United States International Trade Commission
Journal of International Commerce and Economics
July 2019

Chinese Semiconductor Industrial Policy: Past and Present

John VerWey

Abstract

This is the first of two papers that analyze China's semiconductor industrial policies and factors that will dictate their success or failure. China's attempts since 2014 to support and grow its domestic semiconductor industry have drawn considerable international attention. The purpose of this series is to place into context the various attempts by the Chinese government to support its domestic semiconductor industry, dating back to the 1950s. Part one presents a history of China's past efforts at semiconductor industrial planning, describes the current plans, and discusses their execution to date. Part two explains why previous plans have failed, how lessons learned from past failures have been incorporated into current plans, and examines their prospects for success, finding that China's current strategy will likely not achieve its aims.

Keywords: Semiconductors, China, trade, Made in China 2025, industrial planning, global value chains, foreign direct investment.

Suggested citation: VerWey, John. "Chinese Semiconductor Industrial Policy: Past and Present." *Journal of International Commerce and Economics*, July 2019. https://www.usitc.gov/journals/jice_home.htm.

 Please direct all correspondence to John VerWey, Office of Industries, U.S. International Trade Commission, 500 E Street SW, Washington, DC 20436, or by email to John.VerWey@usitc.gov.

The author would like to thank Dan Kim for helpful feedback and thoughtful suggestions throughout, and three anonymous referees for their comments.

Table of Contents

List of Figures and Tables

Introduction

Semiconductors are the enabling hardware for all information technology. Also referred to as integrated circuits (ICs) or "chips,"[1] semiconductors are found in everything from smartphones and computers to automobiles and medical devices. Since Jack Kilby developed the first rudimentary IC for Texas Instruments in 1958, the U.S. chip industry, concentrated in Silicon Valley, has led the world. The semiconductor fabrication process is among the most complicated, knowledge-intensive manufacturing processes known. Large multinational companies (MNCs) regularly invest upwards of 20 percent of their annual profits in research and development (R&D) budgets. At the same time, they are coordinating up to 16,000 suppliers to organize the intellectual and physical property needed to produce chips that are nearing atomic feature sizes in heavily automated factories that cost $10 billion or more and that feature class one cleanrooms.[2]

Depending on how one defines the technology, the Chinese semiconductor industry began sometime between 1956, when the first transistor was created in a state lab, and 1965, when China created its first IC.[3] China's semiconductor industrial development can be divided into four periods. The period from 1956 to 1990 was characterized by a Soviet-style system of industrial organization that emphasized indigenous development, self-reliance, and heavy-handed state planning. The Chinese semiconductor industry spent the period from 1990 to 2002 attempting to catch up with worldwide leaders, partnering with international firms and engaging in joint ventures with limited success. The period from 2002 to 2014 saw the emergence of several Chinese-headquartered semiconductor firms that pursued well-articulated goals while leveraging China's growing domestic market. The period from 2014 to present features China's most ambitious, well-defined, and well-funded plans to date and offers the greatest prospects for success yet seen.

Roadmap

This paper, part one of a two-part series on the Chinese semiconductor industry, first gives an overview of the structure of the semiconductor industry before describing the development of its global value chain and leading firms. Next, China's role in the semiconductor industry and global electronics supply chain is discussed, focusing in particular on China's growing demand for semiconductors. After reviewing literature on Chinese industrial policies, the paper analyzes Chinese semiconductor industrial policies, dividing the various industrial plans into four general periods: 1956–1990, 1990–2002, 2002–2014, and 2014–present. China's plans from 2014 to the present are then discussed in detail, with particular attention paid to the role of subsidies, foreign direct investment (FDI), technology transfer, joint ventures, and investment restrictions, as well as the effect these plans may have on U.S. semiconductor firm competitiveness.

---

[1] A semiconductor is a material that has electrical conductivity between that of conductors (e.g., copper) and insulators (e.g., glass). There are three types of semiconductors: discretes, ICs, and optoelectronics. Discretes are semiconductors that contain only one transistor. ICs are semiconductors that contain more than one transistor. Optoelectronics are semiconductors that detect or generate light. The colloquial term "chip" can refer to any type of semiconductor. The focus of this article is on ICs.

[2] One nanometer is one billionth of a meter. A silicon atom is approximately half a nanometer in diameter and the most advanced chips produced at commercial volumes today have 7 nanometer feature sizes. A class one cleanroom is a space rated 100,000 times cleaner than the average hospital environment. See also Intel Corporation, "Comments Concerning Proposed Determination of Action," July 23, 2018.

[3] Fuller, *Paper Tigers, Hidden Dragons*, 2016, 117. In contrast, Jack Kilby demonstrated the first working IC in 1958 at Texas Instruments, and filed the patent the following year.

Part II of this series attempts to answer two questions. First, why—in spite of 70 years of industrial plans—can't China make commercially viable advanced semiconductors on par with the worldwide industry's leaders? Second, what are the prospects for success of its latest semiconductor industrial plans? The development of the semiconductor industries in Taiwan, Japan, and South Korea is reviewed in the context of literature on latecomer strategies and compared with China's past and present efforts. The key obstacles to China's success are then reviewed, with a particular focus on the role of strategic funding, human capital, and export controls. China's prospects for success with its most recent plans are then detailed, demonstrating that this iteration is better defined and better funded than past efforts.

