number of design-relevant graduates was higher than 400. See also, Simon, “Microelectronics,” PwC, “China’s Impact,” 2007 page 33, and PwC, “China’s Impact,” 2012, page 3.5.

<sup>688</sup> Simon, “Microelectronics.”

<sup>689</sup> PwC, “China’s Impact,” 2004, pages 25-29. PwC, “China’s Impact,” 2007, page 33.

Tiananmen Square crackdown in 1989, the U.S. (a leading destination for Chinese students) offered Chinese students the option of remaining in the U.S. after completing their studies.<sup>690</sup> The tendency of overseas students, which included many of China's brightest, to remain abroad left a technical talent gap in China's labor pool. The Chinese government put in place a number of programs in the 1990s to attract returning scholars, but these programs did not change the overall picture that more Chinese were leaving to study abroad than returning, to the detriment of China's high-end technical talent base.<sup>691</sup> To offset this drain, China expanded its university capacity for advanced students. In 1995, China had just over 8,000 first year Ph.D. candidates in science and engineering, but by 2003, that number had grown to over 48,000.<sup>692</sup>

Meanwhile, in China, young domestically educated engineers had decent technical skills for lower-end design work, but in the 2000s, Chinese semiconductor leaders believed that China's industry was still lacking advanced technological expertise as well as middle and senior managers with finance, marketing, and I.P. management skills. Further, leaders complained that Chinese personnel were still wedded to the "old" norms of putting too much emphasis on degrees and titles, and thus younger people often did not get the opportunity to work on – and learn from – challenging projects. Firms' methods for training and managing human capital and the general mobility of human capital within the industry were also inadequate.<sup>693</sup> Despite these complaints about the talent system, design firms in China grew

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<sup>690</sup> Cong Cao and Denis Simon, *China's Emerging Technological Edge* (Cambridge: Cambridge University Press, 2009.)

<sup>691</sup> Ibid., Chapter Six.

<sup>692</sup> Dieter Ernst, "Innovation Offshoring," *East-West Center Special Reports*, July of 2006.

<sup>693</sup> Interview with Yu Zhongyu, President of China Semiconductor Industry Association, July 2, 2009, CSIA headquarters in Beijing. Interview with Ye Tianchun, July 3, 2009, at the Chinese Academy of Science,



in the 2000s, in part by attracting overseas Chinese investment and talent, as we will see below.

The design sector in China in the early 2000s consisted of different types of organizations. About eighty percent of design firms were domestic and sometimes government-affiliated. These included: new design firms, sometimes incubated at one of “7+1” design bases with partial government support; joint ventures with (or spin-offs from) universities; the design firms of larger Chinese electronics-oriented enterprises or enterprise groups, including design firms affiliated with China Resources (Huajing) and Huahong.<sup>694</sup> These categories are not mutually exclusive. For example, a new design firm might also be a spin-off from a university. (Enterprises such as SMIC and other electronics-related enterprises were effectively training large numbers of design engineers through their in-house design and R&D units, but these in-house units are not counted among the number of design organizations in China.)

The variety of origins and forms of Chinese design firms is captured in the following example. China Resources Microelectronics (CRM, formerly Huajing) had Wuxi China Resources Semico as its primary design company. However, in the early to mid 2000s, CRM augmented its design capabilities with foreign talent, in an attempt to circumvent its overall reputation as a low-end Chinese enterprise. According to one interviewee, in late 2003, CRM began working with a Taiwanese design firm, and together they eventually established two

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Institute of Microelectronics in Beijing. Dr. Ye is the Director of the Microelectronics Institute and a top advisor on national semiconductor industry policies. Wang and Wang, *Wo Guo Jichengdianlu Chanye*, page 354.

<sup>694</sup> Interview with David Gong, June 2, 2009, at Inchange Semiconductor in Wuxi. Mr. Gong had been a manager at Huajing until leaving in 1991 to form a trading company. Interview with General Manager Mao Chengjie, May 19, 2009, at ETEK in Wuxi. Both these firms had engineers from Huajing. ETEK was not technically a “spin-off” from Huajing, but its management team members were all former Huajing employees.

small design houses in Shanghai.<sup>695</sup> Eventually, CRM established a design house in which CRM was the only shareholder, but CRM treated the design house as an independent entity. This design house, located just east of Wuxi, did not use the CRM name. The staff came from the U.S., where they had been working in a California-based design firm, but they were of ethnic-Chinese origin. According to the interviewee, other than CSMC, this was the first foreign group at CRM, and its staff consisted of four U.S. citizens and seven citizens of Taiwan. The purpose of CRM's so-called independent design house was to increase CRM's foreign sales by circumventing CRM's reputation as a Chinese provider of relatively low-end products to Chinese customers. The design house sought U.S. and Taiwanese customers. The hope was that customers would be satisfied with the work, and though customers would eventually realize that the design house was part of CRM, by then the foreign customers would be open to buying from CRM and from Chinese semiconductor companies more generally. So, here was a state owned design house, positioned and marketed as an "independent" firm, with all foreign staff, attempting to sell to foreign customers, and generally, hoping to convince overseas customers that "Chinese" semiconductor enterprises could have appropriate quality.<sup>696</sup>

One important reason for the growth in domestic design firms after 2000 was increased access to financing through government-backed venture capital funds, as

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<sup>695</sup> Interview with a confidential source. This interviewee was on staff at CRM's independent design house, having re-located from the U.S. Due to the design house's ongoing role as a "shield" for CRM, the interviewee did not want his name or his firm's name used.

<sup>696</sup> Interview with a confidential source at CRM's "independent" design house. This interviewee noted that CRM had hired hundreds of new college graduates for their foundry. He said that he and his colleagues were "embarrassed" when customers or foreigners visited CRM's foundry because there were "all these people standing around!," meaning that the staffing level was not optimized and people were not working productively, thus presenting a mis-managed image to visitors.

encouraged in the tenth five year plan and Document 18. In the early 2000s, China's Ministry of Information Industries, the Chinese Academy of Science, municipal governments, technology parks, and other government agencies established venture capital funds. In addition to their government investment, these venture capital funds sought private and foreign investors, and the fund managers committed to "following market principals and international business practice," despite being government supported.<sup>697</sup>

Another twenty percent of design firms in China in the early 2000s were private, sometimes foreign firms, often run by returnees with access to foreign capital.<sup>698</sup> These globally focused organizations included new Chinese (non-state) design houses, several of which grew rapidly in the early 2000s, including Actions Semiconductor, Vimicro, and Spreadtrum. One semiconductor distributor explained that Chinese O.E.M.s, such as Haier and Panda, increasingly used Chinese design houses to meet particular product needs, as they got better service from these local designers than from overseas design houses.<sup>699</sup> Globally focused design organizations in China also included foreign firms such as MEMSIC, which opened a design facility in Wuxi in 2001, and important semiconductor design I.P. licensors ARM and Cadence.<sup>700</sup>

Also, global semiconductor firms opened design units in China beginning in the 1990s. (These units might not be fully captured in data on number of design firms and revenues in

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<sup>697</sup> SIA, "China's Emerging," pages 103-104. The host organization for this research, the Wuxi design base (WXICC), was charged with running several funding programs. WXICC used funds to try to attract overseas Chinese, foreigners, and local Chinese to Wuxi to start new businesses.

<sup>698</sup> PwC, "China's Impact," 2006, pages 34-35.

<sup>699</sup> Interview with Huang Qi, owner of Shenzhen Saifun Semiconductors (a distributor), March 27, 2009 at the Saifun office in Shenzhen.

<sup>700</sup> Semiconductor I.P. suppliers such as ARM, CEVA, Tensilica, Silicon Image and others increasingly licensed I.P. cores to Chinese design houses in the 2000s.

China.)<sup>701</sup> Arrivals in the early to mid 1990s included AT&T, Motorola, NEC, Philips, and SGS Thomsom, among others.<sup>702</sup> Notably, by 2005, between sixty and one hundred of the world's largest semiconductor firms had design or R&D units in China.<sup>703</sup> By locating some design or R&D work in China, these firms could adapt products for the local market and protect local market share by being involved in the technological trends in China. There were also the advantages of lower-cost design engineers and government supported infrastructure and incentives.<sup>704</sup> These global design and R&D units expanded China's talent pool in the semiconductor industry, as they typically have a majority local staff.<sup>705</sup> By 2011, non-Chinese design organizations accounted for approximately forty-four percent of design revenues in China.<sup>706</sup> Both the growth of the commercial design sector in China as well as its international links show that the semiconductor industry in China indeed "moved up the global value chain" in the 2000s.

### 5.34 Intellectual Property Protection

Perhaps the biggest concern for firms considering doing design and R&D activity in China was the legal protection in China of intellectual property, primarily patents. Concerns

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<sup>701</sup> Simon, "Microelectronics," also author's visits to design firms at design bases and various conversations with Chinese and foreign semiconductor personnel.

<sup>702</sup> PwC, "China's Impact," 2004, page 25.

<sup>703</sup> CSIA and CCID identified 100 foreign design organizations in 2005, while PwC was only able to identify 63. However, the 63 were from the world's 200 largest semiconductor firms, and included design units of 18 of the largest 25 global semiconductor firms, see PwC, "China's Impact," 2006, pages 34-35.

<sup>704</sup> PwC, "China's Impact," 2006, page 35; PwC, "China's Impact," 2012, page 3.4.

<sup>705</sup> In other sectors, too, global firms trained local Chinese. Global semiconductor equipment manufacturer ASML had 300 employees in China in the 2000s, and over ninety percent were local Chinese. Hynix is one of the largest memory producers in world. From 2005, approximately forty percent of Hynix' production has been in Wuxi, and Hynix was Wuxi's largest employer in 2008. Interview Fred Knijnenburg of ASML, April 11, 2009 in Wuxi.

<sup>706</sup> PwC, "China's Impact," 2012, page 3.11.

about I.P. protection loom over the whole semiconductor industry in China, although more so in the design and fabrication sectors. Generally, when a firm infringes on another firm's I.P., the infringer gains the advantage of lower costs (due to lack of design effort) and the ability to quickly go to market against rivals. Since the 1980s, the value of many large global firms has increasingly shifted from being located in tangible assets to being located in intangible assets.<sup>707</sup> These intangible assets include intellectual property in the form of patents, trademarks, copyrights, and trade secrets. Firms' I.P. must be legally protected in order to protect their market share, and if I.P. is not protected within a certain product category or geographic region, then ultimately firms might not participate in that region or product line or they might decrease their investment in R&D and design, due to not getting sufficient return on those investments. When global semiconductor firms considered entering China in the 1990s and 2000, I.P. protection was a real concern.

At this writing, global business leaders, semiconductor executives among them, still argue that I.P. protection in China is inadequate. Nonetheless, there were important changes relating to I.P. in China during the period of this study. We must consider these changes in order to understand the context in which some (actually, many) global semiconductor firms opted to locate operations in China in the 1990s and 2000s.<sup>708</sup> Perhaps surprisingly, in 1997,

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<sup>707</sup> PwC, "China's Impact," 2005, page 7, per a Brookings Institute and NYU study by Baruch Lev.

<sup>708</sup> For a longer history of Chinese views on the role of intellectual property, which differ from those in the West, see William Alford, *To Steal a Book is an Elegant Offense* (Stanford: Stanford University Press, 1995.) For an understanding of events and the official discussions between the U.S. and China regarding China's intellectual property regime in the 1980s and 1990s, see Michel Oksenberg, Pitman B. Potter, and William B. Abnett, "Advancing Intellectual Property Rights: Information Technologies and the Course of Economic Development in China," *National Bureau of Asian Research*, November of 1996. In the late 1980s and early 1990s, the U.S. demanded that China expand I.P. institutions and enforcement or face sanctions, based on the Special Section 301 of the Omnibus Trade and Competitiveness Act of 1988. In response, China threatened trade barriers on U.S. imports. Eventually, China agreed to strengthen I.P. protection, however, the results of this process were not promising, and I.P. protection continued to be an issue.

George Scalise, President of the U.S. Semiconductor Industry Association (SIA), testified before the U.S. Committee on Ways and Means that “There has been no piracy of semiconductor intellectual property to date, [as] China’s level of technological development does not yet permit it to manufacture advanced U.S. products or misappropriate U.S. chip designs.”<sup>709</sup> However, six years later in 2003, Daryl Hatano of the SIA testified before the Congressional-Executive Commission on China that there have been “increasing numbers of instances” and “numerous reports of I.P. violations in China.”<sup>710</sup> By 2003, the SIA was imploring the Office of the U.S. Trade Representative and the Chinese government to work together to improve I.P. protection in China. In 2003, China’s government was viewed as not enforcing I.P. related laws and generally having a poor record of establishing the legal and institutional processes required for I.P. protection.

Emerging economies often do not have the institutions or norms to respect intellectual property in their early period of development. As an economy develops, however, protecting I.P. should (at least in theory) further economic growth, and thus become a desirable practice. With economic growth, more groups within a country (firms, individuals, as well as the state) have an increasing interest in protecting intellectual property. Firms and individuals can profit from innovation, and the state can use I.P. to further development and infrastructure goals, as well as demonstrate its capacity and credibility. In the contemporary era, nations that participate in global trade also need to protect intellectual property to attract foreign

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<sup>709</sup> Scalise of the SIA, transcript, “Hearing with the U.S. Subcommittee on Trade of the Committee on Ways and Means.”

<sup>710</sup> Hatano of the SIA, statement to the Congressional-Executive Commission on China, “Is China Playing by the Rules?”

investment and to successfully serve export markets, as products shipped overseas usually need to be “legitimate.”

All these issues apply directly to China, and indeed China’s intellectual property regime has changed as China’s economy developed, though the regime is still imperfect.<sup>711</sup> China passed a series of trademark, patent, and copyright laws in the 1980s,<sup>712</sup> but it was after ascending to the W.T.O. in 2001 that China had to enact new laws, regulations, and processes to protect I.P. under the W.T.O.’s “Trade Related Aspects of I.P.” (T.R.I.P.s). To conform with T.R.I.P.s in the semiconductor industry, China’s State Council adopted new regulations called “Regulations on the Protection of Layout-Designs of Integrated Circuits” on March 28, 2001, to be effective as of October 1, 2001.<sup>713</sup> The global semiconductor industry was hopeful that China’s entry into the W.T.O. would lead to better protection of I.P. in China, though that hope was not realized at least in the short term. Certainly, China’s I.P. regime has been strengthened and expanded since 2001. China’s State Intellectual Property Office (S.I.P.O., formerly the Patent Bureau) has fifty-four branch offices,<sup>714</sup> and the judges that decide patent cases became increasingly professionalized in the 2000s in handling technically complex I.P. cases.

China’s entry to the W.T.O. may have fostered its I.P.-related institutions, yet from the

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<sup>711</sup> “New Progress in China’s Protection of I.P. Rights” (“White Paper Values IPR”), *China Daily*, August 12, 2005.

<sup>712</sup> See Andrew Mertha, *The Politics of Piracy* (Ithaca: Cornell University Press, 2005) for an account of U.S. pressure on China in the 1980s and 1990s to create an effective I.P. regime.

<sup>713</sup> Wang and Wang, *Wo Guo Jichengdianlu Chanye*, page 331. This regulation was promulgated by Decree No. 300 of the State Council of the People’s Republic of China. An English-language version is available at [www.sipo.gov.cn](http://www.sipo.gov.cn).

<sup>714</sup> Richard Suttmeier and Xiangkui Yao, “China’s I.P. Transition: Rethinking Intellectual Property Rights in a Rising China,” *NBR Special Report*, Number 29, July 2011, page 14, citing Elaine Wu, “Recent Patent Related Developments in China,” conference presentation at Berkeley “Beyond Piracy: Managing Patent Risks in New China March 10, 2011.

early 2000s to the present, problems have remained. In the early 2000s, commonly cited problems included dis-connects between intentions and policies at the central and local levels and lack of policy enforcement. Foreigners found China's judicial system to be, generally, not transparent, not standardized, and not predictable.<sup>715</sup> In the courts, some foreigners believed that due process was not entirely respected and discovery processes were weak. Further, some felt that judges were more apt to find against foreigners, and finally, monetary awards were often trifling.

Under China's new I.P.-related laws and regulations from 2001, the Chinese government could compel I.P. holders to license their I.P., which was at odds with the W.T.O.'s T.R.I.P.s agreement. Another point of contention in China was that licensees of I.P. would *own* any improvements that they made to the I.P. In cases of counterfeit products, the SIA also complained in 2003 that, under China's laws, to file claims against counterfeiters, a complainant had to track down an actual buyer of the counterfeit goods and convince the buyer to help with the case (i.e., admit to purchasing counterfeit goods.) The complainant could not hire an investigator to purchase the counterfeit goods, as claims could only be filed if there were "legitimate" purchases.

In light of these and other I.P.-related obstacles in China, foreign firms with design activities in China used several tactics. First, design work assigned to staff in China might be compartmentalized. That is, design staff in China might be assigned to work on narrowly defined problems, and they would not be informed as to how their work was connected to the

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<sup>715</sup> Hatano of the SIA, statement to the Congressional-Executive Commission on China, "Is China Playing by the Rules?"



rest of the design or program.<sup>716</sup> At times, Chinese team design teams' work was not fully electronically connected to the home country's R&D or design center, in order to reduce unauthorized access to the larger project or other proprietary information. Another option for foreign firms was to partner with a Chinese organization in a way that gave the Chinese partner a stake in protecting I.P. (That said, foreign firms have also complained that their Chinese partners steal their I.P.) Further, foreign firms typically did not conduct leading edge design work in China. Rather, design work in China might be geared toward adapting products to the local market or serving local customers with design support. Despite these cautious tactics, when semiconductor I.P. was infringed in China, foreign firms often did not file complaints in China owing to the problems discussed above. Rather, foreign firms would file in their home countries.

And, despite foreign firms' caution, there were a number of ways that semiconductor I.P. was increasingly infringed from 1997 to 2003 and beyond. Generally, China's programs for inward-bound technology transfer created opportunities for potential infringers to gain access to trade secrets and patented technology and products. In a similar way, the de-verticalization of the semiconductor industry caused more inter-firm sharing of information and technology. Further, Chinese partners sometimes licensed patents from their joint venture partners, but then illicitly disclosed the I.P. to outside parties. Of course, as semiconductor personnel moved between companies in China, trade secrets as well as patents could be compromised, as occurred at SMIC, one of China's national champion semiconductor

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<sup>716</sup> PwC, "Redefining Intellectual Property Value: The Case of China," 2005, page 59. I saw a similar phenomenon in defense-related engineering work at Texas Instruments. Individuals and groups were not always informed about how their project served a much larger project.

enterprises.<sup>717</sup>

Semiconductor chips can be copied in two main ways. First, a counterfeiter can optically copy a chip to create an identical chip, and then the copied chip is branded and sold under a different company name. Another way to copy a chip is to reverse engineer the chip, produce an exact copy, and then fraudulently sell the copied chip under the original owner's brand name.<sup>718</sup> In one famous case in 2003, a professor at Shanghai's Jiaotong University allegedly developed China's first digital signal processing chip, called the "Hanxin Chip." Yet, in 2006, an investigation showed that the chip was actually a copy of a Motorola chip, with identifying marks removed. The Chinese government investigated the professor, and he was banned from research and made to return funds.<sup>719</sup> In a 2004 case, several Chinese chip manufacturers including Shanghai Belling (one of China's five key semiconductor enterprises and joint venture partner of Alcatel Bell) were found to be manufacturing and selling a counterfeit chip. Analog Devices of the U.S. was the original owner of the copied chip design. Analog was able to get an injunction against Belling and the other Chinese manufacturers in the U.S. and did not file suit in China.<sup>720</sup>

In the early and mid 2000s, foreign firms believed that they also incurred losses through Chinese firms' patent filings. The annual number of patents filed in China across all industries quadrupled between the late 1990s and 2005, owing to the development of China's

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<sup>717</sup> See Chapter Four, Section 4.34.

<sup>718</sup> Hatano of the SIA, statement to the Congressional-Executive Commission on China, "Is China Playing by the Rules?" For obvious reasons, semiconductor companies do not provide detailed information about how their designs are copied.

<sup>719</sup> David Barboza, "In a Scientist's Fall, China Feels Robbed of Glory," *New York Times*, May 15, 2006.

<sup>720</sup> PwC, "China's Impact," 2004, page 50.

I.P. regime.<sup>721</sup> However, more than two-thirds of patents filed by Chinese firms and individuals were utility model patents or design patents, rather than the more substantive invention patents. Some utility and design model patents were referred to as “petty” or “junk” patents. These were awarded more for minor changes or improvements, and the patents were granted without a full examination.<sup>722</sup> This meant that Chinese firms could get patents on items that were in large part copies of others’ work. Between 2000 and 2010, foreign firms increasingly filed for patents in China, but about eighty percent of foreign patent applications were for the more rigorously examined invention patents.<sup>723</sup> Foreign firms’ I.P. was also devalued when Chinese firms would sell copies or counterfeit products in countries in which the original foreign owner of the I.P. had not yet filed a patent. In these ways, the growth of China’s I.P. regime and the increasing use of patents in China led to loopholes and abuses.

In the semiconductor industry, there is another major area of I.P. beyond the I.P. of completed chips. From the 1990s, semiconductor design firms have increasingly relied on complex and expensive E.D.A. (electronic design automation) software systems and I.P. cores to design chips. E.D.A. software is very expensive and must be licensed; unlike off-the-shelf consumer software, E.D.A. software systems are not readily copied and circulated. I.P. “cores” refer to standard design modules that are licensed by firms like ARM, Cadence, and Synopsis. These I.P. cores are also better controlled than typical software products. Both E.D.A. and I.P.