Several outstanding questions are then addressed, including whether China's plans to catch up are too little too late, the challenges associated with recruiting talent, the possibility that China's firms will develop products to solely meet the Chinese market and fail to compete internationally, and the impact of recent export control and investment restrictions in slowing the Chinese semiconductor industry's development. The paper concludes that China's current semiconductor industrial plans will not result in a commercially viable domestic semiconductor industry that can produce advanced chips at volumes that make them competitive with leading international firms.

The Semiconductor Industry

The semiconductor industry is increasingly mature, with most segments dominated by a small number of large firms that are concentrated in Europe, the United States, South Korea, Japan, Taiwan, and China. The barriers to entry in the semiconductor industry are high and stem from many sources, including first mover advantages, economies of scale, brand recognition, stickiness and customer loyalty, intellectual property (IP), and most importantly, high and fixed capital expenditures.[4] Waves of industry consolidation have resulted in a shrinking number of firms competing in highly specialized industry segments.

As the industry approaches the limits of Moore's Law,[5] the expenses associated with manufacturing a leading edge chip have become cost prohibitive except for all but the largest firms in the world.[6] These increasing costs have forced many companies in the past 20 years to focus on legacy and state-of-the-practice products, reducing the number of firms capable of producing leading-edge chips and ushering in the advent of a new operating model in the industry (figure 1).[7]

[4] King, "Barriers to Entry," January 2003.

[5] Co-founder of Intel Gordon Moore theorized in 1965 that the number of transistors embedded in an IC would double every two years at the same or decreasing prices. This theory has become the industry's pace of innovation for the past five decades, offering faster processing at the same or lower price to consumers. Its end represents an inflection point for the industry. See also Bailey, "Moore's Law Ending," October 29, 2018.

[6] While fixed costs associated with semiconductor fabrication are incredibly high, design costs have also steadily increased due to its complexity.

[7] The terms "leading edge," "state of the practice," and "legacy" refer to the different performance characteristics of generations of chips and necessarily change over time as the industry advances. For chip technology, the smaller the dimensions (measured in nanometers (nm)), the more advanced the chip. Currently, "leading edge" refers to chips with a feature size 14 nm or below (a human hair is about 75,000 nm in diameter); "state of the practice" refers to any chip with a feature size of 32–65 nanometers; and legacy chips have feature sizes from 65 to 10,000 nanometers.

Figure 1: Operating models in the semiconductor industry, and leading firms

Integrated device manufacturer (IDM) model		
Intel, Micron, Samsung, Texas Instruments		
Fabless-foundry model		
Design (fabless)	**Manufacturing (foundries)**	**Assembly, test, and packaging (ATP)**
AMD, Broadcom, MediaTek, HiSilicon, Qualcomm	GlobalFoundries, SMIC, TSMC, UMC	Amkor, ASE, ChipPAC, JCET, J-Devices, Power-tech, SPIL

Source: Adapted from SIA, "Beyond Borders," May 2016.

The production of semiconductors occurs in three distinct stages: design, manufacturing, and assembly, test, and packaging (ATP).[8] Large semiconductor companies, such as Intel (U.S.) and Samsung (South Korea), operate as integrated device manufacturers (IDMs), performing these steps in-house. However, in response to rising semiconductor production costs, niche companies that specialize in one or more steps of the production process have emerged. "Fabless" companies, which engage solely in the design of semiconductors, partner with pure-play foundries (contract semiconductor manufacturers with no design capabilities) to fabricate devices before they are sent to ATP firms.[9]

The Semiconductor Global Value Chain

These different business models have resulted in a uniquely global and geographically disparate value chain in which a chip could be designed by a firm in the United States, fabricated by a foundry in Taiwan, and tested in Malaysia before being sent to China, where it is incorporated in to a final good (e.g., a smartphone).[10] The Semiconductor Industry Association (SIA) estimates that 90 percent of the value of a chip is split evenly between design and manufacturing, with the final 10 percent of value added by ATP firms.[11] In 2018 11 of the top 15 firms were IDMs, the exceptions being Broadcom, Qualcomm, and Nvidia (all fabless) and Taiwan Semiconductor Manufacturing Company (TSMC, a foundry). These 11 firms accounted for approximately 53 percent of the worldwide industry's total sales in 2018 (Table 1).

[8] VerWey, "Global Value Chains," March 2018.
[9] The ATP stage of manufacturing may be outsourced to a different firm, or completed by the same firm.
[10] USITC, *Import Restraints 9*, September 2017.
[11] SIA, "Beyond Borders," May 2016.

Table 1: Worldwide ranking of the top-15 suppliers of semiconductors in 2018[12]

Company	Headquarters location	Operating model	2018 forecasted sales (billion)
Samsung	South Korea	IDM	$65.90
Intel	United States	IDM	$61.70
TSMC	Taiwan	Foundry	$32.20
SK Hynix	South Korea	IDM	$26.70
Micron	United States	IDM	$23.90
Broadcom	United States	Fabless	$17.80
Qualcomm	United States	Fabless	$17.00
Texas Instruments	United States	IDM	$13.90
Toshiba/Toshiba Memory	Japan	IDM	$13.30
Nvidia	United States	Fabless	$9.40
NXP	Europe	IDM	$9.30
STMicroelectronics	Europe	IDM	$8.30
Infineon	Europe	IDM	$8.10
Sony	Japan	IDM	$7.90
Western Digital / Sandisk	United States	IDM	$7.80

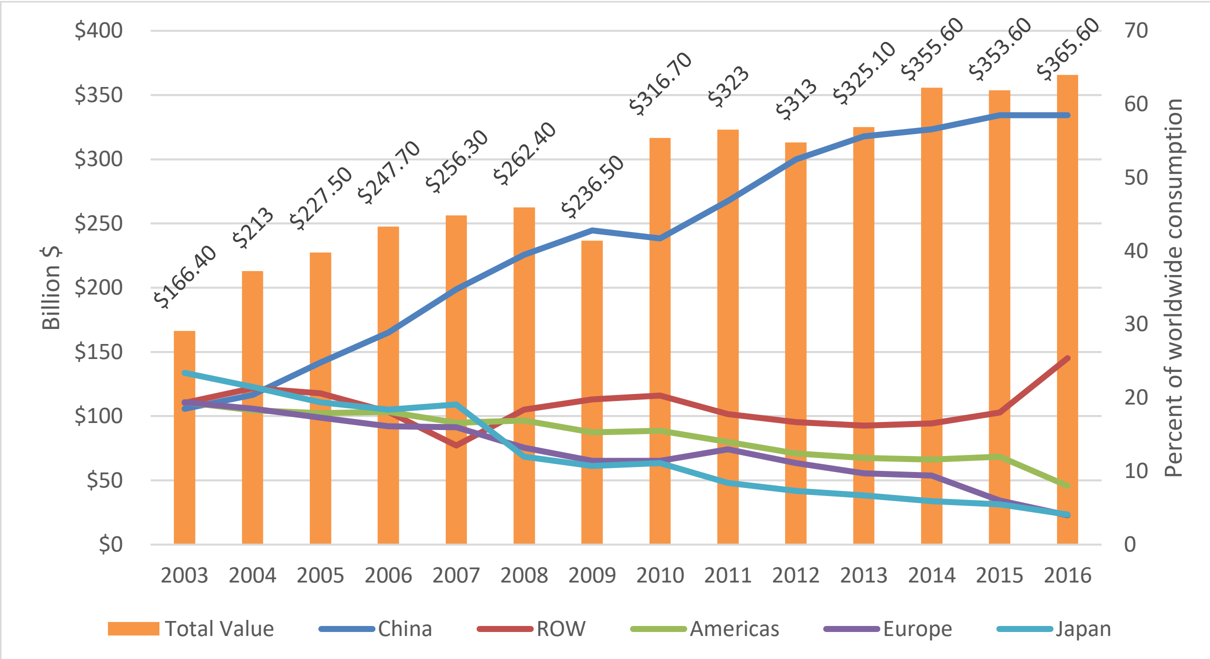
Source: IC Insights, "Nine Top-15 2018 Semi Suppliers Forecast to Post Double-Digit Gains," November 12, 2018.

The Chinese Market and the East Asia Electronics Supply Chain

China is the largest market for semiconductors in terms of consumption, and each of the top 10 worldwide firms in 2018 had a presence in China ranging from R&D centers to fabrication facilities. This is due to the large and growing demand for chips used in goods that China produces and consumes domestically, as well as exports. According to some estimates, 90 percent of the world's smartphones, 65 percent of personal computers, and 67 percent of smart televisions are made in factories located in mainland China, though some of this production is done in facilities operated by non-Chinese-headquartered firms.[13] In addition to assembling these goods for export, China's large and growing demand for chips is fueled by domestic consumption. To take just one example, in 2013 the smartphone penetration rate in China stood at 43 percent; by 2019, it is expected to increase to 63 percent.[14] As figure 2 shows, China has consumed more chips than the rest of the world combined every year since 2012.

[12] IHS Markit, "Global Semiconductor Industry Topped $429 Billion in 2017," March 28, 2018.
[13] Tao, "How China's 'Big Fund' is Helping," May 10, 2018.
[14] Statista, "Share of Mobile Phone Users That Use a Smartphone in China from 2013 to 2019," 2018.

Figure 2: Worldwide semiconductor consumption market by region, 2003–16[15]



Source: PwC, "China's Semiconductor Market," 2017.

Yet, in spite of this reliance on chips and chip-enabled goods, Chinese-headquartered semiconductor firms supply less than 5 percent of the worldwide market and remain at least two generations behind international competitors in their ability to produce semiconductors that are incorporated into these consumer electronics.[16] Some analysis indicates that roughly 90 percent of China's semiconductor consumption is supplied by foreign companies.[17]

Though Chinese-headquartered firms lack worldwide market share, the semiconductor industry has long had a presence in the country. China's central role in the global electronics value chain has prompted many of the leading chip firms to establish back-end assembly, test, and packaging facilities in the country to take advantage of low labor costs and proximity to this market.[18] The SIA estimates that roughly 22 percent of worldwide back-end facilities were located in China in 2017.[19] One metric that portrays this supply chain relationship is the U.S. Census Department's Related Party Trade database, which indicates nearly 60 percent of all U.S. imports of semiconductors from China were actually from U.S.-headquartered firms' China-based subsidiaries in 2017.[20] Given Chinese-headquartered firms' low semiconductor market share, the

[15] PwC, "China's Semiconductor Market," 2017.
[16] SIA, *2018 Factbook*, June 2018, 3.
[17] Udemans, "Nanjing to Create Fund," July 18, 2018.
[18] Torsekar and VerWey, "The East Asia-Pacific's Participation in the Global Value Chain," March 2019.
[19] SIA, "Comments Concerning Proposed Determination of Action," July 20, 2018, 8.
[20] U.S. Census, NAICS Related Party Database (accessed October 30, 2018).

remaining U.S. semiconductor imports were likely imports of chips from non-U.S. semiconductor firms operating subsidiaries in China.[21]