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<sup>721</sup> Annual patents filed in China grew from approximately 83,000 in 1995 to 170,000 in 2000 to 475,000 in 2005 to 980,000 in 2009. Joanna Wu, I.P. attorney at Ropes and Gray, “Recent Patent Developments in China,” conference presentation at “China Scope in NYC,” March 2011.

<sup>722</sup> Suttmeier and Yao, “China’s I.P. Transition,” page 14. USITC, “China: Intellectual Property Rights Infringement, Indigenous Innovation Policies...,” No. 332-514, Publication 4199, November of 2010, data on numbers of patents are from China’s State Intellectual Property Office.

<sup>723</sup> Wu, I.P. attorney at Ropes and Gray, “Recent Patent Developments in China.”

cores are licensed to users, and for example, China's national I.C. design bases (the "7+1" bases) obtained proper licenses for E.D.A. tools for the small firms on their base to legally use and in 2003 the Shanghai Silicon Intellectual Property Exchange was founded which offers databases of I.P. for licensing, design verification, other I.P.-related services. By 2010, 7.4 percent of worldwide license revenues for E.D.A. software and 8.0 percent of worldwide license revenues for semiconductor I.P. including I.P. cores were in China. That is, firms in China were *purchasing* such licenses.<sup>724</sup> The controlled use and licensing of such tools brings visibility and proper usage to I.P. in the semiconductor design sector.

Despite I.P. infringements encountered in China, foreign semiconductor firms did opt to establish operations in China, although their advanced design work was not conducted in China. It is difficult to estimate how many more firms might have come to China, or come earlier, or brought more substantial operations to China had China's I.P. regime been more robust in the 1980s, 1990s, and 2000s. In 2005, CSIA and CCID identified 100 foreign design organizations in China. PwC was only able to identify 63 of these, but the 63 were from the world's 200 largest semiconductor firms, and they included design units for 18 of the world's 25 largest semiconductor firms. Given the numbers and the stature of these foreign firms, it seems that many foreign firms were willing to manage the risks of operating in China's still-developing legal environment.<sup>725</sup>

More broadly, Chinese views of economic development and the role of I.P. have differed from those in the West. Contemporary China could be categorized as a

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<sup>724</sup> PwC, "China's Impact," 2012, page 58, data sources: CSIA, Semi, Gartner Dataquest.

<sup>725</sup> PwC, "China's Impact," 2006, pages 34-35.

developmental state rather than a regulatory state.<sup>726</sup> That is, the Chinese government is directly involved in investing in particular industries and technologies, with the goal of economic development and moving Chinese industries into higher value added activities. Thus, the government has enacted plans and policies to support “indigenous innovation” and (Chinese owned) I.P.<sup>727</sup> In contrast, in a regulatory state like the U.S., innovation is assumed to be mostly a matter for private industry,<sup>728</sup> and the government’s role is to provide a functioning legal system in which property rights are bestowed and protected. However, in China, in thinking about fostering innovation and I.P., Chinese officials consider not just individual property rights but also the public good.<sup>729</sup> Some I.P. might serve China’s national interests and development, and thus the Chinese government supports the industries, technologies, and global partnering that might create I.P. for the public good and enable China to “contribute more to world innovation.”<sup>730</sup> For example, the Chinese government has supported China’s state owned large enterprise groups in pursuing certain technologies and related I.P. (At the same time, high-pressure governmental goals for economic growth have also likely contributed to economic shortcuts in China, including I.P. abuses.) In the semiconductor industry, Chinese leaders see technological advances as not only serving electronics-related needs but also as improving energy efficiency and energy usage across

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<sup>726</sup> The concept of the developmental state is presented in Chalmers Johnson, *MITI and the Japanese Miracle: The Growth of Industrial Policy, 1925-1975* (Stanford: Stanford University Press, 1982).

<sup>727</sup> Suttmeier and Yao, “China’s I.P. Transition,” page 18. PwC, “China’s Impact,” 2005.

<sup>728</sup> Of course, the government in regulatory states typically *do* support I.P. development through universities, defense spending, national institutes, industry subsidies, etc.

<sup>729</sup> There is a history in China of considering the public good aspects of intellectual property. See Alford, *To Steal a Book*.

<sup>730</sup> Interview with Ye Tianchun, July 3, 2009, at the Chinese Academy of Science, Institute of Microelectronics in Beijing. Ye is the Director of the Microelectronics Institute and an advisor on national semiconductor industry policies. Dr. Ye noted that China actively looks for foreign partners to meet its medium and long-term R&D priorities.

society. Power and energy consumption are global issues, and as semiconductors can serve to reduce energy use, Chinese officials see semiconductor advances as advancing the public good.<sup>731</sup> (In contrast, some U.S. observers view the Chinese government's goals for indigenous innovation as nefarious and nationalistic.)<sup>732</sup>

Given China's perspective on the role of I.P., there is also a concern by Chinese officials that Western countries use I.P. to dominate less developed countries. In this view, I.P. rights not only motivate innovation and protect intangible assets, but these rights are used strategically by companies for "demonstrating value to potential investors, deterring competitors, and capturing value from rival firms" via legal actions and "to prevail in competition and to maximize value."<sup>733</sup> In a study entitled "China's I.P. Transition," Richard Suttmeier and Xiangkui Yao argue that "Many Chinese observers, while genuinely lamenting the problems of piracy and counterfeiting, nevertheless lack sympathy for some complaints about Chinese I.P. protection by foreign companies and governments. They point, instead, to the fact that many foreign companies have adopted quite well to Chinese conditions and use

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<sup>731</sup> Wang and Wang, *Wo Guo Jichengdianlu Chanye*, Introduction and Section 2.2.3. Improved semiconductor technologies result in energy savings. "Smart" energy solutions have semiconductors (often sensors) to measure variables (such as temperature) and power management functions to moderate energy usage accordingly. According to the American Council for an Energy-Efficient Economy, there is a "powerful connection between semiconductors and energy consumption... Despite the immediate growth in electricity demands to power the growing number of devices and technologies, semiconductors [enable] a surprisingly larger energy productivity benefit..."

<sup>732</sup> Foreign observers lament I.P. infringement in China, while also lamenting the desire of the Chinese government to support the development of legitimate I.P. There are many examples of foreign critiques of China's policies for indigenous innovation, but for example, see USITR, "China: Intellectual Property Infringement, Indigenous Innovation Policies, and Frameworks for Measuring the Effects on the U.S. Economy," Number 332-514, Publication 4199, November 2010.

<sup>733</sup> Here Yao and Suttmeier are reflecting the views of other scholars, see Suttmeier and Yao, "China's I.P. Transition," pages 14-17, where they discuss Giovanni Dosi, Luigi Marengo, and Corrado Pasquali article "How Much Should Society Fuel the Greed of Innovators,?" *Research Policy*, 35, 2006, page 1114 and David Teece, "Profiting from Technological Innovation...", *Research Policy*, 15, 1986, pages 285-305.

their I.P. with strategic success for profits and competitive advantage.”<sup>734</sup> Indeed, global companies do adopt specific strategies and programs to maximize the value their I.P.

China’s government has its own macro perspective on the role of innovation and I.P., and Chinese individuals and firms also seem to have particular views on these matters. Chinese electronics personnel express pride in the ability of Chinese companies to imitate – and even improve upon – advanced, Western electronics products, such as cell phones. They appreciate “follower” products, as these products demonstrate evolution in Chinese firms’ capabilities. The Western business perspective on follower products is often dismissive (or disdainful, due to I.P. infringement), but there is a huge market for follower products. Non-leading firms consider themselves successful when they are able to develop, produce, and market viable (follower) products, although these voices are not typically heard in Western business case studies.<sup>735</sup> For non-leading firms, gradual improvements in organization, management, and technology are often incremental and not overtly innovative by Western standards.

In sum, I.P. norms and protection in China are still insufficient by Western standards. This situation will likely not change in the short term owing to the gradual development of China’s legal system and I.P. regime, the Chinese government’s “public good” considerations with regard to I.P., and Chinese business people’s acceptance of follower products. Despite the seemingly slow pace of change with regard to I.P. protection in China, the global semiconductor industry made significant commitments to locate operations in China in the

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<sup>734</sup> Suttmeier and Yao, “China’s I.P. Transition,” page 16.

<sup>735</sup> Interviews including Yang Long, Mr. Jiang (WXICC), Toby Chai, Huang Qi, Xu Guochang, Mr. Gong, and Yu Xiekang. See the Interview List for details on dates and organizations. Others expressed similar views.

1990s and 2000s.

#### **5.4 Joining the Global Value Chain**

This chapter has shown that around 2000-2001 the semiconductor industry in China entered a new era of more rapid growth and global integration. Indeed, by 2010, over ten percent of the world's highly sophisticated semiconductor industry, including a portion of the design sector, was located in China, and over forty percent of the global market for semiconductors was in China. This was a phenomenal geographic shift in global technology that was almost unimaginable just fifteen years earlier.

China's new policies adopted around 2000 were highly influential, but they were not the sole determinant of the new era. Indeed, the new era was not entirely "new," as it built upon a foundation that was developed in the 1990s. In that decade, as China's market for semiconductors grew rapidly, Chinese semiconductor enterprises evolved. As we saw in Chapters Three and Four, major Chinese enterprises made organizational, technological, ownership, and management changes, as well as embarking on significant global partnerships. In the design sector, too, Chinese officials made a number of investments and changes. Also in the 1990s, foreign firms sought to establish operations in China, largely to be close to China's market, despite inconsistency and lack of transparency in China's business environment. All this activity resulted in significant organizational learning and an enlarged talent pool in China.

Building on the base established and lessons learned in the 1990s, Chinese officials enacted new semiconductor-related policies from 2000, including Document 18 and the (I.P.-related) Regulations on the Protection of Layout-Designs of Integrated Circuits. China's tenth



five year plan and W.T.O.-related policies also had provisions supportive of the semiconductor industry. Together, these policies fostered both domestic and foreign firms in China after 2000. Further, China's (W.T.O.-non-compliant) V.A.T. policy gave tax advantages to firms located in China, particularly production firms, over firms located abroad. This preferential V.A.T. thus supported both Chinese domestic firms and foreign investment, as foreign firms sought the tax benefits of locating in China. (The discontinuation of the preferential V.A.T. in 2005 did not slow the industry's growth in China.)

This chapter examined several other policy areas that were relevant to the semiconductor industry in China in the 1990s and into the 2000s. These included: 1) Western (mainly U.S.) export restrictions on dual-use technology to China, 2) Taiwan's restrictions on investments in China, and 3) China's fledgling I.P. regime. In effect, this research suggests that both Chinese and foreign leaders found ways to advance the industry in China, despite these policy constraints. With regard to export restrictions on technology, in the 1990s Chinese enterprises were actually able to import semiconductor equipment from non-U.S. sources, and thus export controls did not stifle the industry. As for Taiwan's investment restrictions, we have seen that semiconductor-related investments from Taiwan found their way into Mainland China well before Taiwan lifted its restrictions in 2002, and much of the growth in the industry after 2002 was not attributable to Taiwanese firms. Finally, despite the problems with China's I.P. regime, both foreign and Chinese design firms proliferated in China in the 2000s, with most of the world's largest semiconductor firms opting to locate design units in China. The caveat here is that the quality and quantity of work from these China-based design units may have been compromised by the knowledge that I.P. is not well protected in China, relative to the West.

These chapters have addressed how the semiconductor industry in China transitioned away from central planning in the 1980s (Chapter Two), how large semiconductor enterprises evolved and established global partnerships in the 1990s (Chapters Three and Four), and how the semiconductor industry in China -- with the support of new policies -- integrated with the full global value chain (Chapter Five.) The following Conclusions consider the primary insights of this study as well as comparing the contemporary history of this vital industry in China with its history in Japan, South Korean, and Taiwan.

## **Chapter Six**

### **Conclusions:**

**The Semiconductor Industry in China and  
Comparisons with Japan, Korea, and Taiwan**

## Chapter Six Contents

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This study has addressed one of the most important high technology industries in the world. The semiconductor industry is relatively new in economic history, emerging only in the late 1950s and not really gaining commercial momentum until around 1970 (see Figure Nineteen), yet the industry serves as the core of what business historian Alfred Chandler has called the “Information Revolution” and “The Electronic (21<sup>st</sup>) Century.”<sup>736</sup> In effect, semiconductors are the electronic engines of the Information Revolution. In the first and second Industrial Revolutions, steam, electricity, and the combustion engine revolutionized transit and production, ushering in capital and resource intensive production and distribution. In the Information Revolution, semiconductor “chips” power an era of nearly instantaneous data storage, analysis, and communications for numerous industries around the world, resulting in measurable productivity gains by the late 1990s,<sup>737</sup> and semiconductors serve as the core of a host of new knowledge intensive industries.<sup>738</sup>

Simultaneous with the emergence of the semiconductor-based Information Revolution, East Asia began its contemporary economic ascent in the latter half of the 20th century. Japan

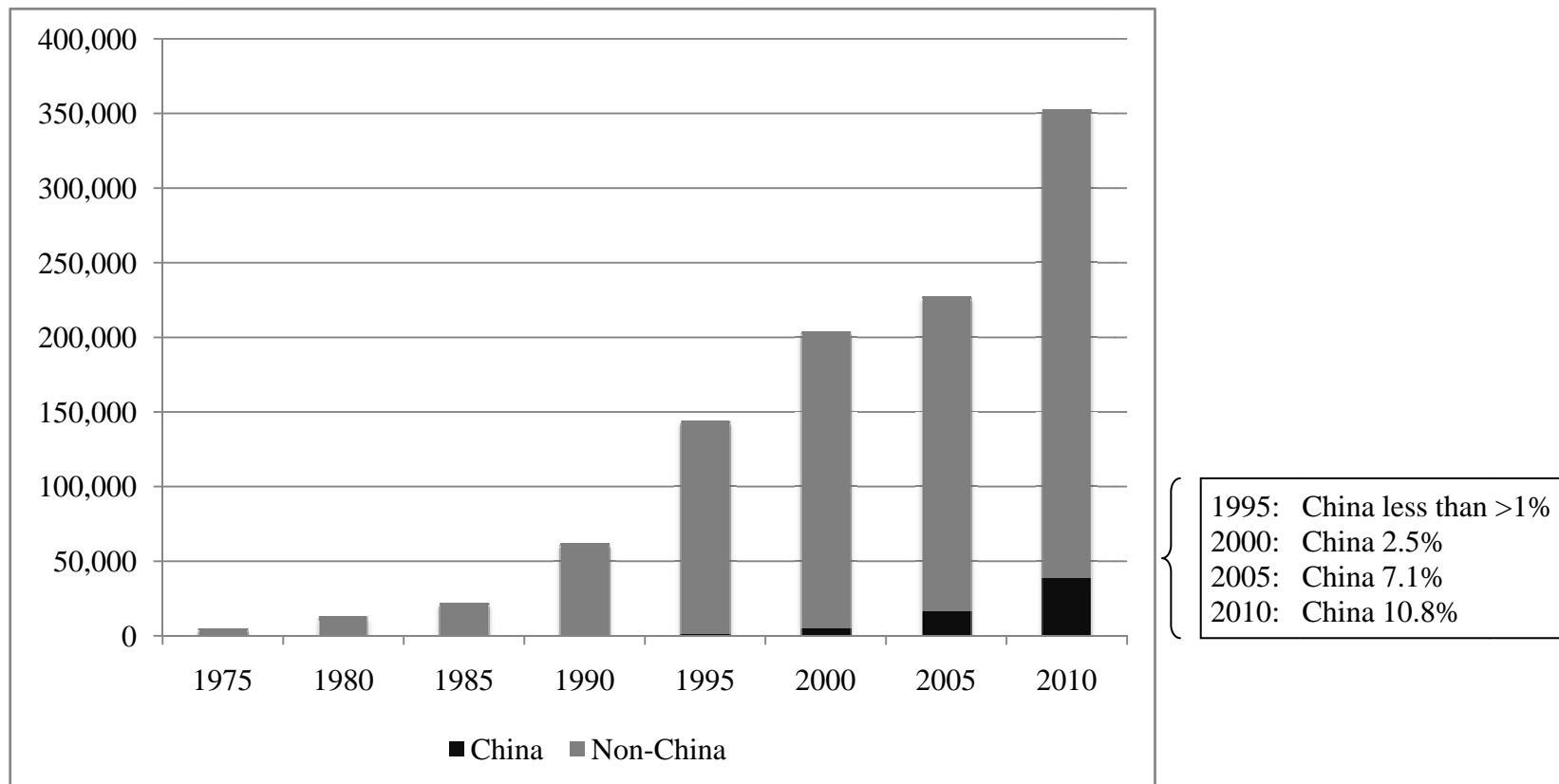
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<sup>736</sup> Alfred Chandler, *The Electronic Century* (Cambridge: Harvard University Press, 2005.) Chris Freeman and Francisco Louca, *As Time Goes By: From the Industrial Revolution to the Information Revolution* (New York: Oxford University Press, 2001.)

<sup>737</sup> National Research Council, *Securing the Future: Regional and National Programs to Support the Semiconductor Industry* (Washington, D.C.: National Academies Press), pages 22-23, citing research by Kenneth Flamm and the U.S. Council of Economic Advisors.

<sup>738</sup> Around 2000, the worldwide semiconductor market was for: computers (~42%), telecommunications (~23%), consumer products (~16%), and other uses such as automotive, military, and industrial (~16%), see *Securing the Future*, page 14. The main semiconductor products are: discrete devices (i.e., transistors, capacitors, and resistors) and integrated circuits (I.C.s.) I.C.s may be: memory chips, microprocessors, application specific I.C.s called A.S.I.C.s (for phones, computers, and other applications), logic chips, microcontrollers, digital signal processors (D.S.P.s), and others.

**Figure 19: Total Semiconductor Industry Production Revenues, US\$ Billions, Global vs. China**



Sources:

- 1) PwC, "China's Impact on the Semiconductor Industry, 2004, 2006, and 2012," data sources include China Semiconductor Industry Association, CCID, and PwC analysis.
- 2) Wang Yangyuan and Wang Yongwen 王阳元 and 王永文, *Wo Guo Jichengdianlu Chanye Fazhan Zhilu: cong Xiaofei Daguo Zouxian Chanye Qiangguo 我国集成电路产业发展之路：从消费大国走向产业强国* (China's Integrated Circuit Industry Development Path: From a Big, Consuming Nation to a Strong, Industrial Nation), Kexue Chubanshe 科学出版社 (Science Press), 2008, page 123, per CSIA.
- 3) Author's analysis

became the world's second largest economy in 1980, and China moved into second place in 2010. The so-called "Tiger" economies of South Korea, Taiwan, Singapore, and Hong Kong and the Southeast Asian nations of Malaysia, Indonesia, Thailand, Vietnam, and the Philippines also experienced economic growth. According to Robert Wade's 1990 study,<sup>739</sup> per capita gross national product rose by more than twenty times for Japan, South Korea, and Taiwan and by more than fifteen times for Hong Kong and Singapore in the 25 years between 1962 and 1986. In the latter half of the 20<sup>th</sup> century, these nations of East and Southeast Asia joined what scholars have called "global production networks"<sup>740</sup> by leveraging, at least at the start, their comparative advantage in low-skill, low-cost labor, undertaking light manufacturing work and exporting products to overseas markets. Asian nations thus joined global supply chains (i.e., global production networks) that were often initiated by global firms in developed countries which sought partners or sought to create offshore facilities in low-wage nations in order to lower their production costs.<sup>741</sup> Notably, leaders in Japan, China, South Korea, Taiwan and elsewhere believed that participating in the rapidly growing global electronics industry, even if initially in low-end manufacturing, was a path to both economic and technological advance. But several of the nations of East Asia moved beyond low value added work in electronics: by 2004, seventy percent of global semiconductor production was

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<sup>739</sup> Robert Wade, *Governing the Market: Economic Theory and the Role of Government in East Asian Industrialization* (Princeton: Princeton University Press, 1990), Chapter Two.

<sup>740</sup> Bruce Cumings, "The Origins and Development of the Northeast Asian Political Economy: Industrial Sectors, Product Cycles, and Political Consequences," *International Organization*, Winter of 1984. Neil Coe, "Global Production Networks," *Journal of Economic Geography*, Volume 8, Number 3, 2008. Dieter Ernst, "Complexity and Internationalization of Innovation," *International Journal of Innovation Management*, Volume 9, Number 1, 2005.

<sup>741</sup> Immanuel Wallerstein, *The Modern World System: Capitalist Agriculture and the Origins of the European World Economy in the Sixteenth Century* (New York: Academic Press, 1974.) Using Wallerstein's world systems framework, one could describes these relationships in terms of core, semi-periphery, and periphery areas playing different roles over time in global trade.

in Asia, and China was the world's largest exporter of electronics and also the world's second largest *importer* of electronics.<sup>742</sup> Of course, in the electronics industry new products rapidly enter the market and replace older products, exemplifying a kind of Schumpeterian “creative destruction” at the product level and thus creating opportunities for new players to enter the market or at least the production chain. In their excellent study of the Korean and Taiwanese semiconductor industries, Dong-Sung Cho and John Mathews argue that the real “East Asian Miracle” was not merely new trade linkages fostered by stable, free-market macroeconomic principals, but rather the real miracle was the high technology upgrading that occurred in a number of East Asian nations as part of the Information Revolution.<sup>743</sup>

China is a particularly significant case of technological and economic advance within the dynamics of the Information Revolution. Upon China's “opening” in 1978, China had a full one fifth of the world's population with very low per capita income. To further complicate matters, China's economy was enmeshed in central planning and state ownership of industries. One important aspect of China's economic opening and evolution from 1978 was its engagement with the global electronics industry and its recent attainment as an important site of the global high-tech semiconductor industry. China's opening and economic growth and its integration with the semiconductor industry are thus at the intersection of East Asia's economic ascent and the Information Revolution in the latter half of the 20<sup>th</sup> century.