China's Past Semiconductor Industrial Policies: 1956–2014

Previous Study of Chinese Industrial Plans

Past study of Chinese strategic industrial plans highlights patterns of success and failure, lessons which have been incorporated into China's subsequent approaches to industrial development. The goal of China's strategic industrial plans is to accelerate technological advances in a particular industry, on the assumption that such advances will drive growth, increase productivity, and improve living standards. These plans, which cover everything from information technology to agricultural industries, have met with mixed success. Some research into the reasons for this mixed success has examined the fragmentation of power between national and local government, which hinders coordination of policies across the Chinese bureaucracy;[22] the way state support both helps and hinders high-tech firm performance;[23] the role of systemic corruption;[24] the misallocation of capital to state-owned enterprises;[25] and the lack of firm-level capacity to absorb FDI-related knowledge spillovers.[26]

In spite of these challenges, Chinese industrial planning has resulted in some notable triumphs. Recent scholarship has analyzed particular industries that have enjoyed success, looking at the role of reverse engineering in accelerating the development of domestically manufactured high-speed railways,[27] the way local government efforts in Shanghai fostered competitive auto industry supply chains,[28] and the extent to which state policy has at once helped and hindered development in the Chinese telecommunications industry.[29]

In addition to industry-specific research, a body of literature looking at the reasons for planning successes has focused on the role of joint ventures in accelerating technology transfer,[30] the positive effects of five-year plans (FYPs) on Chinese state-owned enterprises,[31] and how FDI positively affects China's manufacturing performance with regard to capacity, intensity and quality.[32] Recent scholarship has also looked at the relationship between high-tech manufacturing

[21] Intel Corporation reports not being aware of any Chinese-headquartered company microprocessors currently sold in the United States. Intel, "Comments Concerning Proposed Action," July 23, 2018, 3.
[22] Moore, *China in the World Market*, March 2002.
[23] Fuller, *Paper Tigers, Hidden Dragons*, July 2016.
[24] Wedeman, *Double Paradox*, 2012.
[25] Moore, *China in the World Market*, March 2002; Huang, *Selling China*, 2003.
[26] Lu, Tao, and Zhu, "Identifying FDI Spillovers," 2017.
[27] Lin, Qin, and Xie, "Technology Transfer and Domestic Innovation," December 2015.
[28] Thun, "Industrial Policy, Chinese-Style," September-December 2004. A later work by Brandt and Thun (2010) calls in to question the efficacy of Shanghai's auto policy.
[29] Harwit, *China's Telecommunications Revolution*, 2008.
[30] Jiang et al., "International JVs and Internal vs. External Technology Transfer," March 2018.
[31] Chen, Li, and Xin, "Five Year Plans, China Finance and Their Consequences," September 2017.
[32] Zhang, "China's Manufacturing Performance," 2015.

complexity, the difficulty of knowledge diffusion, and the importance of absorptive capacity as possible explanations for why certain Chinese industrial upgrading initiatives have failed.[33]

Serious scholarly analysis of the Chinese semiconductor industry began in the late 1980s with a study of the nascent industry concentrated around Shanghai, focusing on China's semiconductor-related bureaucracy and the policies that were designed to help the industry.[34] As the industry grew and gained international attention in the 1990s, several studies looked at the effect of semiconductor-related FDI in China[35] and the implications of the Chinese industry's development on competitor countries.[36] Other studies have concentrated on the successes and failures of particular semiconductor planning initiatives[37] or segments of the industry, including IC design[38] and foundries.[39] Several academic dissertations have also provided definitive narratives of the industry's development in an effort to understand why some of China's semiconductor industrial plans have succeeded while others have failed, as well as how China has learned (or failed to learn) from its efforts.[40]

Part one of the present analysis synthesizes the history of China's past efforts at semiconductor industrial planning, describes the current plans, and discusses their execution to date. Part two of this analysis describes why previous plans have failed, details how lessons learned from past failures have been incorporated into current plans, and examines their prospects for success.

Chinese Semiconductor Industrial Plans

China has a long history of strategic industrial planning related to semiconductors, dating from 1956 to the present.[41] In the last decade, China has issued over 100 science, technology, and sectoral development plans singling out domestic semiconductor industry development among their key objectives.[42] Some estimates indicate that the Chinese central and local governments spent 100 billion RMB ($14.7 billion) per FYP for each of the FYPs leading up to 2014.[43] The Chinese government has prioritized the development of a domestically competitive and commercially viable semiconductor industry for decades because it considers semiconductors to be a strategic technology and finds that control over semiconductor production confers both economic and national security benefits. Because this analysis focuses on policy rather than industrial evolution, the time periods into which the Chinese semiconductor industry's development are broken below reflect significant changes in industrial planning rather than technological advances.

[33] Gilli and Gilli, "Why China Has Not Caught Up Yet," Winter 2018/19.
[34] Simon and Rehn, *Technological Innovation in China*, 1988.
[35] Klaus, "Red Chips," 2003.
[36] Wu and Loy, "Rapid Rise of China's Semiconductor Industry," 2004.
[37] Li, *From Classic Failures to Global Competitors*, August 2011.
[38] Fuller, "China's National System of Innovation," 2009; Fuller, Akinwande and Sodini, "The Globalization of R&D's Implications for Technological Capabilities," 2017.
[39] Li, "Development of the Chinese IC Foundries," April 2016.
[40] Fuller, *Creating Ladders Out of Chains*, June 2005; Feng, *Catching Up or Being Dependent*, 2010; Mays, *Rapid Advance*, 2013.
[41] For an indicative list of semiconductor-related industrial plans, see appendix B.
[42] USTR, *Section 301 Report*, March 2018, 10.
[43] Fuller, "Limited Catch-Up in China's Semiconductor Industry," May 2019, 421.

Chinese Semiconductor Industrial Plans: 1956–1990

The Chinese semiconductor industry from 1956 to 1990 was characterized by state-led planning that emphasized indigenous innovation. China's State Council convened a group of scientists to develop an "Outline for Science and Technology Development, 1956–1967" which identified semiconductor technology as a "key priority." Soon thereafter, five major Chinese universities began offering semiconductor-related degrees.[44] In addition to workforce education, several factories began operations, the most notable being the Huajing Group's Wuxi Factory No. 742; beginning in 1960, this factory trained many of the nascent Chinese industry's experts and would be instrumental in later strategic industrial plans. By 1965, when the Chinese Academy of Science started IC research, the industry was far ahead of those in Taiwan and South Korea and "at least as sophisticated as Japan."[45]

During this period, activities in the industry were split: R&D was conducted in state-run labs, while manufacturing was done by state-owned factories, and the activities were rarely co-located. This separation made it difficult for technology developed in state labs to be transferred and manufactured in the factories. In addition, of the roughly 40 factories engaged in semiconductor-related manufacturing in the 1970s, most were producing simple diodes and transistors rather than ICs. The Cultural Revolution (1965–75) exacerbated these problems, effectively interrupting all the progress that had been made by the industry.

The period of reform and "opening" inaugurated by Deng Xiaoping in 1978 fundamentally changed the Chinese economy and China's chip industry. In the early 1980s the State Council, under the auspices of the sixth FYP (1981–85), created a "Computer and Large Scale IC Lead Group" with the intention of modernizing the domestic semiconductor industry.[46] By 1985, state-owned factories had imported 24 secondhand semiconductor manufacturing lines at a cost of 1.3 billion RMB,[47] though only one factory (the Wuxi Factory No. 742 mentioned above) met production targets.[48] The result of this very limited success was a shift by Chinese industry officials to "narrow and deepen" state-led upgrading efforts from over 30 enterprises to just 5 "key" firms.[49] In spite of these efforts, the result of the cumulative setbacks was an industry that never caught up with world leaders. One American researcher visiting a Shanghai factory in the mid-1980s found it was producing chips that were 10–15 years out of date on wafers with yields[50] as low as 20 to 40 percent.[51]

---

[44] Mays, *Rapid Advance*, 2013, 68.
[45] Fuller, *Paper Tigers, Hidden Dragons*, July 2016, 117–18.
[46] Li, "State, Market, and Business Enterprise," April 2016, 5.
[47] Roughly $480 million using the historic average for 1985 USD-RMB exchange rates. https://www.macrotrends.net/2575/us-dollar-yuan-exchange-rate-historical-chart.
[48] Li, "Development of the Chinese IC Foundries," April 2016, 5.
[49] Mays, *Rapid Advance*, 2013, 66.
[50] "Yield" refers to the percentage of operable dies per wafer. Semiconductor manufacturers are always attempting to increase wafer yield. For state-of-the-practice or legacy chips, good yields are typically in the 90 percent range.
[51] Fuller, *Creating Ladders Out of Chains*, June 2005, 252–53; Li, "State, Market, and Business Enterprise," April 2016, 4.

Chinese Semiconductor Industrial Plans: 1990–2002

Throughout the 1990s, the Chinese government pursued a hybrid model of industrial development, endowing a few large firms with the majority of available funds so that they could pursue partnerships with foreign companies in an effort to accelerate progress.[52] Joint ventures with Nortel (Canada), Philips (Netherlands), NEC (Japan), and ITT (Belgium) all began in the late 1980s and early 1990s.[53] Beginning with the eighth (1991–95) FYP, China attempted to develop Huajing (operator of Wuxi Factory No. 742) into a leading IDM, endowing it with 2 billion RMB[54] and negotiating a joint-venture relationship with Lucent Technologies (USA) to facilitate technology transfer.[55] However, the plan (known as Project 908) took eight years to go from idea to reality, resulting in a joint venture that used old manufacturing equipment and process technologies to produce chips that lagged behind the industry's leaders by the time they were brought to market.[56]

China's Ninth FYP (1996–2000) inaugurated Project 909, which called for the development of domestic chips made by an internationally competitive firm using Chinese IP and engineers.[57] A designated Chinese firm, Huahong, successfully leveraged a partnership with NEC (Japan) to enter production on time (avoiding the delays of Project 908) and bring dynamic random access memory (DRAM) chips to market. This success is notable, though it was partially due to the terms of the joint venture, which allowed NEC to copy the fabrication facility's layout from an existing plant and staff the Chinese facility primarily with Japanese engineers. While this decision helped bring chips to market on time, it limited knowledge spillovers and, by 2002, a downturn in the worldwide DRAM market led to losses of 700 million RMB in one year.[58] Not long thereafter, Huahong changed its joint-venture partner and operating model, though it remains in operation as of 2019.[59]

Chinese Semiconductor Industrial Plans: 2002–14

The collapse of Projects 908 and 909 did not deter Chinese ambitions for the industry, particularly as China's share of the global semiconductor consumption grew from 2 percent in 1995 to 25 percent in 2005.[60] China also acceded to the World Trade Organization on December 11, 2001, making it a more attractive destination for leading international firms to establish local operations simultaneous to this growth in consumption.[61] Huahong's failure in 2002 occurred just as another notable firm was beginning production. Semiconductor Manufacturing International Corporation (SMIC) was founded by a Taiwanese veteran of Texas Instruments (U.S.) and Worldwide Semiconductor Manufacturing Company (Taiwan) in 2000 as a wholly foreign-owned Shanghai-