The conclusions in this chapter, then, reflect on not only the development of this particular high technology industry in contemporary China. The conclusions also consider economic development more generally in contemporary China and the history of the

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<sup>742</sup> Dieter Ernst, “Innovation Offshoring,” *East-West Center Special Report*, July of 2006.

<sup>743</sup> John Mathews and Dong-sung Cho, *Tiger Technology* (New York: Cambridge University Press, 2000.)



semiconductor industry in China as compared to its history in Japan, South Korean and Taiwan, where the electronics and semiconductor industries have also been important loci of economic and technological upgrading.<sup>744</sup>

### **Government Involvement in the Global Semiconductor Industry**

This study has been concerned with *how* a critical high technology industry in China evolved from central planning and state ownership to market-based trade and global integration, and the Chinese government is an important force in the story. Specifically, the study has narrated and analyzed the difficult period of about ten to fifteen years which linked central planning and state ownership in the mid 1980s with the industry's era of global integration after 2000. Beginning with deep reforms to China's state owned semiconductor industry in the mid to late 1980s, this study then described the changes in the industry in the 1990s as being driven by "enterprise led development" in conjunction with tactics of "state led development." That is, during the 1990s, Chinese officials pursued certain investments and projects in the semiconductor industry, i.e., tactics of state led development.<sup>745</sup> At the same time, state supported semiconductor enterprises, Sino-foreign joint ventures, and foreign enterprises instigated operations in China's still-reforming environment, bringing new

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<sup>744</sup> Hong Kong, Singapore and Southeast Asian nations are also active in the semiconductor industry, but these conclusions focus Japan, South Korea, and Taiwan, as these are the Asian nations with the largest role in the global semiconductor industry.

<sup>745</sup> Alexander Gerschenkron, *Economic Backwardness in Historical Perspective* (Cambridge: Harvard University Press, 1962.) Gerschenkron identified a kind of state led development in the 1950s and 1960s in the less developed countries of Europe, particularly for capital-intensive industries. He challenged the "generalization...[that] the history of advanced or established industrial countries traces out the road of development for the more backward countries." Instead, backward countries "showed considerable differences...with regard to the productive and organizational structures...These differences were to a considerable extent the result of application of institutional instruments for which there was little or no counterpart in an established industrial country." Backward states had to assist their industries in acquiring foreign technology and skills to foster capital intensive, large-scale production. See pages 6-7.

technology to China and, as important, adopting new organizational structures and management practices, resulting in what this study calls enterprise led development. The obstacles encountered and lessons learned by these enterprises then led Chinese officials to adopt new policies for the industry in 2000-2001. In Japan, South Korea, and Taiwan, too, the state played an important role in fostering and shaping the semiconductor industry, although enterprises were the primary vehicles for transferring, adapting, and commercializing semiconductor technologies.

State agencies played important roles in developing the semiconductor industry in China, Japan, Korea, and Taiwan, and we must recognize at the outset that around the world “the semiconductor industry has never been free of the visible hand of government intervention,” as a former U.S. Chair of the Council of Economic Advisers put it.<sup>746</sup> With the exception of a challenge from Japan in the mid 1980s, the U.S. has been the world leader in the semiconductor industry, and we can see both the importance of the industry and the visible role of government in the industry by looking briefly at the history of the industry in the U.S. This overview will disabuse the notion that the industry can be analyzed in largely neoclassical terms or that government support for the industry is particular to East Asia.

Due to semiconductors’ potential for military applications and infrastructure, the U.S. government funded forty to forty five percent of semiconductor R&D in the industry’s first twenty years, the 1950s through the 1970s. During that time, the largest customer segment of the U.S. semiconductor market was government procurement.<sup>747</sup> The reason for government

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<sup>746</sup> Laura Tyson, *Who’s Bashing Whom? Trade Conflict in High Technology Industries* (Washington D.C.: Institute for International Economics, 1992), page 85.

<sup>747</sup> National Research Council, *Securing the Future*, page 13, citing Kenneth Flamm, *Mismanaged Trade* (D.C.: Brookings Institute, 19996), page 30-34. In addition to the semiconductor industry, the U.S. government has

funding for semiconductor R&D was that government funding could support longer-term projects and priorities, while industry funding tends to have shorter time horizons, focusing on innovations that might be quickly commercialized. And, R&D costs in the semiconductor industry, at ten to fifteen percent of revenues, are high even relative to other high technology industries, such as telecommunications and aerospace.<sup>748</sup> Thus, funding for R&D from both government and industry was critical in advancing the industry in the U.S. Indeed, AT&T Bell Labs' invention of the transistor (the key component of integrated circuits) in the late 1940s was sponsored by government funding for defense and telecommunications, and AT&T Bell's eventual licensing of transistor technology was in part spurred by a government-backed antitrust suit.<sup>749</sup>

Notably, when U.S. dominance in the semiconductor industry was challenged by Japan in the early and mid 1980s, the U.S. government made several "market interventions" to support the national industry.<sup>750</sup> In 1982, the National Cooperative Research Act allowed semiconductor companies to register to form R&D joint ventures, allowing collaborative, "pre-competitive" research (without breaching anti-trust laws) to hasten R&D. That same year, the Semiconductor Research Corporation was founded as a university research consortium dedicated to early stage research and training technical talent.<sup>751</sup> Most famously,

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supported certain key industries (and private enterprise in those industries) over the years; examples cited in National Research Council, *Securing the Future* (pages xix-xx) include the machine tool industry, the telegraph, the railroad industry, agriculture, the aircraft industry, and others, see for example David Mowery and Nathan Rosenberg, *Paths of Innovation: Technological Change in 20<sup>th</sup> Century America* (New York: Cambridge University Press, 1998.)

<sup>748</sup> National Research Council, *Securing the Future*, page 202, citing R&D percentages in 2000.

<sup>749</sup> Ibid., page 13, citing Michael Borrus, *Competing for Control: American's Stake in Microelectronics* (Cambridge: Ballinger, 1988.)

<sup>750</sup> Ibid., pages 191-192.

<sup>751</sup> Ibid., page 66.

in 1986 the U.S. and Japan negotiated the Semiconductor Trade Agreement, which gave U.S. companies access to Japan's market and essentially established a price floor for DRAM (memory) semiconductor chips, which the U.S. had accused Japan of "dumping" in the U.S.

Then, the U.S. industry opted to establish a major government-industry consortium called SEMATECH to focus on research and manufacturing process quality, an area where Japan had bested the U.S. Not all U.S. government and industry leaders agreed that this was a good approach, but nonetheless, SEMATECH was established in 1986 with government funding to match funding from member companies. Government funding for SEMATECH was discontinued in 1996-1997 after the U.S. industry had recovered from Japan's onslaught in DRAM, but individual companies continued to fund SEMATECH, and new member companies joined.<sup>752</sup> The government-industry SEMATECH model was imitated in Europe (via the MEDEA consortium and others) and East Asia, as we will see.

Indeed, in the semiconductor industry, infrastructure such as national consortia, government funded labs, and university R&D have been key governmental supports in the U.S., Europe, and a bit later in East Asia due to the size and importance of the electronics and semiconductor industries. In the U.S., for example, electronics remained the largest U.S. manufacturing industry in 2000, accounting for fifteen percent of the U.S. gross domestic product, and the semiconductor industry was the largest value-added segment of the overall electronics industry, employing over 283,000 people in the U.S.<sup>753</sup>

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<sup>752</sup> Since the 1980s, in the U.S. private funding for R&D in the semiconductor has exceeded government funding, but there has been ongoing debate about the short-term focus of industry funding, National Research Council, *Securing the Future*, pages 189-202.

<sup>753</sup> National Research Council, *Securing the Future*, pages 3, 189-202, 40-43, 57-58, 66, 160-161, citing numerous sources.

## **China's Semiconductor Industry**

In terms of how the high technology semiconductor industry advanced in China, from this study we can conclude that at least four broad approaches were highly influential. These approaches included: 1) the establishment of large enterprises as regional anchors for the industry value chain, 2) Chinese officials' recognition and leveraging of the de-verticalization of the global industry, 3) the adoption of new industry "guidance mechanisms" rooted in bottom-up input and competitive grants, and 4) Chinese officials' unique and limited use of state led development tactics. Importantly, in each of these areas, collaboration with foreign firms was prioritized. These approaches led to industry upgrading in the 1990s and thus created a foundation for the era of faster growth after 2000, especially under new policies issued in 2000-2001.

### **0.2.1. Establishing Large Enterprises as Anchors in Regional Bases**

From the late 1980s, Chinese officials sought to establish semiconductor "bases," that is, areas where the nascent industry would spatially concentrate. Initially, semiconductor industry leaders planned for a "North Base" and "South Base," and eventually several key bases of activity were founded. These included the Caohejing and Zhangjiang Hi-Tech Parks in Shanghai, Zhongguancun in Beijing (including the Northern Microelectronics Industry Base, consisting of the "North Microelectronic Technology Research and Development Base" and the "North Microelectronic Production Base"), and Design Bases in eight major Chinese cities. The intention was to foment spatial concentration so that firms in the various bases would have access to common infrastructure and subsidies and would be able to exchange human capital and knowledge. As importantly, the hope was that an entire semiconductor industry value chain of firms of diverse ownership forms (state, private, Sino-foreign joint

ventures, foreign) would emerge in these bases, which were also located in the proximity of major universities and government agencies.

The decision by Chinese officials in the 1990s to sponsor national champions Huajing, Huahong, and SMIC, each of which were major semiconductor manufacturing enterprises, should be seen not as an attempt to create more or better or larger state owned semiconductor enterprises (or in the case of SMIC, a state “invested” enterprise.) In each case, the new enterprises did seek more advanced technology, but the long term goal of Huajing, Huahong, and SMIC was that each of these new enterprises would serve as a beacon to other firms in their geographic region, both foreign and domestic, demonstrating that a relatively advanced semiconductor enterprise could function in Mainland China’s admittedly difficult environment. The existence of these enterprises, it was hoped, would attract a full industry value chain to their areas. Also, Chinese officials’ formation of the five key semiconductor enterprises in the 1990s represented a desire to consolidate the existing industry and to quickly form just a handful of key enterprises as Sino-foreign joint ventures. These enterprises, too, were located in Wuxi, Shanghai, and Beijing, contributing to the geographic concentration of the industry.

The advent of Huajing, Huahong, SMIC, and the key enterprises demonstrates Chinese officials’ recognition of the important role that large enterprises have played in industries around the world historically,<sup>754</sup> while officials also saw these new large enterprises (especially Huajing, Huahong, and SMIC) as seedlings for the emergence of small and medium sized firms, operating synergistically in concentrated spaces. Like the key

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<sup>754</sup> Chinese semiconductor industry leaders including Huahong leader Hu Qili and SMIC founder Wang Yangyuan cite the works of Alfred Chandler as well as the role of Japan’s zaibatsu-keiretsu and Korea’s chaebols in economic development when describing China’s plans to establish several large enterprises.

enterprises, Huajing, Huahong, and SMIC were founded with the intention of proactively establishing foreign partnerships for technology, management, and markets, as well as partial financing and ownership.<sup>755</sup> That is, Huajing, Huahong, and SMIC were not merely passive recipients of technology transfer from foreign firms when such firms sought partners in China. Rather, Huajing and Huahong identified existing technology that they wanted and they proactively sought global partnerships to acquire the desired technology, management, etc., for themselves and their geographic base. Here, the leading global semiconductor firms were very helpful: AT&T, NEC, Infineon, Chartered, IBM, and others all entered into technology transfer arrangements with China's key and national champion semiconductor enterprises. Finally, the different ownership forms of China's three national champions (Huajing was state owned, Huahong-NEC was a Sino-foreign joint venture, and SMIC was wholly foreign owned) demonstrate that officials did not create or support these enterprises in an attempt to create new state owned enterprises. With the exception of Huajing's early years, these enterprises differed from China's previous state owned semiconductor enterprises in both ownership and organization.

### **0.2.2. Leveraging De-Verticalization**

Huajing and Huahong were both initially organized as I.D.M.s, and industry sources often generally describe the main enterprises in China in the 1990s as "I.D.M.s." However, Chinese leaders were well aware of sector specific opportunities in the industry, i.e., design, fabrication, and (packaging-assembly-test) P.A.T.; they were not unduly wedded to the then-current I.D.M. model. (In the 1990s, Taiwan's UMC and TSMC were operating under the

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<sup>755</sup> Initially, Huajing mainly sought foreign help with technology, but Huahong and later Huajing also sought financing as well as management and marketing help from foreign partners.

new de-verticalized foundry model, but otherwise, the I.D.M. was still the dominant global business model in the industry.) Indeed, we can see important moves toward de-verticalization in China in the 1990s, which set the stage for integrating with the increasingly de-verticalized global industry in the 2000s. China's key semiconductor enterprises Shougang-NEC and ASMC were manufacturing for export in the 1990s (essentially acting as foundries for their global partners), and Huajing explicitly adopted the foundry model in 1997 in partnership with CSMC. SMIC, of course, was a foundry from its inception in 2000, and Huahong converted to the foundry model (while also maintaining its other lines of business) in 2002. Officials' support for the fabrication (foundry) sector in China aligned with the already de-verticalized electronics industry, which had been increasingly outsourcing manufacturing and assembly work to E.M.S. firms and O.D.M.s in China throughout the 1990s. By fabricating semiconductors in China, semiconductors were close to the customers who would install the chips into various electronic products.

The rise of the fabrication sector in China in turn supported the rise of the design sector. The availability of local foundries meant that design firms did not need to have the huge capital needed for foundry operations. In the 1990s, different Chinese government organizations prioritized and funded R&D and design efforts, but in that decade, the design sector in China was in its infancy. Around 2000, the design sector was able to rapidly take off due to the availability of foundries coupled with new policies specific to the design sector that offered venture capital and other benefits. On the other end of the industry chain, Chinese officials did not target the relatively low-end P.A.T. semiconductor sector, but nonetheless, officials allowed a number of major foreign firms to establish P.A.T. operations in China in



the 1990s, as global firms sought low cost locations and wanted to be near China's growing semiconductor market.

From the sources available in this study, Chinese semiconductor industry leaders had a clear view on fostering individual sectors in the industry in the 1990s, including materials and equipment. This is somewhat ironic in light of the fact that a major concern in the pre-reform era was the separation of research from production in China's state controlled industries and the resultant lack of production-ready designs. So, there were two developments from the late 1980s. On the one hand, within large organizations like Huajing and Huahong, design and production groups were better aligned and coordinated, but on the other hand, there was an industry trend toward de-verticalization that saw the emergence of design (only) firms and stand-alone foundries. At Huajing and Huahong, production groups were better aligned with design groups, but more broadly, both of these large enterprises restructured to create different subsidiaries by sector, e.g., Huajing (now called CRM) has a design subsidiary called Semico, a P.A.T. subsidiary called Anst, and the CSMC foundry.

### **0.2.3. Adopting New Industry Guidance Mechanisms**

After the "divestiture" of China's state owned semiconductor industry in the mid to late 1980s (described in Chapter Two), Chinese officials created new mechanisms to support and guide this nationally strategic industry. The new mechanisms had three interesting aspects: 1) they were not managed under one central organization, 2) input on priorities and which organizations would pursue priorities was in part bottom-up and 3) funding was sought -- again, bottom up -- by enterprises and was allocated on the basis of competitive grants.

Under these new guidance and funding mechanisms,<sup>756</sup> expert committees comprised of specialists from around the country would designate priority projects for the semiconductor industry. Then, staff from semiconductor enterprises or research organizations could apply on a competitive basis for grants, thus taking the initiative themselves to pursue funding and to earn the funding through competition with other organizations. These guidance mechanisms were funded by priorities established in China's much broader five year plans.

#### **0.2.4. Using Limited State Led Development Tactics**

In the 1990s, the Chinese government pursued a number of tactics that fall under the rubric of state led development in its efforts to foster the semiconductor industry. The designation of semiconductor design bases, the funding of Projects 908 and 909 and national champions Huajing, Huahong-NEC, and SMIC, and the guidance and funding mechanism cited above all suggest state led development. However, China's semiconductor national champions had some surprising characteristics that do not align with commonly held notions of state led development and national champion enterprises (see discussion in Chapter Four.) These enterprises were not established to dominate the industry, to preclude foreign competitors, to foment oligopolistic competition within China, nor to attain self-sufficiency in semiconductor production. As mentioned above, the primary goal was to attract more semiconductor-related firms, both foreign and domestic, to locate in China. Each of the national champions was technologically the most advanced in China in their time, yet these enterprises were not expected to achieve global technological leadership, at least not in the

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<sup>756</sup> These included: the National Engineering Research Centers, the Electronic Industry Development Fund, the 863 I.C. Specialist Project, the I.C.C.A.D. and I.C.C.A.T. specialist committees, among others.

short or medium term. Finally, for national champions, they had a surprising degree of foreign ownership and management.

State led development in Japan, Korea, and Taiwan has been associated with industry wide policies, often trade related, that are intended to protect infant industries. In the semiconductor industry in China, trade policies in the 1990s may seem to have stifled foreign competition. Indeed, there were high official tariffs and taxes on imported semiconductors, restrictions on foreign ownership and distribution, and local content requirements and export requirements for foreign firms. However, it does not appear that the Chinese government enacted such policies specifically to hinder foreign semiconductors enterprises. The exception here is that the Chinese government did place a higher import V.A.T. on the low-end discrete devices that Chinese firms were adept at producing. But generally, the obstacles that foreign firms faced were not established uniquely for the semiconductor industry, as part of a state led development effort to foster local firms at the expense of foreign firms. For example, China's official seventeen percent V.A.T. on imported semiconductors was common across all electronic and computer related products in the 1990s.<sup>757</sup> Indeed, the research suggests that the foreign firms that established operations in China in the 1990s and early 2000s were often able to negotiate to have tariffs, taxes, and other restrictions and requirements reduced, as Chinese officials on the whole wanted foreign firms to set up partnerships and facilities in China.<sup>758</sup> Policy-related obstacles were problematic for foreign

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<sup>757</sup> Jeff Zhang and Yan Wang, *The Emerging Market of China's Computer Industry* (Connecticut: Quorum Books, 1995), page 143.

<sup>758</sup> China's official tariff rates prior to the W.T.O. were misleading (they were often lowered), and local content requirements were easily evaded, see Nicholas Lardy and L. Branstetter, "China's Embrace of Globalization," in *China's Great Economic Transformation* (New York: Cambridge University Press, 2008), page 635 discussed by Loren Brandt, "The Fight for the Middle: Upgrading, Competition, and Industrial Development in China, *World Development*, Volume 38, Number 11, 2010, page 1556.

firms not so much because they were actually enforced but because they created uncertainty and a lack of transparency in China's operating environment. These policies forced foreign firms to negotiate tariffs, export requirements, and the like, often with a number of Chinese agencies. Such policies, however, were not indicative of state led development; they were indicative of China's still-reforming policies and institutions.

So, for ten to fifteen years (late 1980s to 2000), new semiconductor enterprises – both foreign and domestic – established operations in China, meeting many policy-related obstacles along the way. Finally in 2000, Chinese officials announced new semiconductor industry-wide policies, and initially, these policies included a W.T.O.-non-compliant preferential V.A.T. that favored semiconductor producers with facilities in China. This particular policy was discontinued in 2005. Otherwise, the new policies in 2000 benefitted both domestic and foreign enterprises in China, and while these policies certainly aimed to develop the industry, they were not domestic favoring in the sense that state led development often implies.

### **Progress, but Ongoing Problems**

This study suggests that each of the four broad approaches above were influential in the industry's evolution in the 1990s, but nonetheless the industry in China was hindered by lasting influences of the era of central planning and state ownership. Despite deep reforms to the industry in the 1980s (addressed in Chapter Two), the industry in the 1990s was still long on bureaucracy and short on capital. This study revealed importance instances of government agencies providing no funding, slow funding, or low funding or disputing which government body was responsible for funding. For example, the ninth and tenth five year plans both committed substantial capital to microelectronics, but in the sources available in this study,

there was no accounting for how the named amounts were ultimately distributed or used, although other amounts for more specific projects were documented. Certainly in the case of Project 908 all sources indicate that “bureaucratic delays” caused central funding to simply not be delivered to Huajing until well after 1995, the year when the project was supposed to be complete. Also, there were central-local and regional disputes over funding. In the case of Shanghai’s Caohejing Hi-Tech Park in the 1980s, Shanghai’s municipal government and the central government clashed over which government bodies would fund the base.<sup>759</sup> On yet another level, semiconductor leaders complained that the industry’s new guidance mechanisms for project funding awarded grants for research too slowly, relative to the fast pace of technological change in the semiconductor industry.<sup>760</sup> Semiconductor industry personnel also voiced concerns that the grant awards might not always be based on competitive merit but rather on relationships.<sup>761</sup> These examples seem not to be outliers; the tenor of both written sources and interviews with industry personnel suggest that the bureaucratic channels for funding were contentious.<sup>762</sup>

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<sup>759</sup> Denis Simon, *Technological Innovation in China* (Cambridge: Ballinger, 1988), pages 136-140.

<sup>760</sup> Interview with Yu Zhongyu, President of China Semiconductor Industry Association, July 2, 2009, CSIA headquarters in Beijing. Interview with Ye Tianchun, July 3, 2009, at the Chinese Academy of Science, Institute of Microelectronics in Beijing. Dr. Ye is the Director of the Microelectronics Institute and a top advisor on national semiconductor industry policies.

<sup>761</sup> Interview with Prof. Yang, June 8, 2009, in Shanghai. Prof. Yang (retired) was formerly with a Fudan microelectronics-related institute. Fudan University alumni group interview, May 30, 2009, in Shanghai. Interviewees all studied microelectronics at Fudan Daxue from 1963, and all returned to the electronics industry in the late 1970s. Interviewees included: Xu Guochang of the Shanghai IC Industry Association, Ma Peijun of Credy Industries, Li Weide (retired), and Xu Tian who now runs an industry consulting firm.

<sup>762</sup> In the semiconductor industry, the practice of individuals holding multiple appointments continued in the 1980s, 1990s, and 2000s. That is, one person could be an official in the Ministry of Information Industry, an executive in a semiconductor enterprise, and a professor at the Chinese Academy of Science. On the positive side, such dual (and triple and quadruple) appointments ensured that government officials were aware of the challenges faced by industry executives, since the executives themselves were usually officials. However, with so many dual appointments, as a foreigner, I am not able to detect the constructive criticism between the spheres of business, government, and academia in China, which is visible in the U.S.

## Semiconductor Industry Results

Despite problems with bureaucracy and funding, there were important accomplishments in the 1990s. China's national champion and key enterprises served as training grounds for China's talent pool, with many personnel in the 2000s joining private or foreign firms or even starting new firms. The foreign partnerships in the 1990s as well as the arrival of other foreign firms in China brought new management practices, technical and marketing expertise, capital, and access to foreign markets. This exposure surely affected the shifting ownership forms of the three largest "Chinese" semiconductor enterprises established in the 1990s: the first was a state owned enterprise (Huajing), then a Sino-foreign joint venture (Huahong-NEC), and finally a wholly foreign owned enterprise (SMIC.) Yasheng Huang has argued that foreign investment in China too often did not bring leading edge technology, but in the emerging semiconductor industry in the 1990s, even exposure to foreign management and organization was valuable.<sup>763</sup> Finally, government funded R&D and design projects as well as sectoral restructuring at Huajing were early tangible steps toward fostering the individual sectors of the semiconductor industry in the 1990s.

These results stand in contrast to most descriptions of the semiconductor industry in China in the 1990s. In industry and even scholarly sources, the industry is usually described only briefly, with allusions to certain problematic characteristics. Observers say that enterprises in China were inefficient and state owned in the 1990s and that Chinese officials attempted unsuccessful state led projects (meaning Project 908 and sometimes 909 is included

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<sup>763</sup> Yasheng Huang, *Selling China: Foreign Investment during the Reform Era* (New York: Cambridge, 2003.) Notably, in the semiconductor industry, Chinese enterprises seemed to view foreign firms first and foremost as potential collaborators rather than competitors.

as problematic.) The enterprises in China are also faulted for operating on the “outdated” I.D.M. model. This study has shown, however, that the so-called state owned semiconductor enterprises in the 1990s in China were not of the same ilk as state owned enterprises from the pre-1978 era. In fact, most were Sino-foreign joint ventures, though the Chinese side was indeed state owned. Also, the enterprises of Project 908 (Huajing) and 909 (Huahong-NEC) did advance the technological level in China and were the most advanced enterprises in China in their time. These enterprises made many organizational and process improvements, and it was through these enterprises and others that Chinese officials learned what new policies were needed for the industry. Further, to describe the enterprises in China as I.D.M.s is a stretch as their independent design capabilities were weak, but anyway, the I.D.M. business model was not outdated in the 1990s. To label it as such is anachronistic,<sup>764</sup> and the label implies that the industry in China was not attuned to the growing global trend of de-verticalization. This research has shown, however, that activities in the semiconductor industry in China in the 1990s demonstrated increasing alignment with the industry’s de-verticalization. China lacked leading edge technology and innovation in the 1990s because of its history of isolation before 1978 and because of the difficult and slow restructuring of the centrally planned, state owned industry from the mid 1980s. China did not lack leading edge technology in the 1990s because of the character (allegedly “state owned I.D.M.s”) of its new enterprises. Further, to explain China’s shift to more rapid growth after 2000, observers attribute the shift to: 1) Western nations’ loosening restrictions on dual-use technology to China, 2) Taiwan allowing semiconductor investment in China from 2002, and 3) China easing restrictions on foreign

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<sup>764</sup> In 2003, for example, a majority of the semiconductor market was still being met by longstanding global I.D.M.s such as Intel, Renesas, Samsung, TI, and Toshiba, see PwC, “China’s Impact,” 2004, page 19.

investment under the W.T.O. These descriptions of the early 2000s are not entirely inaccurate, but they do not capture the enterprise-level organizational changes and policy learning that did occur in China in the 1990s, which are important if we want to understand changes in China's contemporary economy.

### **China's Contemporary Economy and Industry Development**

What then can we conclude more generally about China's contemporary economic development from this study of one high technology industry? The most notable outcome of this study in terms of China's broader economy is the effects of this particular industry on China's institutional, policy, and operating environment. Ultimately, developments in the semiconductor affected norms of business organization and behavior, industry-wide organizations, national and local trade policies, and even laws.

From the late 1980s and in the 1990s, Chinese semiconductor leaders sought to acquire foreign technology and instigate operations, but this rush to use new technology was undertaken in a context where organizations, policies, and institutions were weak. "Organizational capabilities" in China were undeveloped, supportive industry organizations were in the formative stages, semiconductor-related university training was at low capacity, trade policies were inconsistent and cumbersome, and I.P. protection was weak. Scholars such as Douglas North, Peter Evans, and Oliver Williamson have demonstrated the importance of strong institutions for economic development,<sup>765</sup> and economists widely agree that technology is a primary driver of economic advance. To these consensuses, Richard Nelson has added that between physical technologies and formal institutions lies a realm of

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<sup>765</sup> Douglas North, *Institutions, Institutional Change, and Economic Performance* (Cambridge: Cambridge University Press, 1990.) Peter Evans, *Embedded Autonomy* (Princeton: Princeton University Press, 1995.) Oliver Williamson, *The Economic Institutions of Capitalism* (New York: Free Press, 1985.)



“social technologies,” that is, ways of doing things that do not rise to the level of formal institutions but that nevertheless enable physical technologies to be effectively utilized or advanced.<sup>766</sup> In the case of the semiconductor industry in China, Chinese enterprises’ acquisition of more advanced, foreign technology was an important step, but the establishment and operation of Sino-foreign ventures in the 1990s led to necessary changes in social technologies, organizations, policies, and even formal institutions in China. Thus the gradual evolution of one industry arguably prompted more general changes in China’s operating environment.

Specifically, the semiconductor industry’s development prompted the following changes. At the level of formal *institutions*, China’s State Council enacted a new law to protect semiconductor intellectual property in 2001 and China’s I.P. regime was expanded, including the establishment of I.P. “exchanges.” In terms of *policies*, the Ministry of Information Industries – in cooperation with foreign advisors – adopted significant, industry-wide new trade and investment policies for the semiconductor and software industries in 2000. Throughout the 1990s and early 2000s, we have seen that China’s semiconductor industry leaders were building new industry support *organizations* such as the China I.C. Design Center (CIDC) in Beijing from 1986, the various project funding mechanism from the late 1980s, the China Semiconductor Industry Association from 1990, the “7+1” Design Bases from 2000, and the Shanghai I.C. R&D Center Consortium (ICRD) in 2002. Also, at the intersection of *policy* and *organization*, new policies in 2000 encouraged semiconductor firms to seek domestic venture capital and foreign capital, and in furtherance of this policy, various

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<sup>766</sup> Richard Nelson, “What Makes an Economy Productive and Progressive? What are the Needed Institutions?,” Columbia University, October 2007.

government agencies in China established new organizations to provide venture capital.

While many of these organizations were specific to the semiconductor industry, it is reasonable to conclude that the process of establishing and operating such organizations likely resulted in learning that transcended the boundaries of this particular industry. That is, these semiconductor organizations may have served as examples, whether positive or negative, of how to operate support organizations.

Finally, at the level of norms, this study has shown that Chinese semiconductor industry leaders gradually altered the tactics they utilized over the years to foster the industry. At a high level, officials gradually moved from using state owned *enterprises* as development sites, to using state supported *projects* to foster development, to using state drafted *policies* to further development. Throughout this transition, Chinese leaders used what Richard Nelson might call “routinized social technologies” that have been common in China, such as using state led technology transfer agreements, state organized industry delegations for overseas learning trips, and government officials in dual roles as enterprise leaders. Foreign observers might question the top-down methods utilized in China, but Chinese leaders may have seen these methods as their only options. Chinese leaders, acting in China’s context, likely did not have effective “social technologies” to do things differently, at least in the late 1980s and into the 1990s. However, over the years, China’s semiconductor industry leaders gradually changed their methods. For example, by the late 1990s, we see Chinese officials asking foreigners to lead projects and allowing an industry association to set industry guidelines. In the terminology of evolutionary economics, these changes to “routine social technologies” constitute innovation, though the innovation is organizational or process-based rather than

technological.<sup>767</sup> Here again, it seems reasonable to conclude that shifting norms in the critical semiconductor industry might have influenced business practices in other industries in China.

The preceding discussion of the semiconductor industry's influence on laws, policies, organizations, and norms suggests that the development of other industries in China might also affect China's capital "I" and small "i" institutions. This is not, of course, to deny the importance of Chinese officials' direct efforts to improve China's legal system, financial system, and policies. Further research might attempt to unpack the ways in which China's contemporary economic context has been influenced by the evolution of individual industries relative to direct efforts to reform China's institutions.

### **China and Comparisons with Japan, Korea, and Taiwan**

By around 1990, the portion of global trade attributable to Asia had risen such that Asia was by then a third major global axis of trade, in addition to North America and Europe.<sup>768</sup> At the same time, the global electronics industry was rapidly growing, and East and Southeast Asia were responsible for an ever-larger share of the global electronics trade each year. One way to capture the growth in the global electronics trade is to look at the trade in "manufactured intermediate goods" (instead of "finished goods.") Intermediate goods indicate the value of all parts, components, and assemblies that move across borders. By looking at intermediate goods, we can see the electronics trade value for different nations,

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<sup>767</sup> Richard Nelson, *Technology, Institutions, and Economic Growth*, (Cambridge: Harvard University Press, 2005), pages 154-155.

<sup>768</sup> Denis Simon and Michael Kau, editors, *Taiwan: Beyond the Economic Miracle* (New York: M.E.Sharp, 1992), page 123.

regardless of which nation gets credited with selling the finished good.<sup>769</sup> In 1988, electronics and automotive parts were by far the two largest categories of intermediate goods in global trade, each accounting for about eight percent of such trade. By 2006, however, electronics was the stand-alone largest category, accounting for almost fourteen percent. (The second largest category, automotive, had just above nine percent in 2006.) Given this increase in the relative importance of electronics in global trade between 1988 and 2006, we can now consider how much of this trade was attributable to East and Southeast Asia. Again using intermediate goods, by 2006, Asia accounted for fifty-five percent of global electronics imports and sixty-four percent of global electronics exports. Of these figures, China (including Hong Kong) accounted for one-third to one-half of Asia's electronics imports and exports in 2006.<sup>770</sup> From these measures, we can see the increasing dominance of electronics in global trade in the late 20<sup>th</sup> and early 21<sup>st</sup> century, and we can see Asia's importance as a site of global electronics trade.

The semiconductor industry provides a window on how the Information Revolution influenced East Asia's transformation from a low-cost manufacturer to a high technology provider and the third axis of global trade. When Japan, Korea, Taiwan, and other Asian nations became more involved in global trade in the latter half of the 20<sup>th</sup> century, they initially leveraged their low-wage, low-cost labor. However, from the late 1970s to the early 1990s, Japan, Korea, and Taiwan each made significant inroads in the high technology

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<sup>769</sup> Timothy Sturgeon and Momoko Kawakami, "Global Value Chains in the Electronics Industry," *World Bank, Policy Research Working Paper*, September 2010.

<sup>770</sup> *Ibid.*, pages 4 and 6.

semiconductor industry.<sup>771</sup> Initially, these nations seemed to not be serious players in the industry. After all, their products were essentially copies, and they seemingly lacked human resource talent, R&D capability, brands, and marketing expertise. Further, they were relying on heavy capital investments by companies and their governments, which were likely unsustainable.<sup>772</sup> In hindsight, we know that Japan proved to be a major challenger to U.S. semiconductor dominance in the mid 1980s, and this onslaught was rapidly followed by Korea's entry (late 1980s), Taiwan's entry (early to mid 1990s), and then China's entry (around 2000) as real participants in the global semiconductor industry.

In their detailed studies of the semiconductor industries of Korea and Taiwan, John Mathews and Dong-sung Cho have described technological upgrading as an “overriding goal of public policy” in Korea and Taiwan in the latter half of the 20<sup>th</sup> century, and this was true in Japan as well.<sup>773</sup> Though each nation's political economy was unique, they had a shared history given Japan's colonial occupation of Korea and Taiwan until the end of World War II. In the decades after World War II, each had an authoritarian state that undertook industrial planning which eventually included policies and investments in support of high technology industries. In this same period, global electronics firms increasingly sought lower-wage locations, including Asia, for certain manufacturing and assembly work. By the 1970s, Japan, Korea, and Taiwan all had enterprises that could work with global firms in contracting arrangements or joint ventures. (China began making such arrangements in the 1980s and

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<sup>771</sup> Hong Kong, Singapore, Malaysia, Indonesia, Thailand, and the Philippines also engaged in low-wage electronics work in the 1970s, including P.A.T. work for the global semiconductor industry. For simplicity, this discussion takes Hong Kong as part of China. Among these other nations, only Singapore developed notable strength in the semiconductor industry (for example, Chartered Semiconductor), but still Singapore was a small participant relative to Japan, Korea, and Taiwan.

<sup>772</sup> Cho and Mathews, *Tiger Technology*, page 72.

<sup>773</sup> *Ibid.*, page 20.

1990s.) For the semiconductor industry, there were essentially three primary drivers of the industry's development in each of Japan, Korea, Taiwan, and China. These were: 1) large domestic enterprises, 2) global firms and global trade, and 3) government support. Much of the following discussion centers on these three drivers in considering the similarities and differences in the history of the semiconductor industry in Japan, Korea, Taiwan, and China.

#### **0.4.1. Large Enterprises**

In each of Japan, Korea, and Taiwan, large enterprises were able to acquire, adapt, and commercialize more advanced foreign technology, usually through relationships with global firms. Because semiconductor manufacturing is a capital and scale intensive industry, it was by necessity large enterprises that entered the industry. The semiconductor industry had developed in the U.S. from the 1950s, and by the 1970s, the U.S. and Europe already had leading semiconductor firms and products. Thus, Japan, Korea, Taiwan, and China all entered the industry in “catch-up” mode, and their large would-be semiconductor enterprises initially made use of existing foreign technology. Japan secured technology from the late 1950s from IBM, AT&T, and GE.<sup>774</sup> Korea, Taiwan, and China all proactively sought joint ventures and other arrangements with foreign partners to enter the semiconductor industry. Also, in Korea and Taiwan, the arrival of global P.A.T. facilities and P.A.T. joint ventures in the 1960s and 1970s were early sources of technology transfer.<sup>775</sup>

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<sup>774</sup> Alfred Chandler, *Inventing the Electronic Century* (Cambridge: Harvard University Press, 2005), page 189.

<sup>775</sup> By the 1980s, Korea and Taiwan were no longer considered low-cost enough for global P.A.T. activity, and thus more global P.A.T. activity was established in Southeast Asian nations. In China, global firms began to establish P.A.T. sites in China in the 1990s to be near China's electronics manufacturing and market, but perhaps because China was not prioritizing P.A.T. and because China also had significant other low-value electronics activity in the 1990s, it seems that the arrival of global P.A.T. activity in China in the 1990s did not serve as a major source of technology transfer.

A few high-level observations about the nature of the large semiconductor enterprises in these nations merit mention. First, the origins and character of these enterprises differed in each nation, and this was due in part to the state of the Information Revolution and global electronics trade, as well as each nation's domestic context, at the time when each nation entered the semiconductor industry. Briefly, in the U.S., recall that the early large semiconductor enterprises took the form of integrated device manufacturers (I.D.M.s.) In Japan, however, the major semiconductor enterprises that emerged in the 1970s were Japan's existing large computer-electronics enterprises. They were Japan's *keiretsu* or other existing large electronics-related enterprises. With existing experience in electronics, these were the enterprises that were also able to develop semiconductor technology. In Korea, the initial large semiconductor enterprises in the 1980s were Korea's existing *chaebol*, which were diversified enterprises groups that were not exclusive to electronics but which eventually included semiconductor units. In the 1980s, Japanese and Korean semiconductor enterprises competed directly with U.S. and European semiconductor enterprises, as global trade and competition in electronics increased in that decade.<sup>776</sup>

Taiwan entered the electronics industry with small and medium sized electronics and semiconductor-related firms, and Taiwan's first large semiconductor enterprises (UMC and TSMC) had to be newly formed with government assistance. These enterprises were (almost) exclusive to semiconductor manufacturing, originating the "foundry model." Focusing on manufacturing in this way was possible because, by the 1990s, electronic exchange and standardization in the semiconductor industry had advanced to the point where the industry could accommodate the de-verticalization (essentially outsourcing) of manufacturing. In

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<sup>776</sup> Ibid., pages 214-215.

China, the initial large enterprises in the 1990s were Sino-foreign joint ventures that have been called I.D.M.s, however they were not truly developing and designing their own products in house but rather they were producing, often for export, existing products of their foreign partners. In the late 1990s and early 2000s, the largest semiconductor enterprises in China (Huahong-NEC, SMIC, Huajing) turned explicitly to the foundry model, following Taiwan's lead, as de-verticalization in the industry was, by then, in full swing.<sup>777</sup> Thus, while large enterprises were important in each of the major East Asia semiconductor producing nations, their origins differed from the I.D.M. model (of the U.S., Europe, and ostensibly China), to computer-electronics enterprises (Japan), to diversified conglomerates (Korea), to foundries (Taiwan and China.)

A further difference between these nations' large semiconductor enterprises was their fundamental contribution to innovation in the global industry. In the U.S. and Europe, leading semiconductor enterprises focused on *product* innovation. When Japanese enterprises entered the industry, their contribution was on *process* innovation and improvement, leading to better quality, high volume manufacturing through the development of new manufacturing equipment and processes.<sup>778</sup> Then, Korea attempted to catch up with Japan knowing that it could purchase improved manufacturing equipment on the market (thanks to Japan's efforts), so Korea's innovation was then a mix of incremental product and process improvements. Finally, with the West and Japan and Korea having paved the way before them and with Japan

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<sup>777</sup> Global firms had been outsourcing P.A.T. work to Taiwan, Korea, Hong Kong, and Southeast Asia since the 1960s and 1970s, but because the P.A.T. is considered relatively low-end, nations were not really credited with having "entered the industry" until they had manufacturing (fabrication) capability.

<sup>778</sup> With Japan's success in manufacturing processes and quality in the 1980s, U.S. companies sought to emulate Japanese methods. Engineers and managers sought "process control," "process improvement," "continuous improvement," "statistical process control," "quality control," "quality circles," etc.



and Korea serving as two successful examples of “catching up,” Taiwan and China faced less uncertainty about investing in the semiconductor industry. With the industry’s growth, Taiwan and China could pursue a *structural* innovation in the industry (the foundry model), and they also had the option of serving lower end product markets rather than initially attempting to compete head to head on state of the art products. Thus, as the Information Revolution advanced in the final decades of the 20<sup>th</sup> century, the nature of innovation in participating nations evolved.<sup>779</sup>

#### **0.4.2. Government Support**

Japan, Korea, and Taiwan each utilized national, government funded, collaborative R&D programs to assist domestic enterprises with learning and adapting highly sophisticated semiconductor technologies. These collaborative programs served to diffuse knowledge across domestic enterprises. Somewhat different than in the West, however, these nations’ collaborative R&D was not focused on leading edge products or processes. Instead, “imitation” of existing technology was seen as a “viable strategy,” to use Mathews and Cho’s description of these national programs which, they argue, were critical sources of “knowledge diffusion across firms” in Japan, Korea, and Taiwan.<sup>780</sup> The R&D was focused more toward potential commercial applications. To cite just the most significant programs,<sup>781</sup> Japan undertook a V.L.S.I. project from 1975-1979, in which firms such as NEC, Toshiba, and Hitachi participated in upgrading the production technology for D.R.A.M. (memory) chips.

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<sup>779</sup> Cho and Mathews, *Tiger Technology*, Chapters Three and Four.

<sup>780</sup> Cho and Mathews, *Tiger Technology*, page 10.

<sup>781</sup> For more on the V.L.S.I. programs of Japan, Korea, and Taiwan, see: Cho and Mathews, *Tiger Technology*, Chapters Three and Four; Chandler, *Inventing the Electronic Century*; and National Research Council, *Securing the Future*.