---

[52] Mays, *Rapid Advance*, 2013, 4.
[53] Li, "Development of the Chinese IC Foundries," April 2016, 5.
[54] Roughly $377 million using historic average for 1991 USD-RMB exchange rates. https://www.macrotrends.net/2575/us-dollar-yuan-exchange-rate-historical-chart.
[55] Fuller, *Paper Tigers, Hidden Dragons*, July 2016, 117–18.
[56] Li, "Development of Chinese Semiconductor Industry," 2011, 25.
[57] Fuller, *Creating Ladders Out of Chains*, June 2005, 260.
[58] Li, "Development of Chinese Semiconductor Industry," 2011, 27.
[59] See appendix B of VerWey, "Chinese Semiconductor Industrial Policy—Prospects for Future Success," August 2019, for Huahong's current production capabilities.
[60] Mays, *Rapid Advance*, 2013, 124.
[61] Hong, "WTO Accession and FDI in China," 2008.

based foundry. Since starting volume production in 2002, it has emerged as the largest and most advanced chip maker in China and is currently among the top five foundries in the world. Leveraging Chinese central and local government support, including a five-year tax holiday (and another five-year tax break at 50 percent of standard rates), tariff exemptions, reduced value-added tax rates, and loans from state-owned banks, SMIC has pursued a largely successful fast-follower strategy. In particular, SMIC has used partnerships with foreign firms and recruited ethnic Chinese engineers (primarily returnees from the United States, Taiwan, and Singapore) to keep the firm only one to two years behind the industry's leading firms.[62]

In 2005, China's State Council issued a *National Medium- and Long-Term Science and Technology Development Plan Outline* for 2006–20 (MLP), which articulated a holistic vision of the technology ecosystem, recognizing the importance of semiconductors as an enabling hardware and "core technology" for future advances. The MLP spurred subsequent supporting documents and policies, one of which promoted the concept of IDAR: Introducing, Digesting, Absorbing, and Re-innovating intellectual property and technologies as a means of industrial catch-up.[63] This concept emphasized targeted acquisitions of foreign technology as well as state and industry collaboration to analyze, distribute, and develop products using the technology gleaned from these acquisitions, with the ultimate goal being indigenous innovation derived from these efforts.[64] China's current efforts to promote its semiconductor industry illustrate how the IDAR concept has been executed.

China's Current Semiconductor Industrial Policies: 2014–Present

China's current goals for the development of its domestic semiconductor industry are ambitious. A recent report from the Office of the United States Trade Representative (USTR) frames these goals in black and white terms:

> "China's strategy calls for creating a closed-loop semiconductor manufacturing ecosystem with self-sufficiency at every stage of the manufacturing process—from IC design and manufacturing to packaging and testing, and the production of related materials and equipment."[65]

This analysis echoes an earlier assessment of China's policies from the SIA, which noted:

> "Some of these policies have the potential to: (1) force the creation of market demand for China's indigenous semiconductor products; (2) gradually restrict or block market access for foreign semiconductor products as competing domestic products emerge; (3) force the transfer of technology; and (4) grow non-market based domestic capacity, thereby disrupting the fabric of the global semiconductor value chain."[66]

[62] Mays, *Rapid Advance*, 2013, 234; Fuller, *Paper Tigers, Hidden Dragons*, July 2016, 132.
[63] USTR, *Section 301 Report*, March 22, 2018, 12.
[64] USTR, *Section 301 Report*, March 22, 2018, 12–13.
[65] USTR, *Section 301 Report*, March 22, 2018, 113.
[66] Goodrich, "China's 13th Five Year Plan," April 27, 2016, 6.

China's goals and implementing guidelines are spelled out in three documents released in 2014 and 2015: *The Guidelines to Promote a National Integrated Circuit Industry*, *Made in China 2025*, and *The Made in China 2025 Technical Area Roadmap*. After detailing the structure and content of each plan, their execution to date will be discussed in detail.

The National Integrated-Circuit Plan and Fund

In June 2014, the Chinese Government released *Guidelines to Promote National Integrated Circuit Industry* (National IC Plan). This document articulates a well-defined strategy that identifies "national champions" supported by ample funds and bolstered by policies promoting inbound and outbound FDI that is designed to accelerate technology transfer and bring China's semiconductor industry on par with leading international competitors.[67] While some ideas were recycled from earlier proposals, the document represented a departure from them in both its level of detail and its focus on inbound and outbound FDI.[68] Notably, the 2014 Guidelines called for the establishment of a National Integrated Circuit Investment Fund (National IC Fund). Endowed with $150 billion in funds from the central and provincial governments, this fund was tasked with acquiring companies throughout the semiconductor supply chain.