This resulted in their ability to successfully compete against Western firms by the early 1980s. Recall that V.L.S.I. is “very large scale integration,” which was state of the art in the late 1970s. Korea first achieved V.L.S.I. production in the telecomm sector in 1976, and in the early 1980s, an industrial reorganization resulted in Korea’s telecomm semiconductor units being transferred to the *chaebols*. Korea’s 1981-1986 development plan included investments in V.L.S.I., and the government pressured the *chaebols* to further invest in semiconductor industry. In the mid 1980s, Samsung in conjunction with the government instigated a national, collaborative V.L.S.I. program under Korea’s Electronic Technology Research Institute. The government provided relatively little of the funding, but the program resulted in the *chaebols* becoming significantly more competitive in D.R.A.M. Finally, in Taiwan, the Industrial Technology Research Institute (ITRI) and its subsidiary the Electronics Research Service Organization (ERSO) served to diffuse semiconductor technology to firms. In the mid 1980s, ERSO undertook a V.L.S.I. project which included the founding of TSMC, the originator of the global “foundry model.”<sup>782</sup> Recall that around this same time, the U.S. formed the consortium SEMATECH, so these collaborative projects were not unique to Asia.

Interestingly, in assessing the influence of these major collaborative projects, scholars note a decreasing degree of government influence over industry from Japan to Korea to Taiwan. Mathews and Cho conclude that Korea’s collaborative V.L.S.I. project “played only a minor role in the companies’ efforts; in the end, they had to develop their 1M DRAMs themselves.”<sup>783</sup> Hatano of the U.S. semiconductor industry described the situation in Korea in 1985 writing “one does not sense the same powerful influence that is exerted by the elite

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<sup>782</sup> Ibid.

<sup>783</sup> Cho and Mathews, *Tiger Technology*, page 129.

bureaucracy in Japan....[Korea's] strategy for assailing the world export market appears to emanate from the private sector.”<sup>784</sup> Then, assessing the situation in Taiwan relative to Korea in 1992, Denis Simon argued that there was “more distance” between government and business in Taiwan (relative to Korea), and that Taiwan’s many disaggregated electronics and semiconductor-related firms were less apt to engage with government initiatives.<sup>785</sup> (However, this caused Taiwan’s government to take a more direct and somewhat independent approach to managing technology transfer.) Finally, China had an R&D sharing initiative via Project 909 that began in 2002, but it did not have an early impact on the industry’s competitiveness.<sup>786</sup> The level of influence of these particular large-scale collaborative projects was indicative of the different political economies of the nations, but these mega projects were not the only government interventions in the industry.

The governments of Japan, Korea, Taiwan, and China all considered the semiconductor industry a priority, and they took care to foster, if not protect, their domestic industries. The methods of supporting the industry were strikingly similar across the nations, and clearly as one nation followed another into the industry, they took lessons from their predecessor. In the case of Japan, with a domestic market larger than that of Korea or Taiwan and technological assistance from the U.S. as an ally, Japan was able to initially protect its

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<sup>784</sup> Daryl Hatano, “The American Semiconductor Industry and the Ascendancy of East Asia,” *California Management Review*, Summer of 1985.

<sup>785</sup> Simon, *Taiwan*, page 139.

<sup>786</sup> Project 909 with Huahong-NEC (1995-2000) was known as China’s U.L.S.I. (ultra large scale integration) project. The Shanghai I.C. R&D consortium that Project 909 established in 2002 was somewhat analogous to the V.L.S.I. projects in Japan, Korea, and Taiwan. Hu Qili 胡启立, *Chao Daguimo Jichengdianlu Gongcheng Jishi 超大规模集成电路工程纪实* (Ultra Large Scale Integrated Circuit: Project Records), Beijing: Dianzi Gongye Chubanshe 电子工业出版社 (Electronics Industry Publishing House), 2006. By the late 1990s, ultra large scale integration was the leading global technology.

infant semiconductor industry by limiting foreign investment and competition and imported products. In this way, Japan allowed its semiconductor industry to first develop domestically in the 1970s before attempting to compete globally via exports in the 1980s.<sup>787</sup> Japan set a standard for state led semiconductor industry development, but Korea, Taiwan, and China did not have the luxury of protecting their semiconductor industries from the start. Already engaged in electronics production, Korea, Taiwan, and China were importing most of the semiconductors needed in their electronics products, so their semiconductor industries had to compete with foreign imports from the start.<sup>788</sup> That said, in Korea and Taiwan, government agencies vetted and managed semiconductor-related foreign investment and joint ventures, most of which were Japanese or American, for the benefit of domestic development.<sup>789</sup> In China, foreign investment and joint ventures had to be approved by government agencies, but China's agencies seem to have been less coordinated and less selective. Their goal seems to have been *more* foreign semiconductor-related investment as opposed to *selected* foreign investment. Nonetheless, in all cases, the government was proactively involved in managing the interplay between foreign firms and the domestic industry.

In each of Japan, Korea, Taiwan, and China, the government took common steps to create a constructive eco-system of industry, trade, investment, research, education, and foreign engagement. The governments of each nation subsidized or arranged for banks to offer credit to important domestic semiconductor enterprises. As well, government funding

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<sup>787</sup> National Research Council, *Securing the Future*, Part II.

<sup>788</sup> After a period of import substitution, Japan, Korea, and Taiwan all selectively used "export led development," supported by devalued currency.

<sup>789</sup> Cho and Mathews, *Tiger Technology*, pages 50, 110-111, National Research Council, *Securing the Future*, page 157. Simon, *Taiwan*, page 92. Tax holidays, decreased import duties, and other preferential policies were common across Korea, Taiwan, and China for foreign invested enterprises.

supported various R&D efforts in addition to the mega V.L.S.I. programs discussed above.<sup>790</sup>

In the 1990s, each of Japan, Korea, and Taiwan adopted more venture capital-entrepreneurial oriented funding approaches, mimicking the U.S. market-based approach.<sup>791</sup> Along with research and enterprise funding, each of the nations augmented their talent pool through increased spending on higher education in electronics-related fields and through programs to attract experienced overseas nationals back home. In addition, government procurement provided a market for the nascent semiconductor industries. Also, in each of these nations, an industry association was established to coordinate industry policies, goals, and collaboration, and to serve in many cases as a bridge between government and individual enterprises. In Japan, it was the EIAJ, in Korea the EIAK, in Taiwan the TSIA, and in China the CSIA.<sup>792</sup> Last but certainly not least in terms of common state led development tactics, each national government established geographically concentrated free trade zones to foster trade and later electronics-semiconductor (geographic) bases to foster high technology development.<sup>793</sup> All these state led policies, infrastructure, and investments enabled these late developing nations of East Asia to get a foothold and catch up in the capital intensive, high technology, and highly competitive semiconductor industry.

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<sup>790</sup> The relative levels of government R&D funding may have declined from Japan, to Korea, to Taiwan, to China, judging from certain amounts presented in Mathews and Cho and National Research Council and from China's governmental expenditures presented in this study.

<sup>791</sup> National Research Council, *Securing the Future*, pages 218-221.

<sup>792</sup> Simon, *Taiwan*, page 92, National Research Council, *Securing the Future*, Panels Four and Six. Mathews and Cho, *Tiger Technology*, Part II, Sections 4 and 5.

<sup>793</sup> Some of the most notable sites include Japan's "Silicon Island" from 1984 in Kumamoto prefecture on Kyushu Island. Korea established a free export trade zone at Masan in 1970 and the "Taedok Valley" (or Taedok Science Town) in the 1980s. Taiwan established a free export zone at Kaohsiung in 1965, Hsinchu Park in the 1980s, and Tainan Park from 1995.

### 0.4.3. Foreign Investment

Changes in the global electronics industry and the level of global trade over the last decades of the 20<sup>th</sup> century led to a notable difference in how the semiconductor industry developed in Japan, Korea, Taiwan, and finally China. Foreign investment came to play a larger role in earlier stages of the industry's development. Japan's semiconductor industry was developed more independently (though admittedly with foreign patents), while Korea used selective foreign joint ventures and licensing agreements.<sup>794</sup> As electronics production became increasingly globalized in the 1960s, 1970s, and 1980s, Taiwan had become a popular low wage (but relatively high skill) site for foreign firms. The many electronics and semiconductor-related joint ventures and foreign firms on Taiwan in effect served as training sites for Taiwanese personnel into the 1980s. By the mid 1980s, however, Taiwan's government became more selective about which foreign firms could locate in Taiwan. That said, Taiwan's large semiconductor enterprises all had technology initiatives with global leaders such as RCA, Philips, and TI, though Taiwan's enterprises remained under domestic control.<sup>795</sup>

In comparison with Japan, Korea, and Taiwan, foreign investment played an even larger early role in the semiconductor industry's development in China, and foreign investment was also behind much of China's huge market for semiconductors.<sup>796</sup> After restructuring the semiconductor industry in the mid to late 1980s, Chinese officials decided that China's key semiconductor enterprises would from the start be Sino-foreign joint

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<sup>794</sup> Mathews and Cho, *Tiger Technology*, Part 2, Section 3.

<sup>795</sup> Mathews and Cho, *Tiger Technology*, pages 188-189. Simon, *Taiwan*, Chapter Six.

<sup>796</sup> Recall from Chapter Five that about two-thirds of semiconductors used in China in the 1990s (that is, China's market) were used in products that were ultimately exported.

ventures with technology from foreign partners. In this way, foreign investment was an early and leading strategy for the industry's development. And, with so much foreign investment in broader electronics manufacturing and assembly in China in the 1990s, semiconductor enterprises in China had a huge domestic semiconductor market that was closely tied to foreign investment. As well, Chinese firms were exposed to foreign semiconductor firms that were investing in a presence in China to be close to the market. In all these ways, foreign investment in China was influential in China's semiconductor industry, more so than in Japan, Korea, or Taiwan. As one comparison, in China, foreign direct investment as a percent of gross domestic product was over four percent in the late 1990s when China's semiconductor industry was taking off. In contrast, foreign direct investment in Japan and Korea when their semiconductor industries were growing rapidly was only around 0.5 percent of gross domestic product.<sup>797</sup> So, as electronics became the most significant category of global trade and as East Asia became the largest global hub of electronics trade,<sup>798</sup> foreign investment became an earlier and more important source for the development of the semiconductor industry, the later the industry's host nation entered the industry.

#### **0.4.4. Catch Up Time**

Another difference in the history of the semiconductor industry in Japan, Korea, Taiwan, and China was the time required to catch up, or at least to become a real participant in the global industry. The U.S. and Japan each spent about twenty years to develop and

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<sup>797</sup> Dieter Ernst and Barry Naughton, *China's Emerging Industrial Economy* (New York, Routledge, 2008), Chapter Three.

<sup>798</sup> Recall, by 2006, electronics was the stand-alone largest category of global trade in intermediate goods, accounting for almost fourteen percent. By 2006, Asia accounted for fifty-five percent of global electronics imports and sixty-four percent of global electronics exports. Of these figures, China (including Hong Kong) accounted for one-third to one-half of Asia's electronics imports and exports in 2006, per Sturgeon and Kawakami, "Global Value Chains."

commercialize semiconductor technology, with the U.S. initially being about ten years ahead of Japan. If we look at the timeline of Korea, Taiwan, and China from the time they began in earnest to develop the industry until they were achieving some commercial success, we see a shorter time span. For Korea and Taiwan, it was closer to ten plus years: Korea from circa late 1970s to late 1980s and Taiwan from circa 1980 to 1990. This shorter time line to industry participation was likely due to having predecessors as examples and to the increasing globalization of the electronics industry.

China was the last of these nations to develop its semiconductor industry, and China faced the added complexity of emerging from decades of central planning and state ownership, yet in effect, China's industry also developed in about ten years, circa 1990 to 2000. China's approach to developing the industry in the 1990s, however, was somewhat different than those of Japan, Korea, and Taiwan, all of which made early use of national, collaborative research programs to foster their enterprises' capabilities.<sup>799</sup> By the time that China was entering the industry, Japan, Korea, and Taiwan already had successful, operational enterprises, so Chinese leaders opted to rapidly move to the operational stage via partnering.<sup>800</sup> Chinese officials sought to quickly establish working enterprises in order to leverage foreign organizational, management, and marketing experience. Chinese semiconductor personnel needed not just technological learning, although that was certainly important. Given their history of working in China's (relatively inefficient) state owned

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<sup>799</sup> Mathews and Cho, *Tiger Technology*.

<sup>800</sup> China did have various research programs and funding from the late 1980s, as discussed in Chapter Two, but Chinese officials did not opt to establish a new singular "centralized" research organization, right on the heels of "divesting" and restructuring the centrally planned semiconductor industry.



enterprises and institutes, Chinese officials wanted Chinese personnel to work with foreigners to learn new ways to organize and manage enterprises.<sup>801</sup>

China's leap into manufacturing operations and adoption of the foundry model as early as 1997 (at Huajing) relate to China's early recognition and embrace of de-verticalization in the industry. Recall that from the start of both Projects 908 (Huajing) and 909 (Huahong-NEC), the goal of these new enterprises was to attract a diversity of firms from different sectors in the semiconductor industry value chain. And, China was more integrated with global electronics production when its semiconductor industry took off, relative to Japan, Korea, and Taiwan. (Recall from above that China had significantly higher levels of foreign investment versus Japan, Korea, and Taiwan.) China's electronics and semiconductor industries also benefitted from global business trends in the 1990s that favored de-verticalization including focusing on core competencies, outsourcing, and optimizing supply chains. At the same time, the global semiconductor industry was increasingly relying on licensed e-tools for semiconductor design, further enabling de-verticalization in the industry. By the early 2000s, all sectors of the semiconductor industry in China were growing, and the global industry was beginning to ask if China might become a semiconductor leader in the 21<sup>st</sup> century.

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⁸⁰¹ Because China's key semiconductor enterprises and national champions were newly established in the 1990s as Sino-foreign joint ventures, we can not trace an evolution in these enterprises of what scholars call "organizational learning" or developing "absorptive capacity" or "learning how to learn" within the 1990s, although learning was surely underway. It would be more feasible to examine how these organizations and personnel learned and if they developed so-called learning capacities over a longer period.

Looking back at the latter half of the 20th century, the rise of Asia as a major global trading axis and the growth of the electronics industry are two of the most important global economic phenomena. This study has offered a view of how China and other East Asian nations successfully navigated to enter the global electronics industry, specifically the highly sophisticated and competitive semiconductor industry, as part of their thrust for overall economic development. In the 21st century, East Asia's important role in global trade combined with the global Information Revolution will – hopefully – continue to improve living standards and enhance openness, connectivity, and opportunities in East Asia and around the world.

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Appendix: Interview List and All Figures

Interviews 2008-2009

Name	Current Organization and Title	Date	Primary Interview Topics
Xu Xiaotian	Chief of Electronics, Ministry of Information Industries (and other roles)	January 2009	Ministry of Information Industries; CSIA (Secretary General); Director Key Enterprise (Shanghai Belling)
Yu Zhongyu	President, CSIA (and other roles)	July 2, 2009	CSIA; Projects 908, 909, SMIC; Five Year Plans; industry history
Xu Guo Chang	Director, CSIA Shanghai	June 17 and May 30, 2009	CSIA; Fudan University; "divestiture" of state sector
Jia Xiao Hong	Shenzhen Semiconductor Industry Assoc	March 27, 2009	CSIA Staff; 7+1 Design Bases (Shenzhen)
William Zhou	Director, Foreign Investment Promotion Bureau, Wuxi	Feb 28, 2009	7+1 Design Bases (Wuxi); Wuxi semiconductor enterprises
Zhou Shengming	Shenzhen IC Design Industrial Center	March 27, 2009	7+1 Design Bases (Shenzhen); talent pool
Chen Tianbao	Director, Wuxi IC National Design Base Company	various	7+1 Design Bases (Wuxi); Project 908 and Huajing; JCET
Mr. Jiang	Vice Director, Wuxi IC National Design Base Company	various	7+1 Design Bases (Wuxi); intellectual property
Yang Long	Manager, Wuxi IC National Design Base Company	various	7+1 Design Bases (Wuxi); Wuxi enterprises; foreign integration
Ye Tianchun	Director, CAS-Institute of Microelectronics	July 3, 2009	CAS-Institute of Microelectronics; Five Year Plans; R&D funding programs; talent pool
Leng Min	Scholar, CAS-Institute of Policy Management	March 5, 2009	CAS-Institute of Policy Management; strategic industries
Dr. Zhao Gang	Vice Director, Ministry of Science and Technology	March 5, 2009	CASTED, Ministry of Science and Technology; scholarship on China's semiconductor industry

Interviews 2008-2009, continued

Name	Current Organization and Title	Date	Primary Interview Topics
Mao Chenglie	General Manager, ETEK	May 19, 2009	Project 908 and Huajing (former employee); private sector; talent pool
Teng Jingxin 藤敬信	Chief Engineer, Huarun (CRM)	April 8, 2009	Huajing and Project 908; Wuxi as "cradle" of semiconductor industry; 1980s technology transfer
Wang Guoping	CEO, Huarun (CRM)	July 16, 2009	Huajing and Project 908; new generation management
Teng Jingxin 藤敬信	Chief Engineer, Huarun (CRM)	July 16, 2009	Huajing and Project 908; Wuxi as "cradle" of semiconductor industry; 1980s technology transfer
Xu Juyan	Chief Engineer, Institute 58	July 22, 2009	Huajing and Project 908 (former employee); Institute 58; Wuxi as "cradle" of semiconductor industry
Zhang, General Mgr	General Manager, ANST (of CRM)	June 19, 2009	Huajing (CRM) PAT company; Project 908; sector reorganization at Huajing; foreign management and technology transfer; new generation management
Yin Guohai (sp?), elder engineer	Chief Engineer, ANST (of CRM)	June 19, 2009	Huajing (CRM) PAT company; Project 908; sector reorganization at Huajing (former employee); foreign management and technology transfer; talent pool; industry history
Yu Xiekang	CEO, JCET	June 2, 2009	Huajing (former GM) and Project 908; CSIA (Vice Secretary); sectoral growth; divestiture of state sector
Gong	General Manager, Inchange Semiconductor	June 2, 2009	Huajing (former employee) and Project 908; Wuxi as "cradle" of semiconductor industry; new firm formation; now in private sector

Interviews 2008-2009, continued

Name	Current Organization and Title	Date	Primary Interview Topics
Brian	Design Engineer, Huarun	June 6, 2009	Huajing (CRM); design sector; global integration; talent pool
Li Zhihong	General Manager, Chipown	March 26, 2009	Huajing (former employee); private sector; firm formation; talent pool
Mr. Zheng	Deputy, Huarun's Semico	Cancelled	Huajing; design sector
Yu Xiekang	CEO, JCET	June 2, 2009	Huajing (former GM) and Project 908; CSIA (Vice Secretary); sectoral growth; divestiture of state sector
Zhou Weiping	CEO, ASMC	July 15, 2009	Key Enterprises (CEO of ASMC and former GM of Shanghai Belling); new generation management; talent pool; foreign partners
Richard Chang, CANCELLED	CEO, SMIC	July 30, 2009	National Champions; SMIC; CANCELLED
Chee Teck	Engineer, SMIC	July 1, 1905	SMIC
Li Weide	Retired (Fudan, SOE, start company)	June 4, 2009	"Divestiture" of state enterprises; Fudan University; firm formation; foreign integration; now in private sector
Li Weide	Retired (Fudan, SOE, start company)	June 8, 2009	"Divestiture" of state enterprises; Fudan University; firm formation; foreign integration; now in private sector
SAIC	SAIC	May 18, 2009	"Divestiture" of state enterprises; relations between Wuxi and Shanghai
Ma Peijun	Credy Industries	May 30, 2009	"Divestiture" of state enterprises; Fudan University; firm formation; foreign integration; now in private sector

Interviews 2008-2009, continued

Name	Current Organization and Title	Date	Primary Interview Topics
Li Weide	Retired (Fudan, SOE, start company)	May 30, 2009	"Divestiture" of state enterprises; Fudan University; firm formation; foreign integration; now in private sector
Ma Peijun	Credy Industries	July 1, 1905	"Divestiture" of state enterprises; Fudan University; firm formation; foreign integration; now in private sector
Fred Knijnenburg	Manager, ASML	April 11, 2009	Global equipment sector; talent pool
Farokh Fares	Asia-Pacific Manager, Machine Vision Products	June 10, 2009	Global electronics industry
Dr. Tsui	General Manager, GEM	June 11, 2009	Global P.A.T. sector; foreign integration
Wang Ping	General Manager Asia Pacific, Coining	June 11, 2009	Global electronics industry
Joseph Chen	Manager (Shanghai/Wuxi), ASML	June 29, 2009	Global equipment sector; SMIC; foreign integration; talent pool
Jeffrey Yap	Manager, Samina	various	Global electronics industry
Toby Chai and boss	Universal Enterprise Beijing HTCY Microelectronics	July 3, 2009	Distributors; semiconductor market
Huang Qi (黄琦)	Owner, Shenzhen Saifun Semiconductors Co Ltd	March 27, 2009	Distributors; semiconductor market; Chinese design houses
Chen Xushu 陈学术	General Manager, Shunda 顺大 半导体发展有限公司	April 19, 2009	Solar sector; foreign integration; firm formation
Prof. Yang	Professor, Fudan University Institute	June 8, 2009	Fudan University; "divestiture" of state enterprises; firm formation; talent pool; foreign integration
Dr. Henry Wang	General Manager, IDETCO	May 5, 2009	Technical education; talent pool
Peter Li	worker, Wuxi factories	various	Talent pool; Wuxi firms

Interviews 2008-2009, continued

Name	Current Organization and Title	Date	Primary Interview Topics
Jifu Wang	Professor, Corporate Strategy in China (currently in Texas)	June, 2009	Huajing
Gu Xiaofeng	Professor, Jiangnan Daxue	March 18, 2009	Huajing; Wuxi as "cradle" of semiconductor industry
Chen Ling	Professor, Qinghua University	March 4, 2009	Sector growth; industry history
Professor	Professor, Wuxi Technical Collge	Spring 2009	Talent pool
James Tang	McKinsey, Shanghai	April 1, 2009	Foreign integration; design houses in China; sector growth
Staff	SH Museum, IC Exhibit	May 26, 2009	Shanghai's semiconductor industry
Staff	Wuxi Museum, IC Exhibit	May 1, 2009	Wuxi; Huajing; Wuxi as "cradle" of semiconductor industry

Figure 1: China's Largest Semiconductor Production Facilities in the 1980s

Facility	Location
Jiangnan Semiconductor Factory	Jiangsu, Wuxi
Tianguang Electronics Factory	Gansu, Qinan
Dongguang 878 Factory	Beijing
Changzhou Semiconductor Factory	Beijing
Beijing Semiconductor #2	Zhejiang, Shaoxing
Shaoxing Electronics Factory	Shanghai
Shanghai #5 Components Factory	Shanghai
Shanghai #14 Radio Factory	Shanghai
Shanghai #19 Radio Factory	Shanghai
CAS Factory #109	Beijing
Lishan Microelectronics Corporation	Xian
Tianjin Semiconductor Factory	Tianjin

Source: From Denis Simon, *Technological Innovation in China*, page 67.

Figure 2: Gap Between China and Global Leading Technology (year attained)

	Wafer Size in Inches (larger is more advanced)	
Year	Global	China
1970	2	1.5
1975	4	1.5
1980	5	2
1985	6	3-4
1990	6-8	3-4
1995	8	6
2000	12	6-8
2005	12	12
2010	12-18	12

< Shougang-NEC

< Huahong-NEC and CSMC-Huajing

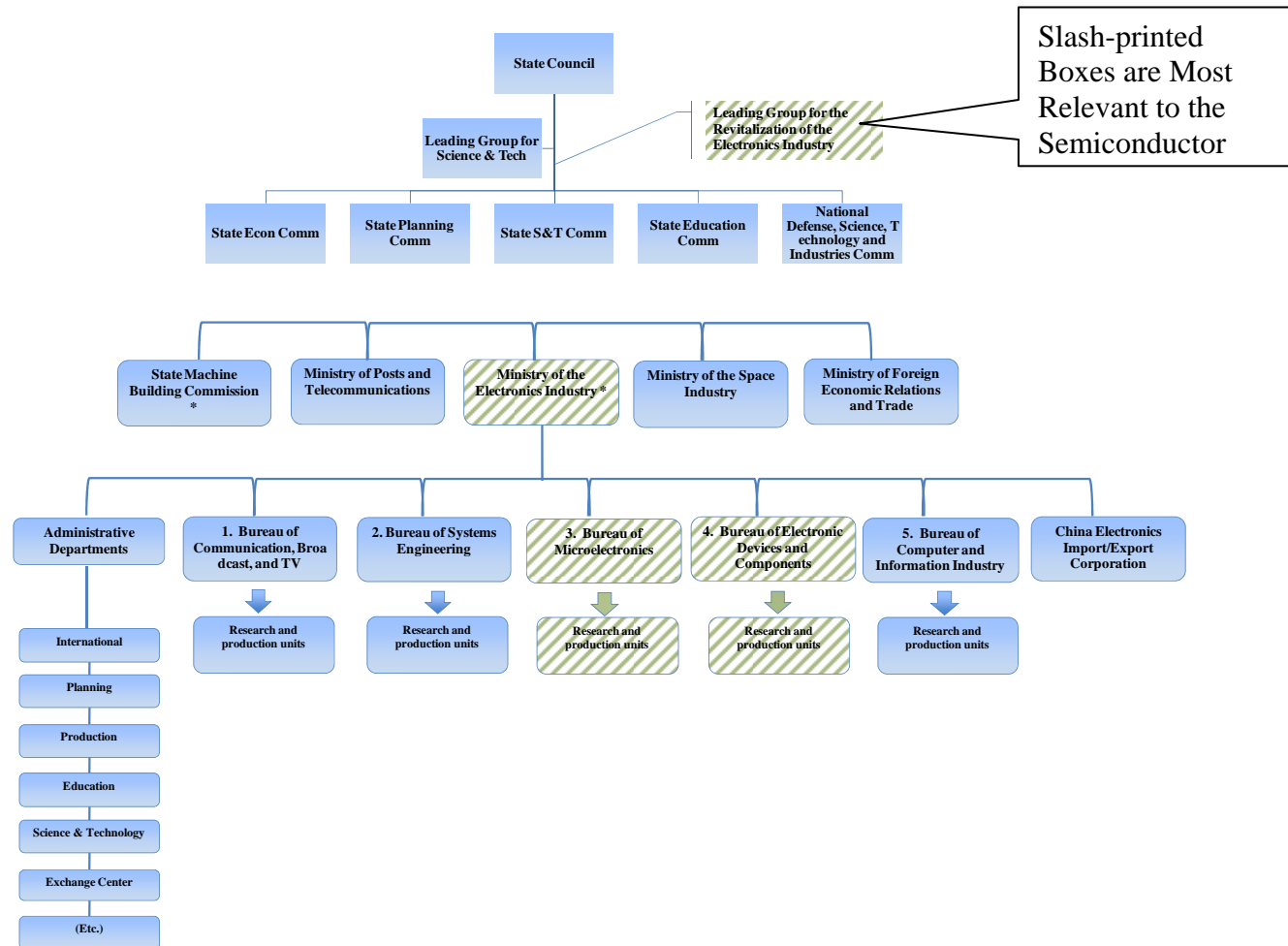
< SMIC

	Small Scale Integration	Medium Scale Integration	Large Scale Integration	Very Large Scale Integration	Ultra Large Scale Integration
Global	1958	1964	1966	1976	1986
China*	1965	1972	1972	1986	1999

The years indicated for China seem optimistic. They may reflect technological understanding more than actual production capabilities.

Source: Zhu Yiwei 朱贻伟, *Zhongguo Jichengdianlu Chanye Fazhan Lunshu Wenji 中国集成电路产业发展: (China's IC Industry Development: Collected Works)*, Beijing: Xinsidai 新时代出版社 (New Times Press), 2006, page 69.

Figure 3: China's Electronics Industry, Circa 1986



** Simon notes that in 1985, the Ministry of the Electronics Industry oversaw some 2600 production units and 130 research institutes.

* In 1988, the State Machine Building Commission and the Ministry of the Electronics Industry merged to form the Ministry of Machine Building and Electronics Industry.

Source: Denis Simon, *Technological Innovation*, page 54, from China's Ministry of the Electronics Industry, Beijing, July 1987.

Figure 4: China's Five Key Semiconductor Enterprises

Five Key Enterprises	Founded	Prior Enterprises Joining	Initial Joint Venture Foreign Partner	Location	Estimates of Initial Investment circa 1990*	Production in 1995	Staff in 2000*	Products and Market*
Huajing/CSMC (Project 908)	1989	#742 Factory (Wuxi) and Institute 24 (Sichuan)	CSMC of Hong Kong, with Taiwan Mgmt	Jiangsu, Wuxi		2, 3, 5 micron 4 inch line: 140,000 units/yr 5 inch line: 130,000 units/yr	1600 tech staff plus other employees	discrete devices, bipolar and CMOS ICs, primarily for TVs and audio equip, per IEEE 1995
Huayue	1988	#871 Factory (Gansu and Shaoxing branch)	[Lacked a foreign partner as of 1995]	Zhejiang, Shaoxing		3, 5 micron 3 inch line: 120,000 units/yr 4 inch line: 60,000 units/yr		a candidate for Project 908 in 1990; analog devices and bipolar ICs for TVs and phones
Shanghai Belling (China's first Sino-foreign microelectronics joint venture)	1988	#14 Factory (Shanghai) and Shanghai Electronics and Operation Instruments Holding Company	Shanghai Bell Telephone Equipment Mfg Co, which was a joint venture with Alcatel Bell of Belgium	Shanghai	US\$82.4 m	2.4, 5 micron 4 inch line: 120,000 units/yr	500+ employees, of which 200 are tech staff	ICs for Shanghai Bell Telephone, the first switch-maker to use locally made circuits, per IEEE 1995
ASMC (Advanced Semiconductor Manufacturing Corporation); Chinese name Shanghai Xianjin, formerly known as Shanghai-Philips.	1988	#5 and #7 and #19 Factories (Shanghai)	Philips of the Netherlands (Also Nortel of Canada from approx 1995-2000)	Shanghai		3 micron 5 inch line: 120,000 units/yr	450+ employees	began as a foundry; Philips transferred older tech and producing for export
Shougang-NEC	1991	Beijing Shougang Gongtie (Capital Steel)	NEC (Nippon Electric Company) of Japan	Beijing	US\$240 m	1.2, 1.5 micron 6 inch line: 36,000 units/yr	800+ employees	color TVs, air conditioners, VCDs, IC cards, clocks, palm PCs

This chart is compiled from the following sources:

1) Interview with Zhou Weiping, July 15, 2009, at ASMC headquarters in Shanghai. Zhou is C.E.O. of ASMC and a former General Manager of Shanghai Belling.

2) Zhu Yiwei 朱贻伟, *Zhongguo Jichengdianlu Chanye Fazhan Lunshu Wenji 中国集成电路产业发展: (China's IC Industry Development: Collected Works)*, Beijing: Xinshidai 新时代出版社 (New Times Press), 2006, pages 162 and 164.

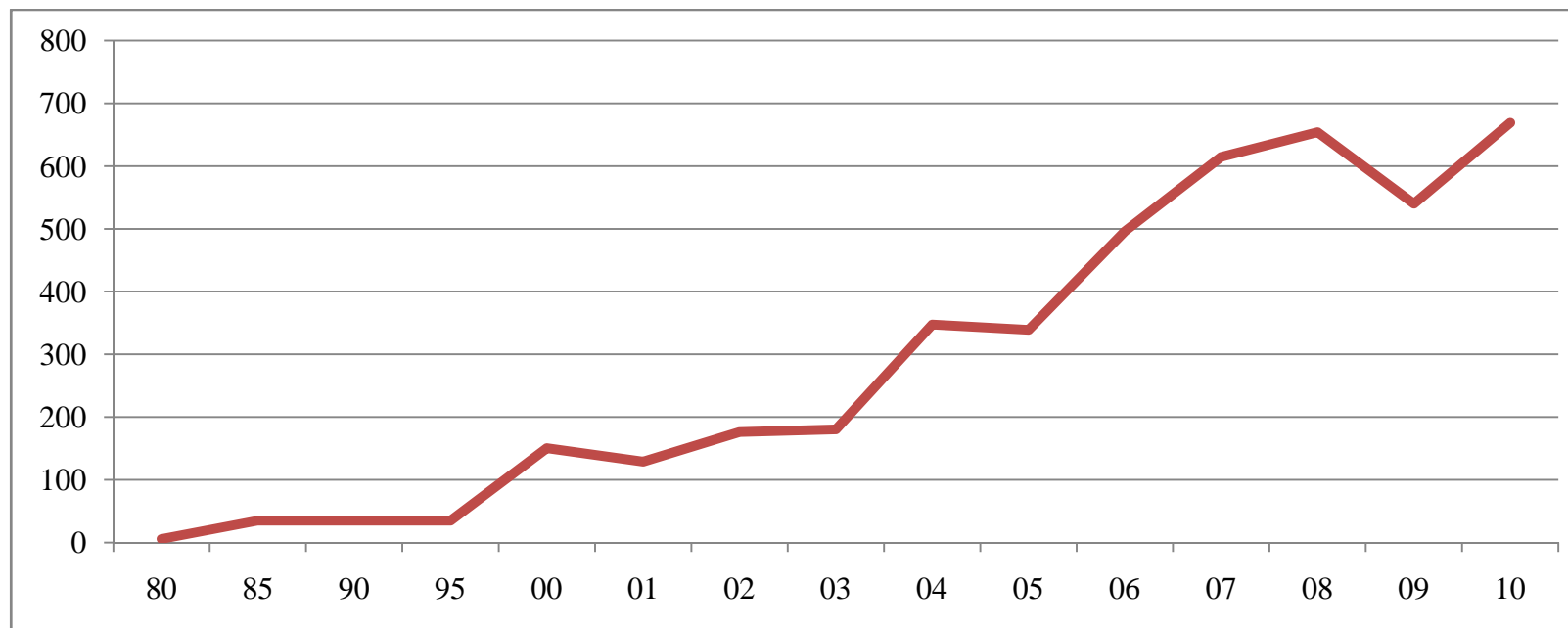
3) Wang Yangyuan and Wang Yongwen 王阳元 and 王永文, *Wo Guo Jichengdianlu Chanye Fazhan Zhilu: cong Xiaofei Daguo Zouxian Chanye Qiangguo 我国集成电路产业发展之路: 从消费大国走向产业强国 (China's Integrated Circuit Industry Development Path: From a Big, Consuming Nation to a Strong, Industrial Nation)*, Kexue Chubanshe 科学出版社 (Science Press), 2008, page 294.

4) iSupply, "Semiconductor Wafer Manufacturing in China: A Panacea or a Global Investment Trap?," Q3, 2002, page 11.

5) Michael Pecht, Weifeng Liu and David Hodges, "Chapter Two: Electronics Manufacturing Update," Office of Naval Research and U.S. Department of Commerce, 2000-2001.

Figure 5: Estimates of Huajing-affiliated Organizations' Revenues in US\$ millions

These estimates are based on ratios of revenues among Huajing-affiliated organizations. Since 2008, Huajing-affiliated organizations have combined financial statements under CRM, but previous years are estimated based on Huajing data from earlier years.



Sources include:

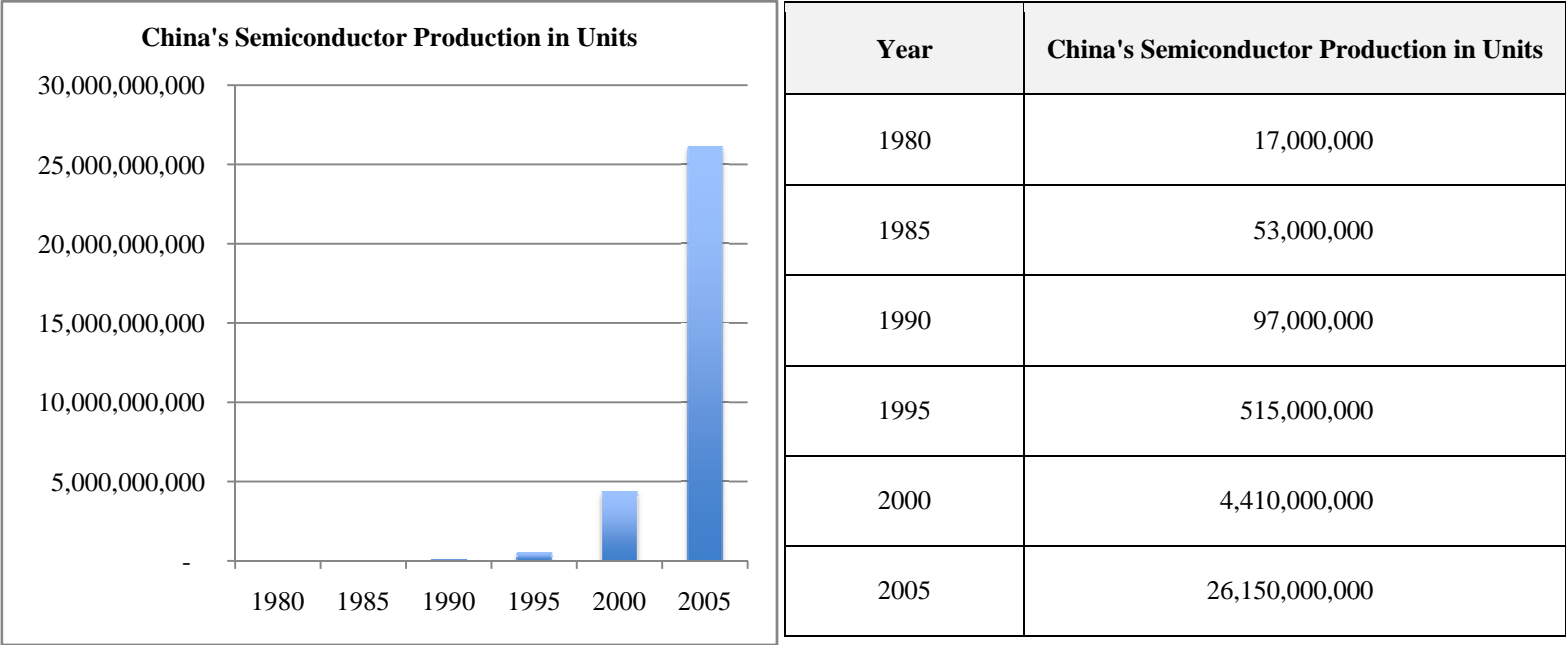
Zheng Shilong, Lu Zhixin and Tian Jingying 郑世隆, 陆志信 和田婧瑛, ““Huajing Jingshen”: Ji Guoying Jiangnan Wuxiandian Qicaichang

华晶精神: 记国营江南无线电器材厂 (The Spirit of Huajing: Jiangnan State-owned Radio Equipment Factory),” *Liaowang 瞭望 (Outlook)*, Period 22, 1986.

CRM (China Resources Microelectronics) annual reports.

PWC, "China's Impact on the Semiconductor Industry," 2010 and 2011, data sources China Semiconductor Industry Association, CCID, and PwC analysis.

Figure 6: Semiconductor Production in China



This chart is compiled from the following sources:

1) Zhu Yiwei 朱贻伟, *Zhongguo Jichengdianlu Chanye Fazhan Lunshu Wenji 中国集成电路产业发展: (China's IC Industry Development: Collected Works)*, Beijing: Xinshidai 新时代出版社 (New Times Press), 2006, pages 127, 163 and 164.

2) Ling Chen and Lan Xue, "Global Production Networks," *China and the World Economy* (published by Chinese Academy of Social Sciences), Volume 18, Number 6, 2010, page 114. Chart footnotes: a) Chen and Xue, "Global Production Networks," this amount refers to investment in the five key enterprises (including Huajing) from 1985-1995.

Figure 7: Largest 15 Semiconductor Firms in China in 2003 by Revenue

Chinese enterprises in *italics*.

Note: These are the firms with highest revenues *operating* in China.

These are not the same as the largest semiconductor *suppliers* to the Chinese market because most of the semiconductors that meet China's market demand are imported.

Analysis:

Of the top 15 firms' revenue in 2003, "Chinese" firms constituted 47 percent.

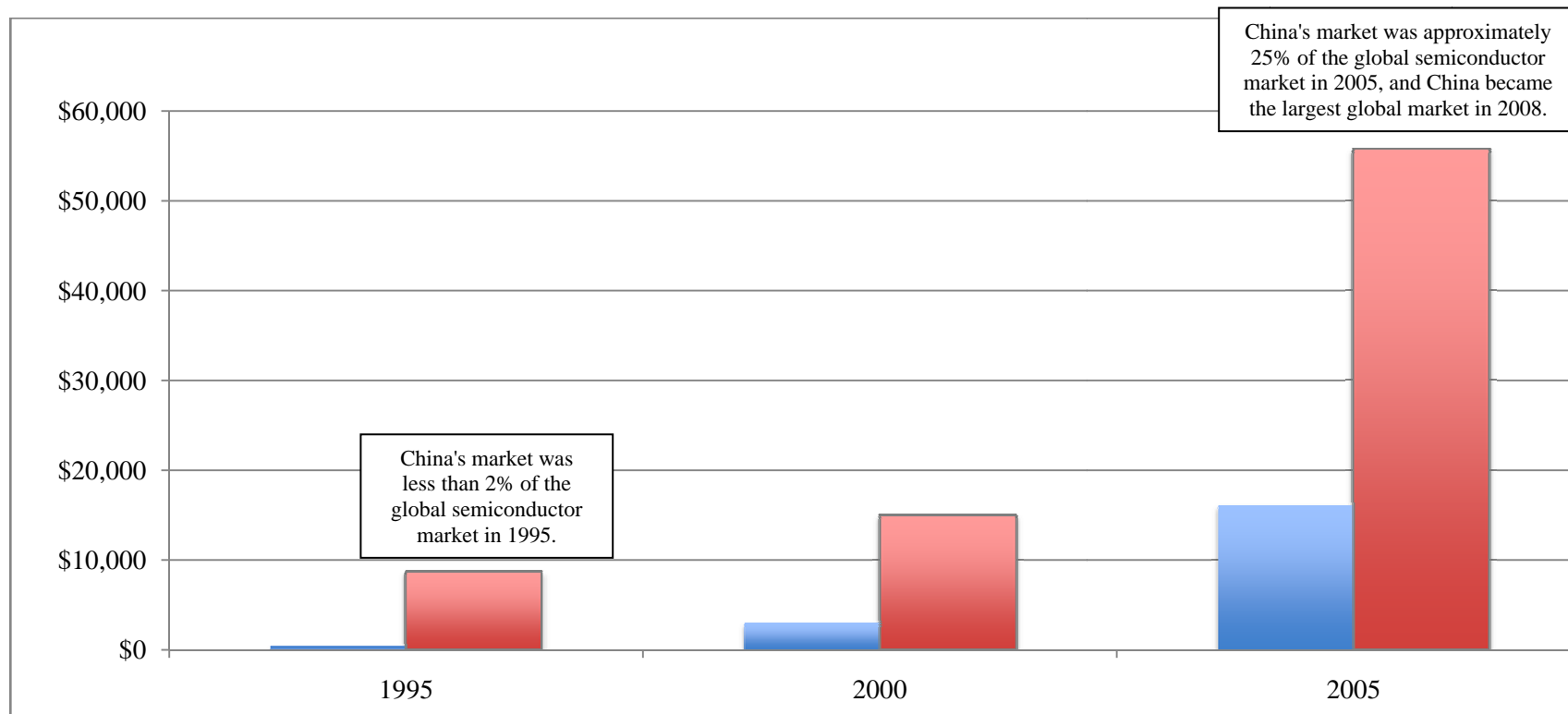
The "Chinese" firms were a mix of ownership forms.