Since it was launched in September 2014, the National IC Fund has engaged in a two-pronged strategy. On one hand, it funds outbound FDI to acquire foreign companies. On the other, it provides funds to facilitate inbound FDI such as greenfield investment and joint ventures with non-Chinese companies to help realize the vision of the National IC Plan. Analysis of where the National IC Fund's capital comes from reveals that it is largely endowed by state-owned enterprises and financial institutions. A filing from Nantong Tongfu Microelectronics, which counts the Fund as an investor, indicates that the Ministry of Finance is the Fund's largest shareholder with a 36.74 percent share, followed by the China Development Bank Capital Corporation (22.29 percent share) and China Tobacco (11.14 percent share).[69]

In addition to the National IC Fund, multiple local and regional governments have established their own IC-related funds, received capital from the National IC Fund, or invested in the National IC Fund. For example, both Beijing E-Town International Investment and Development Co. (an investment vehicle owned by the municipality of Beijing) and Shanghai Guosheng Group (an investment vehicle owned by the municipality of Shanghai) have invested in the National IC Fund, while regional governments in Hubei, Fujian, and Anhui provinces have stood up IC-related investment funds of their own.[70] The SIA estimated that, as of 2017, while the National IC Fund had secured roughly $21 billion in funding, provincial and municipal IC-related funds have raised over $80 billion and are well on their way to reaching the goal of $150 billion.[71] In 2018 news reports indicated that the National IC Fund was in talks with the Chinese government to establish a second investment vehicle valued at $47 billion.[72]

[67] State Council, "The National Outline of the Development," June 24, 2014.
[68] U.S. Chamber of Commerce, *Made in China 2025*, March 16, 2017.
[69] Tao, "How China's 'Big Fund' is Helping," May 10, 2018. See also USTR, *Section 301 Report*, March 22, 2018, 93.
[70] Adapted from USTR, *Section 301 Report*, March 22, 2018, 93–94.
[71] Adapted from USTR, *Section 301 Report*, March 22, 2017, 92 and 94.
[72] Crichton, "China New Chip Fund," May 7, 2018.

Made in China 2025

Less than one year after the National IC Plan was announced, the Chinese government released "Made in China 2025," an initiative designed to develop select manufacturing sectors in to worldwide industry leaders. Ten sectors, which cumulatively constitute 40 percent of China's value-added manufacturing,[73] were identified: next generation information technology, controlling instruments and robotics, aerospace and aviation equipment, maritime equipment and shipbuilding, railway equipment, energy-efficient and new-energy vehicles, electrical equipment, new materials, medical devices, and agricultural machinery. Made in China 2025's goal is to cultivate high quality manufacturing sectors capable of producing advanced products at modern facilities operated by well-known brands, ultimately increasing the market share of Chinese companies to meet domestic and international demand. A series of national and provincial funds were established to facilitate indigenous R&D, acquisition of technology from overseas, and cultivate the technology, intellectual property, and brand identity necessary to achieve this goal.

The announcement of the Made in China 2025 initiative reiterated China's focus on next generation information technology, with reference to semiconductors and, more specifically, ICs. On the heels of the National IC Guidelines and Made in China 2025, in October 2015 the State Council issued a Technical Area Roadmap, establishing non-binding goals for the next generation information technology sector to "develop the IC design industry, speed up the development of the IC manufacturing industry, upgrade the advanced packaging and testing industry, facilitate breakthroughs in the key equipment and materials of integrated circuits."[74] By 2020, the Roadmap suggests that China's semiconductor design and manufacturing should be one to two generations behind industry leaders and supported by, a robust domestic supply chain of equipment, material at ATP service suppliers. By 2030 the roadmap specifies that "the main segments of the IC industry . . . reach advanced international levels."[75] Another document released in 2015, China's 13th FYP (2016–20), was even more specific, prioritizing the development of DRAM chips (reminiscent of Huahong's Project 909 attempt) to lessen its dependence on memory chips from the United States.[76]

Implementing the Plan: Subsidies[77]

The National IC Plan and Made in China 2025 represent China's current semiconductor industrial plans. Taken together, these two strategies propose that the Chinese semiconductor industry adopt a "fast-follower" approach. In this scenario, the industry will leapfrog ahead several generations to catch up with international competitors at a time when the decay of Moore's Law is slowing the ability of leading firms to win the innovation race simply by building faster and more powerful chips.

---

[73] U.S. Chamber of Commerce, *Made in China 2025*, March 16, 2017, 10.
[74] State Council, "Made In China 2025 Technical Roadmap," October 29, 2015, 2.
[75] U.S. Chamber of Commerce, *Made in China 2025*, March 16, 2017, 65.
[76] USTR, *Section 301 Report Update*, November 20, 2018, 17.
[77] A January 2017 report from the President's Council of Advisors on Science and Technology Policy (PCAST) identifies subsidies and zero-sum tactics as the primary tools of the current Chinese semiconductor industrial policy. The terms are adopted for use here without bias.

Essential to China's semiconductor industrial plan are subsidies, which take the form of regional, provincial, and national funds (such as the National IC fund); investment vehicles; and policies that incentivize industry investment, such as tax breaks.[78] To understand the importance and scale of the funds China is directing at the semiconductor industry, it is worth bearing in mind two points. First, out of the 11 funds the U.S. Chamber of Commerce has identified as targeting Made in China 2025 industries, the National IC Fund is the second largest, behind only a more-general Special Constructive Fund.[79] Second, advances in the semiconductor industry require enormous capital expenditures. The R&D required to design an advanced chip can easily exceed one billion dollars. However, to then build a new factory capable of fabricating that advanced chip design is among the largest capital expenditures a private company can incur across any industry. For example, TSMC's newest factory in Taiwan—which, when completed, will manufacture some of the most advanced chips in the world—is expected to cost $16 billion.[80]

The fact that the Chinese government chose to establish a fund dedicated to promoting this industry, and then endowed it with a sum of money capable of building over 20 leading-edge manufacturing facilities, speaks to the importance the government places on developing indigenous capabilities in this industry. In addition to setting up funds, there are also more direct measures of support, such as exemptions from corporate income taxes for semiconductor companies.