Ran k	Headquarters	Name	Revenue in 2003 (US\$ million)	2003 Notes on "Chinese" Firms
1	US	Motorola	962	
2	<i>China/Cayman Islands/International</i>	SMIC	350	SMIC is a WFOE registered in the Cayman Islands.
3	Japan	Renesas	195	
4	<i>China/Japan</i>	Huahong-NEC	188	Huahong-NEC of Project 909 is a Sino-Foreign JV.
5	<i>China/US</i>	Leshan	149	LeShan has a JV with Motorola and provides mainly discrete devices.
6	Switzerland	Shenzhen Sai STMicroelectronics	125	
7	US	Intel	109	
8	<i>China</i>	Jianxin XinChao	108	XinChao is a state owned group.
9	<i>China/Netherlands</i>	ASMC	94	ASMC has a JV with Netherlands-based Philips and serves mainly as a foundry for Philips.
10	<i>China/Japan</i>	Nantong-Fujitsu	92	Nantong-Fujitsu is a Sino-foreign JV.
11	<i>China</i>	JCET	84	JCET is large state owned P.A.T. enterprise near Wuxi.
12	<i>China/Hong Kong</i>	China Resources Microelectronics/CSMC	77	CRM is a member of the CR enterprise group; it includes Huajing and CSMC of Project 908.
13	<i>China</i>	Datang	75	Datang is a state owned enterprise group in electronics-related industries.
14	Singapore	ChipPAC	73	
15	<i>China/Japan</i>	Shougang-NEC	68	Shougang-NEC is a Sino-foreign JV; Chinese partner is Beijing Shougang, a steel enterprise group.

Source: PWC, "China's Impact on the Semiconductor Industry, 2004," data sources include CSIA, CCID, and PwC analysis.

"Chinese" revenue:	1,285	47%
Other revenue:	1,464	53%
Total revenue:	2,749	100%

Figure 8: China's Estimated Semiconductor Production (blue) and Market (red), in US\$ millions



This graph is constructed from the following sources:

1) PWC, "China's Impact on the Semiconductor Industry, 2004, 2006, and 2012," data sources include China Semiconductor Industry Association, CCID, and PwC analysis.

2) Wang Yangyuan and Wang Yongwen 王阳元 and 王永文, *Wo Guo Jichengdianlu Chanye Fazhan Zhilu: cong Xiaofei Daguo Zouxiang Chanye Qiangguo* 我国集成电路产业发展之路：从消费大国走向产业强国 (China's Integrated Circuit Industry Development Path: From a Big, Consuming Nation to a Strong, Industrial Nation), Kexue Chubanshe 科学出版社 (Science Press), 2008, page 123, per CSIA.

Note: The PWC analyses uses data from CSIA and CCID, both associated with China's Ministry of the Information Industries.

The data includes all enterprises operating in China, including foreign enterprises, not just Chinese owned or state owned enterprises.

Figure 9: Largest 15 Semiconductor Firms in China in 2011 by Revenue

Chinese enterprises in *italics*.

Note: These are the firms with highest revenues *operating* in China. This is not the same as the largest semiconductor *suppliers* to the Chinese market because most of the semiconductors that meet China's market demand are imported.

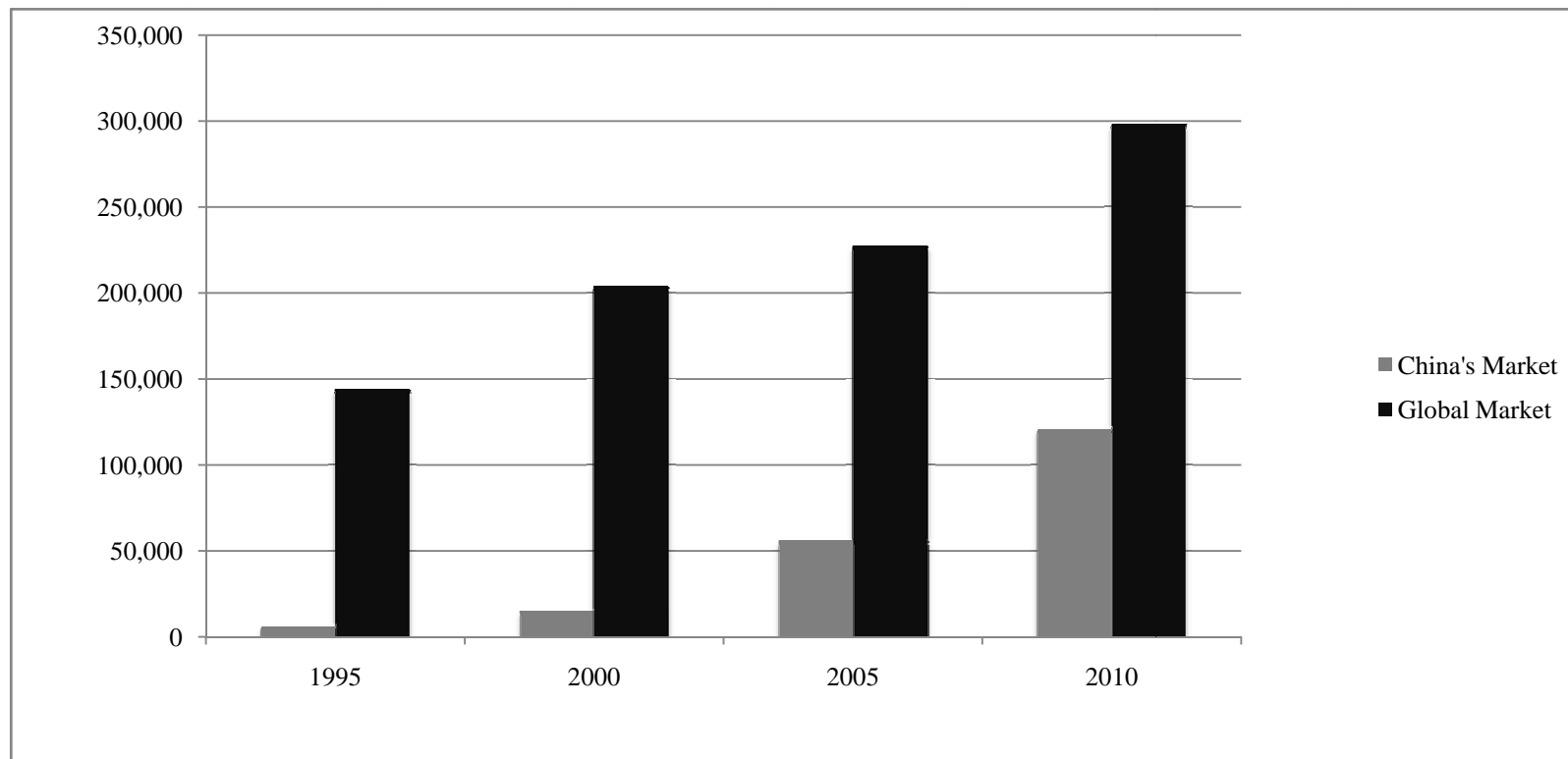
Rank	Headquarters	Name	2011 Revenue US\$mm	2011 Notes on "Chinese" Firms
1	US	Intel	4,765	
2	Korea	Hynix	2,452	
3	<i>China/Cayman Islands/international</i>	SMIC	1,315	SMIC is a WFOE registered in the Cayman Islands.
4	US	Freescall	1,119	
5	<i>China</i>	HiSilicon (formerly with Huawei)	1,032	HiSilicon was formerly part of state-owned Huawei (telecomm), but is now a private, listed firm.
6	<i>China</i>	XinChao (JCET)	969	XinChao is a state owned group; it includes the large P.A.T. firm called JCET.
7	Korea	Samsung	838	
8	<i>China</i>	Spreadtrum	684	Spreadtrum was private from its inception.
9	<i>China/Japan</i>	Huahong	671	Huahong includes Huahong-NEC of Project 909, which is a Sino-foreign JV.
10	Taiwan	ASE	657	
11	Japan	Renesas	643	
12	<i>China/Hong Kong</i>	China Resources Microelectronics	631	CRM is a member of the CR enterprise group; it includes Huajing and CSMC of Project 908.
13	US	Cree Huizhou	631	
14	<i>China</i>	Nantong Huada	620	Nantong is a state owned group.
15	Japan	Panasonic	602	

Source: PWC, "China's Impact on the Semiconductor Industry, 2012 Update," data sources include CSIA, CCID, and PwC analysis.

"Chinese" revenue:	5,922	34%
Other revenue:	11,707	66%
Total revenue:	17,629	100%

Analysis: Of the top 15 firms' revenue in 2011, "Chinese" firms constituted 34 percent. The "Chinese" firms were a mix of ownership forms.

Figure 10: Semiconductor Market: China and Global, in US\$ Billions

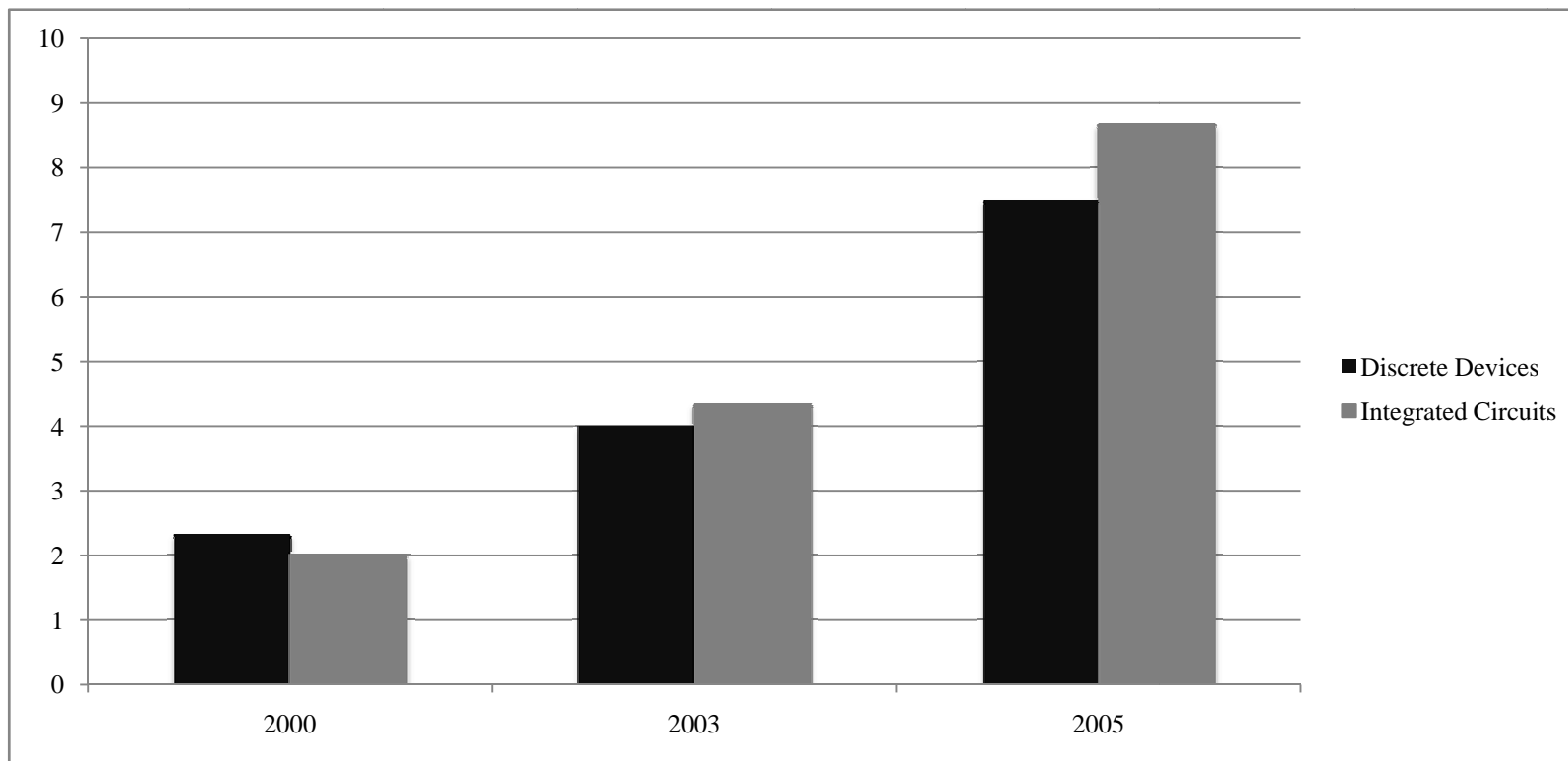


Sources:

1) PWC, "China's Impact on the Semiconductor Industry, 2004, 2006, 2011 and 2012," data sources include China Semiconductor Industry Association, CCID, and PwC analysis.

2) Wang Yangyuan and Wang Yongwen 王阳元 and 王永文, *Wo Guo Jichengdianlu Chanye Fazhan Zhilu: cong Xiaofei Daguo Zouxian Chanye Qiangguo 我国集成电路产业发展之路：从消费大国走向产业强国* (China's Integrated Circuit Industry Development Path: From a Big, Consuming Nation to a Strong, Industrial Nation), Kexue Chubanshe 科学出版社 (Science Press), 2008, page 123, per CSIA

Figure 11: Estimated Semiconductor Production in China in US\$ Billions



Source:

PWC, "China's Impact on the Semiconductor Industry, 2006," page 20, data sources include China Semiconductor Industry Association, CCID, and PwC analysis.

Figure 12: The Global Electronics Supply Chain: OEMs and Contract Manufacturers

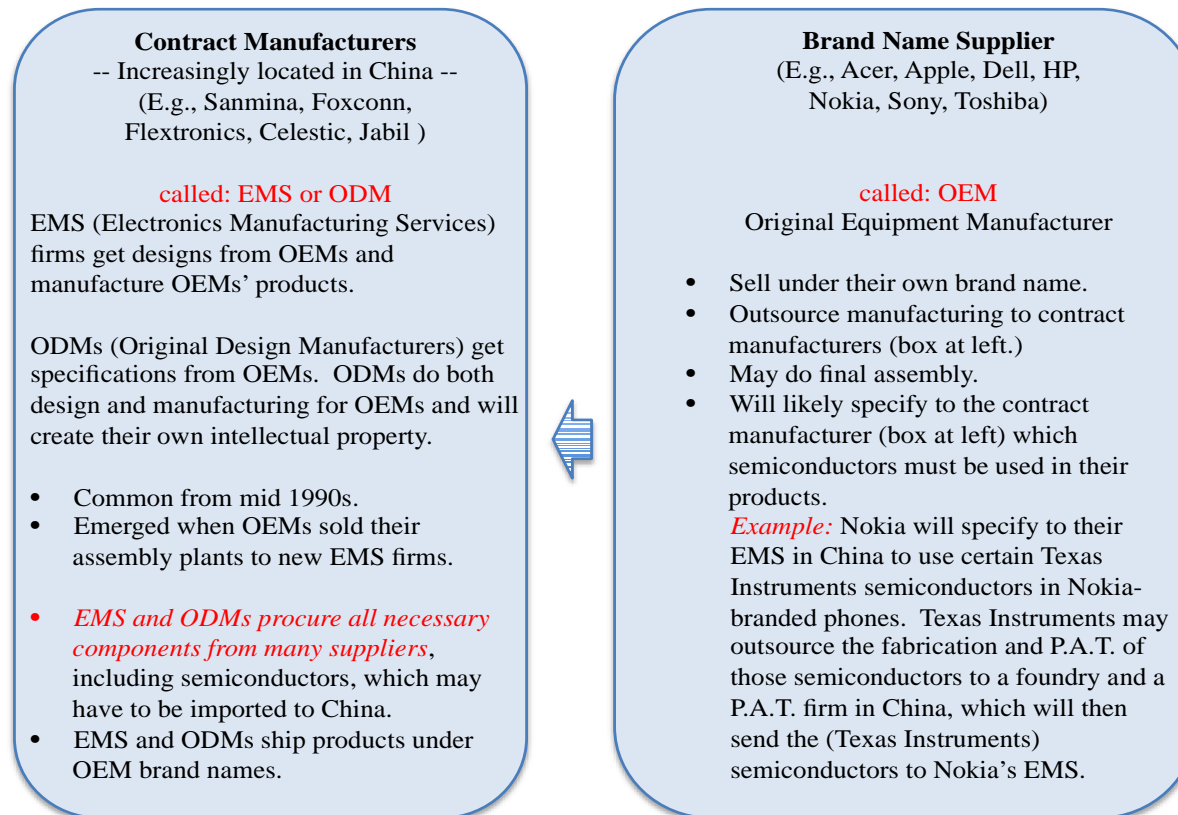


Figure 13: Examples of Global Semiconductor Firm Activity in China in the 1980s and 1990s

Year	Global Firm	Activity in China	Source
1984	Applied Materials	Began selling in China in 1984 and by 2000 had sites in Wuxi, Shanghai, Beijing and Tianjin.	21
1985	Hewlett-Packard	Established assembly (P.A.T.) operations with multiple Chinese partners from 1985.	7
From 1986	Fujitsu	Transferred technology to Nantong Huada for assembling logic chips; established JVs in Nanjing (1992), Jiangsu (1994), Xian (1995), Nantong (1997), and another Nanjing (1999.) Also established a research center with CAS in Beijing in 1994. Also operated a semiconductor assembly (P.A.T.) plant from 1999.	1
1986	Texas Instruments	Established first office in Beijing in 1986.	2
1991	Daw Technologies	Chinese government signed possibly the "single largest" semiconductor equipment purchase from Daw for Huajing, for clean room equipment.	3
1992	United States (various companies)	China sent three delegations to the U.S. to buy older, used semiconductor equipment.	4
1992	Motorola	Established Tianjin production facility for discrete devices and ICs, a wholly (Motorola) owned subsidiary.	5
1993	AMD	Opened a design office in Beijing.	7
1993	Diodes	Established production in China of discrete devices.	
1994	Toshiba	Established an assembly (P.A.T.) plant near Shanghai.	1
1994	Intel	Subcontracted P.A.T. work to Huajing for 386 chips; 1995, set up operations in Shanghai.	4
1994	Northern Telecom	Established joint venture with Shanghai government bodies to produce Ics; Norther was majority owner; the joint venture was to supply Northern's other China-based joint ventures. Northern set up four agreements and had locations in Beijing, Shanghai, and Guangzhou.	6

Figure 13, continued: Examples of Global Semiconductor Firm Activity in China in the 1980s and 1990s

Year	Global Firm	Activity in China	Source
1994	ITT	Formed joint venture with Zhejiang Connector Factory; ITT owned 51 percent of the joint venture.	8
1994	Toshiba	Established JV with Haujing to produce semiconductors. Toshiba owned 60 percent of the JV.	9
1994	U.S. Department of Commerce	The DOC along with three U.S. electronics-related trade associations established a U.S. Information Technology Office in Beijing.	10
1994	Microelectronic Packaging	Contracted with Chinese organizations to provide technology, training, and equipment for manufacturing (semiconductor) ceramic packaging.	12
1994	National Semiconductor	Signed agreement with Chinese government to provide semiconductor-related technologies to China.	13
1994	IBM	Supplied capital equipment and a major research contract to Beijing's Application Software Development Corp (associated with Qinghua University.)	19
1994	Hitachi	Established first China office in 1994; established an assembly (P.A.T.) site for DRAM in 1999.	20
By 1995	Sun Microsystems	Established a partnership with China-based Huasun.	19
1995	AlphaTec	Formed JV in Shanghai with Huaxu of the MEI for P.A.T.; Microchip Technologies (of Arizona) also participated in the venture.	11
1995	General Instruments	Received a business license to establish a semiconductor wholly foreign owned manufacturing facility in Tianjin.	14
1996	AT&T-Lucent	Established six JVs and two wholly foreign owned enterprises in China, with a total of 20,000 workers (also transferred primary technology to Huajing under Project 908.)	16
1996	Daw Technologies	Sold semiconductor equipment to Huajing, Huayue, and Chinese Design Institute No. 10.	18

Figure 13, continued: Examples of Global Semiconductor Firm Activity in China in the 1980s and 1990s

Year	Global Firm	Activity in China	Source
Before 1997	Siemens	Sold equipment to Huajing; established a production facility in Jiangsu Wuxi.	17
1997	Hitachi	Established a packing (P.A.T.) plant for DRAM.	1
1997	Bell Labs (the R&D unit of Lucent)	Built branches in Beijing and Shanghai and launched a joint lab with Shanghai Jiaotong Daxue.	16
1997	Matsushita	Provided technology to Wuxi Little Swan, a large electronics/semiconductor R&D firm.	17
Before 2000	Fairchild	Established manufacturing in China.	15

Sources:

- 1) Jifu Wang, "China Huajing Electronics Group Corporation," unpublished business case study, 2000.
- 2) Texas Instruments, see article at http://www.ti.com/corp/docs/csr/news_community_ti_china.shtml.
- 3) *High Beam Research*, November 1992.
- 3) *High Beam Research*, "Daw Technologies," August 1, 1991.
- 4) *New York Times*, "Intel to Begin China Venture," March 26, 1994.
- 5) Bill Rumbler, "Motorola Building \$120million Factory in China," *Chicago Sun Times*, March 28, 1992.
- 6) *PR Newswire*, "Northern Telecom Announces Large Investment Program...in China," April 22, 1994.
- 7) Rebecca Smith, "China's Growing Market Lures U.S. Computer Chip Makers," *Tribune Business News*, April 3, 1994.
- 8) *PR Newswire*, "ITT Unit Forms JV with China's Largest Connector Company," April 12, 1994.
- 9) *New York Times*, "Toshiba in Chinese Deal," August 9, 1994.
- 10) *PR Newswire*, "U.S. Department of Commerce Awards First Ever Grant for U.S.-Beijing Information Technology Office," October 26, 1994.
- 11) *Business Wire*, "Alphatec Groups Forms JV in Shanghai, China," July 18, 1995
- 12) *Business Wire*, "Microelectronic Packaging Receives \$2million Contract from Chinese Government Electronics Concern," November 23, 1994.
- 13) *Business Wire*, "National Semiconductor and Chinese Government Sign Agreement...in China," December 22, 1994
- 14) *PR Newswire*, "General Instrument Corp. Division Receives Business License from PRC," May 25, 1995.
- 15) *Business Wire*, "Fairchild Semiconductor Completes Acquisition of QT Optoelectronics," May 30, 2000.
- 16) *Xinhua News Agency*, "Lucent Technologies' Investment Exceeds 100million," January 19, 1998.
- 17) *Washington Post*, "'Made in China' Takes Great Leap Forward," June 15, 1997.
- 18) *Business Wire*, "Daw Technologies Inc. Receives Approximately \$8billion in New Contracts," January 9, 1996.
- 19) Michael Zielenziger, "Pacific Rim: China Builds 'Brainpower Center'," *Tribune News Service*, November 1, 1995.
- 20) Hitachi, see article at <http://www.hitachi.com/about/corporate/history/1980.html>.
- 21) *Business Wire*, "Applied Materials Expands Global Presence to Better Serve Customers in Asia," May 8, 2001.

Figure 14: Examples of Global Firms' Major Activities in China in the Early 2000s

Year	Global Firm	Activity in China	Source
2000, 2001	Applied Materials	Re-enforced existing science funding and training center in cooperation with the Shanghai Science and Technology Commission	6
2000	Accord Advanced Technologies	Hired by Huajing-CSMC for "multi-million dollars" to refurbish equipment; AAT's first project in China	15
2000	AMD	Announced wholly owned subsidiary in Suzhou with US\$108 million investment	14
2000	Philips	Announced a wholly foreign owned P.A.T. operation in Dongguan	18
2000, 2001	SMIC (foreign owned, though considered "Chinese")	Established in 2000, began production in 2002.	
2000	Grace	Established in 2000, began production in 2003.	
2000	Motorola	US\$1.9 billion investment in a Tianjin IC fabrication and P.A.T. facility.	18
2001	Cirrus Logic	Signed a five year agreement with CSMC for CSMC to manufacture semiconductors for Cirrus	17
2001	Ericsson	Announced US\$5 billion investment in China from 2001-2006	2
2001	Nokia	Invested in a US\$1.2 billion project in Beijing	3
2001	Dell	Moved its Asia headquarters to China	4
2001	Alcatel	Moved its Asia Pacific headquarters to Shanghai	5
2001	Nelco Wuxi (part of Park Electromechanical Corporation)	Opened semiconductor materials facility in Wuxi	9
2002	ASML	Received a major order for multiple equipment products from Huajing	16
2002	Motorola	Announced US\$10 billion investment in China from 2002-2012	1
2002	KEC	Doubled Wuxi production	7

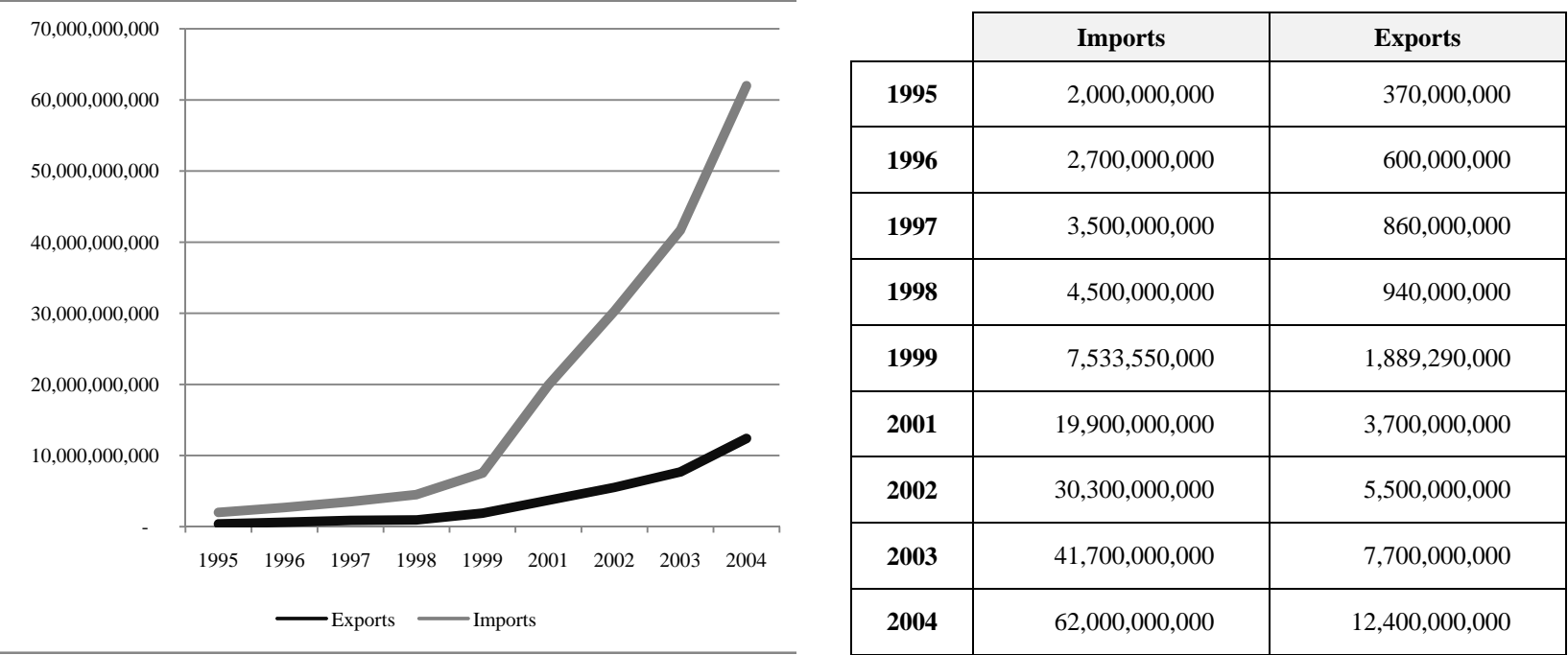
Figure 14, continued: Examples of Global Firms' Major Activities in China in the Early 2000s

Year	Global Firm	Activity in China	Source
2002	Texchem-Pack	Established a wholly foreign owned subsidiary in Wuxi to supply semiconductor firms	8
2002	Toshiba	Bought the Toshiba-Huajing P.A.T. joint venture and formed a wholly owned subsidiary called Toshiba Wuxi Semiconductor Company	10
2002	MEMSIC	Established P.A.T. facility in Wuxi	11
2002	TOWA	Established an equipment facility in Shanghai for P.A.T. firms	12

Sources:

- 1) www.motorola.com, noted in Nasa Tsai, President of Grace Semiconductor, "China: An Emerging Centre for Semiconductor Manufacturing," Future Fab International, Issue 13, July 8, 2002.
- 2) *China Computer News*, November 22, 2001, noted in Tsai, "China: An Emerging Centre..."
- 3) *People's Daily*, December 21, 2001, noted in Tsai, "China: An Emerging Centre..."
- 4) www.finance.lycos.com.cn, October 10, 2001, noted in Tsai, "China: An Emerging Centre..."
- 5) *Shanghai Computer News*, May 23, 2001, noted in Tsai, "China: An Emerging Centre..."
- 6) *Business Wire*, "Applied Materials Pledges Additional Funds...", May 5, 2000 and "Applied Materials Shanghai...", October 18, 2001.
- 7) *China Daily*, "In Brief," June 25, 2002
- 8) *Asia Pulse News*, "Malaysia's Texchem Resources to Set Up Unit in Wuxi," April 12, 2002.
- 9) *PR Newswire*, "Park Electrochemical Announces...", November 8, 2001
- 10) *Asia Info Services*, "Toshiba Expands Semiconductor...", July 11, 2002
- 11) *Sensor Business Digest*, "From the Editor: Market Opportunities Abound...", June 1, 2002
- 12) *Asia Info Services*, "TOWA Comes to Shanghai," November 26, 2002
- 14) Rand (James Mulvenon), "Shanghaied? The Economic and Political Implications...", July 2004, page 109.
- 15) *PR Newswire*, "Accord Advanced Technologies Announces...", June 21, 2000.
- 16) *Business Wire*, "ASML Increases Presence in China with Huajing...", December 3, 2002.
- 17) *Business Wire*, "Cirrus Logic Signs Five Year Foundry...", August 30, 2001.
- 18) Denis Simon, "The Microelectronics Industry Crosses a Critical Threshold," *China Business Review*, November-December 2001

Figure 15: China's Imports and Exports of Semiconductors (I.C.s and Discrete Devices) in \$US



Sources:

1) 1995-1998 data from *China Electronics Industry Yearbook*, 1997 page 147, and 1999 page 211, shown in Michael Pecht, *China's Electronics Industry*, 1999, page 28.

2) 1999 data from Xu Xiaotian, Chief of Electronics Department, China's Ministry of Information Industry, cited in Michael Pecht, *China's Electronics Industry*, 1999, page 29.

3) 2001-2004 data from Taipei Times, cited in Michael Pecht, *China's Electronics Industry*, 2007, page 97..

Figure 16: Policies Supporting the Semiconductor Industry, Circa 2000

Year	Title	Issue Addressed	Notes
November 1997	"ITA: Information Technology Agreement"	Eliminating Tariffs on Information Technology Products	China to Eventually Join the ITA in 2003, as part of the WTO.
January 1998	"Guiding Catalog for Foreign Investment in Industry"	"Encouraged Industries"	A guide of industries for which foreign investments would likely be approved. Microelectronics enterprises utilizing 0.35micron or better technology were "encouraged."
June 1999	(Document by Ministry of Science and Technology and other departments)	Capital Access	Semiconductor enterprises (are newly) allowed to use venture capital and other capital channels.
November 1999	"U.S.-China Bilateral Trade Agreement"	Various	Defined issues in anticipation of China joining the WTO.
July 2000	"Document 18: Some Policies to Encourage the Development of the Software and Integrated Circuit Industries"	Various	
July 2000	"863 Plan"	Prioritization and Funding for Semiconductor Industry	The 863 Plan funded research for semiconductors.
August 2000	(updated catalog)	"Encouraged Investments"	The catalog encouraged investments in the design and fabrication of 1.2micron or better semiconductors.

Figure 16, continued: Policies Supporting the Semiconductor Industry, Circa 2000

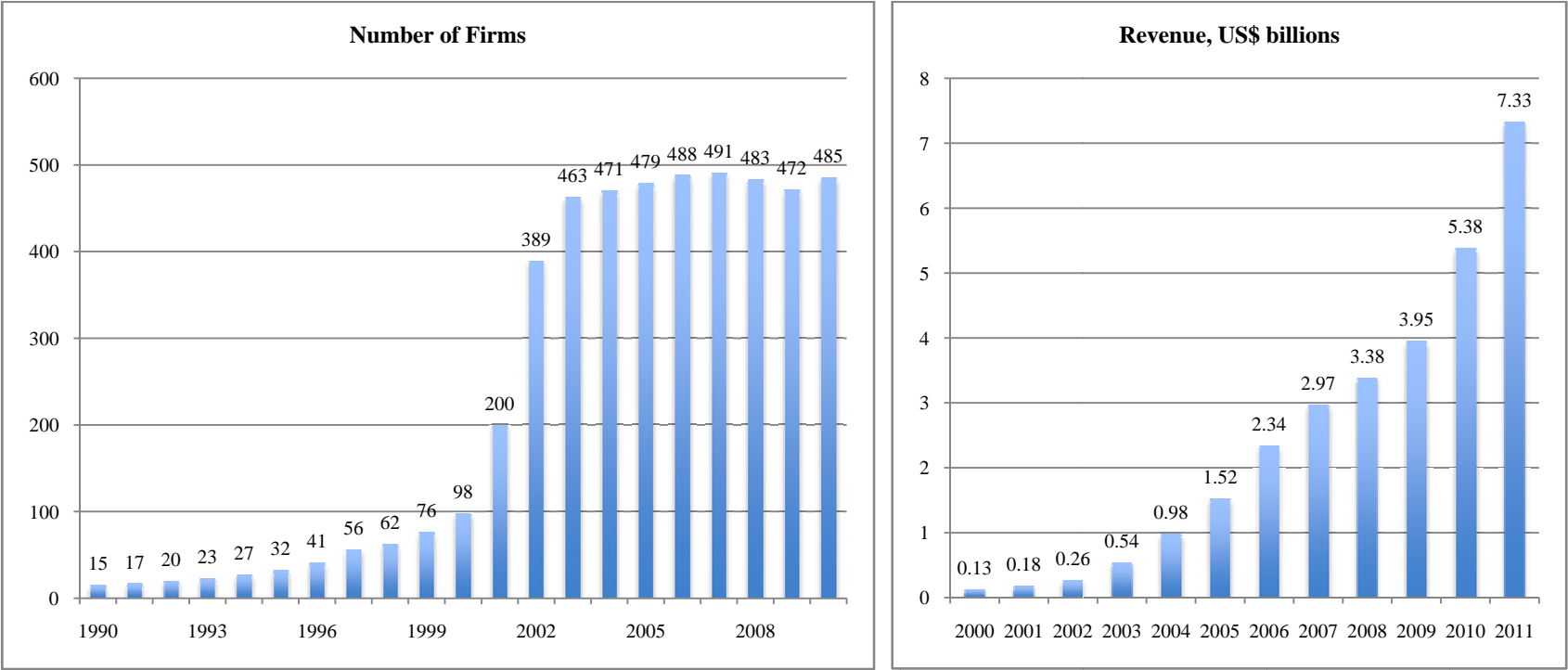
Year	Title	Issue Addressed	Notes
March 2001	"10th Five Year Plan"	Prioritization and Funding of Semiconductor Industry	The 10th FYP included investments in critical high tech areas and high tech projects, including semiconductors at the nano technology level. Planned for US\$120billion in semiconductor industry investments between 2001-2005.
April 2001	"Regulations on the Protection of Layout Designs of Integrated Circuits"	IP Protection for Semiconductors	Protected semiconductor designs; enforced by the State Intellectual Property Office.
December 2001	WTO Entry		
January 2002	(China eliminates tariffs on semiconductors, per WTO and ITA)		
January 2003	"Government Procurement Law"	Government Procurement	This law regulated and brought transparency to government purchasing in China.
March 2004	(US WTO complaint against China)	China's Semiconductor VAT Policy	China's VAT gave domestic producers a lower VAT than foreign producer, making imported semiconductors more expensive than China-produced semiconductors.
July 2004	(China agrees to revoke its semiconductor VAT policy)		
April 2005	(China's preferential semiconductor VAT policy is discontinued)		

Figure 17: Semiconductor Production Revenues in China, by Sector (RMB100 million), excluding Discrete Devices

Year	2000	2001	2002	2003	2004	2005
Design	9.8	14.8	21.6	44.9	81.8	124.3
• Percent of industry	5	7	7	13	15	18
Fabrication (manufacturing)	48	27.7	33.6	60.5	180	232.9
• Percent of industry	26	14	14	17	33	33
Packaging, Assembly, Testing (P.A.T.)	128.4	161.1	213.3	246	283.5	344.9
• Percent of industry	69	79	79	70	52	49
Total	186.2	203.6	268.5	351.4	545.3	702.1

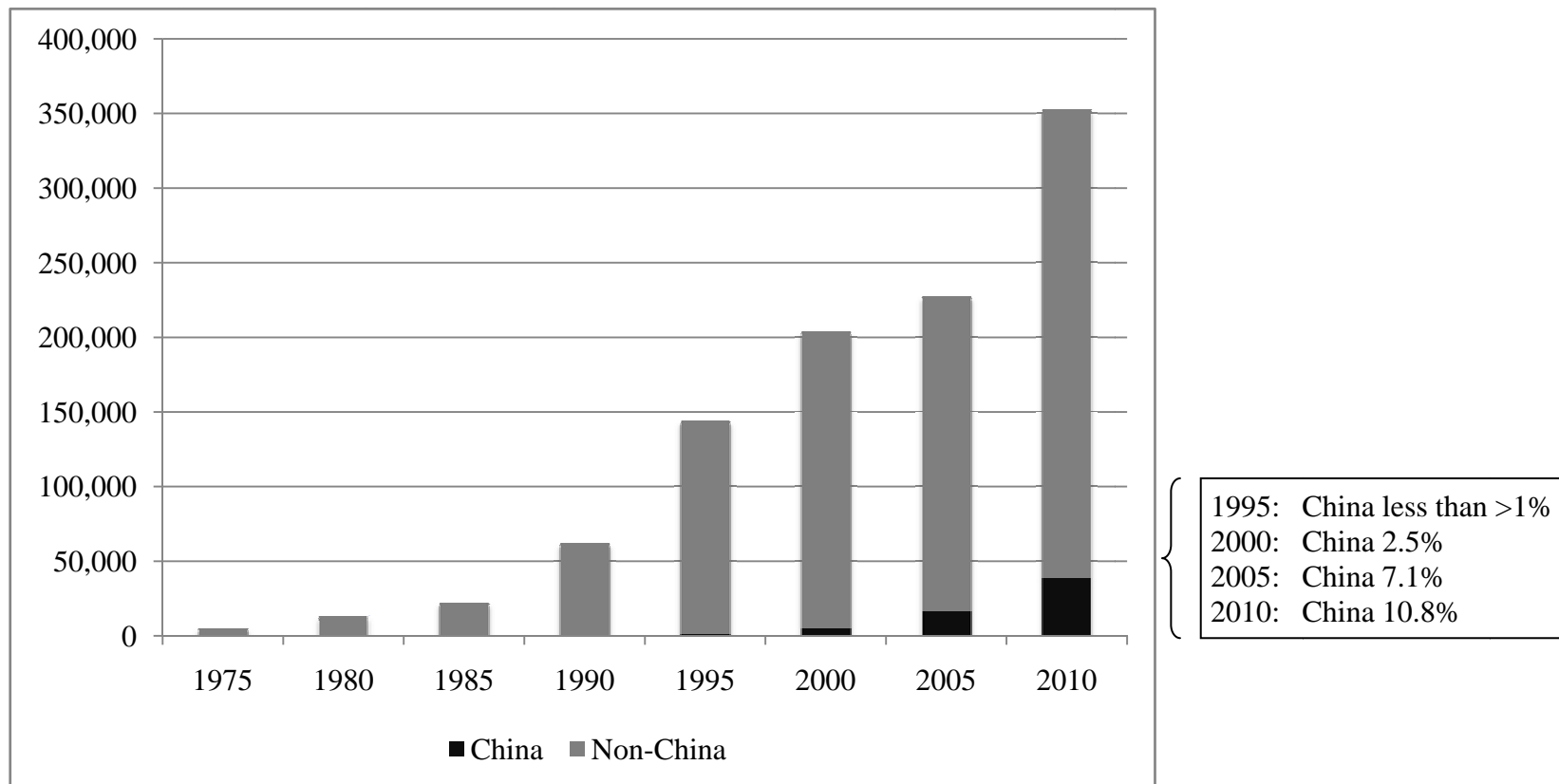
Source: National Bureau of Statistics, 2001-2005, shown in Chen Ling and Xue Lan, "Global Production Networks," *China and the World Economy*, Volume 18, Number 6, 2010, page 114, Table 1.

Figure 18: Semiconductor Design in China, Revenue Growth and Firm Growth



Source: PwC, "China's Impact on the Semiconductor Industry," 2012, page 3.2, data from C.C.I.D. and C.S.I.A..

Figure 19: Total Semiconductor Industry Production Revenues, US\$ Billions, Global vs. China



Sources:

- 1) PwC, "China's Impact on the Semiconductor Industry, 2004, 2006, and 2012," data sources include China Semiconductor Industry Association, CCID, and PwC analysis.
- 2) Wang Yangyuan and Wang Yongwen 王阳元 and 王永文, *Wo Guo Jichengdianlu Chanye Fazhan Zhilu: cong Xiaofei Daguo Zouxian Chanye Qiangguo* 我国集成电路产业发展之路：从消费大国走向产业强国 (China's Integrated Circuit Industry Development Path: From a Big, Consuming Nation to a Strong, Industrial Nation), Kexue Chubanshe 科学出版社 (Science Press), 2008, page 123, per CSIA.
- 3) Author's analysis