Foreign Direct Investment

The influx of money from national and subnational funds has prompted a dramatic increase in outbound Chinese FDI in the semiconductor industry. A recent report from USTR characterizes this increase in no uncertain terms:

> Since 2014, when the government issued the Guidelines, Chinese companies and investors—often backed by state capital—have undertaken a series of acquisitions to achieve technology breakthrough, shrink the technology gap between China and advanced countries, cultivate domestic innovation clusters, and reduce China's reliance on IC imports.[81]

Research by the Rhodium Group indicates that, before 2014, Chinese companies engaged in only six mergers or acquisitions (M&A) with U.S.-based semiconductor companies, valued at $213.8 million total. By 2016, taking advantage of newly available funds, the number of announced mergers and acquisitions grew to 34 U.S. companies, and the total value of completed transactions reached $8.1 billion. An analysis published at the end of 2017 put the number closer to $11 billion (see appendix B for a complete list).[82]

In addition, large sums of Chinese venture capital money has targeted the U.S. chip industry. The most notable instance is Canyon Bridge Partners' bid for Lattice Semiconductor (which was nixed

[78] Cadell, "China Cuts Tax Rates for Chipmakers," March 30, 2018.
[79] U.S. Chamber of Commerce, *Made in China 2025*, March 16, 2017, 64.
[80] TSMC, "TSMC Breaks Ground on Fab 18," January 26, 2018.
[81] Adapted from USTR, *Section 301 Report*, March 22, 2018, 114.
[82] Yue and Lu, "China's Latest Semiconductor M&A," November 16, 2017.

by the U.S. government on national security grounds[83]); more generally, there are funds like Danhua Capital (now known as Digital Horizon Capital), which has invested in 113 U.S. companies engaged in industries that the Chinese government has flagged as "strategic priorities."[84] These investments have included companies throughout the semiconductor supply chain, from upstream equipment manufacturers and IP owners to downstream companies that specialize in assembly, test and packaging. This M&A has not been directed towards the development of a particular chip but rather has included everything from companies that specialize in memory chips, to microelectronic mechanical devices (MEMS), to chips built on non-silicon materials.[85]

Chinese outbound investment has not been limited to the U.S. industry. Other countries with advanced semiconductor companies have seen a similar spike in M&A activity from newly acquisitive Chinese investors. As a condition of its acquisition of Freescale Semiconductor, NXP Semiconductors (The Netherlands) was forced to divest its Radio Frequency (RF) business unit by the U.S. Federal Trade Commission. Subsequent to this divestiture, the RF business unit was acquired by Jianguang Asset Management and Wise Road Capital, two investors with ties to the Chinese government.[86] More recently the China Development Bank and the National IC Fund partnered with municipal and national government entities as well as state-owned enterprises in the acquisition of STATS ChipPAC, a Singapore-based packaging and testing company.[87]

Chinese acquisitions became subject to scrutiny in 2016 when an increase in overtures from Chinese companies interested in Germany's advanced manufacturing industry elicited fears that some of the country's "crown jewels" could be uprooted.[88] The acquisition of Kuka, a robotics company, and rumors of a Chinese bid for Munich-based lighting and semiconductor manufacturer Osram Licht raised concerns among German policymakers.[89] Not long thereafter, Aixtron, a German manufacturer of equipment used in the semiconductor manufacturing process, saw its stock price collapse following the cancellation of a major order from a Chinese customer while it was considering a takeover offer from a separate Chinese investor. It later emerged that Aixtron's prospective investor had unannounced ties with the company that cancelled their order, leading to speculation that the decline in Aixtron's value had been engineered and ultimately resulted in the German government and U.S. Committee on Foreign Investment in the United States blocking the transaction.[90] Subsequent analysis of both the Chinese customer and prospective investor revealed ties to the Chinese central government.[91]

[83] Executive Order Regarding the Proposed Acquisition of Lattice Semiconductor Corporation by China Venture Capital Fund Corporation Ltd., 82 Fed. Reg. 43665, September 13, 2017.
[84] USTR. *Section 301 Report Update*, November 20, 2018, 47.
[85] Hanemann and Rosen, *Chinese Investment in the U.S.*, December 2016.
[86] Wübbeke et al., *Made in China 2025*, December 12, 2016, 51.
[87] China Development Bank, "Investment Strategies," 2015.
[88] Mozur and Ewing, "Rush of Chinese Investment," September 16, 2016.
[89] Mozur, "Germany Withdraws Takeover Approval," October 24, 2016.
[90] Mozur, "Obama Blocks Chinese Acquisition," December 2, 2016.
[91] Wübbeke et al., *Made in China 2025*, December 12, 2016, 53.

Implementing the Plan—Joint Venture and Tech Transfer Requirements

Investment Restrictions: Joint Ventures

Though international semiconductor companies have had ample incentives to establish operations in China in order to take advantage of low wages and a growing consumer base, they have also been compelled to do so in order to gain market access. According to the Organisation for Economic Co-operation and Development (OECD), China maintains the most restrictive inward FDI policies of any G20 country.[92] The Information Technology and Innovation Foundation has noted that "in most cases, U.S. technology firms seeking market access in China must engage in a joint venture with a Chinese firm." A recent report by the Office of the United States Trade Representative [93] indicates that Chinese government officials may condition approval of investments based on:

- Foreign equity caps and joint-venture requirements
- The maintenance of a case-by-case administrative approval system for a broad range of investments
- A requirement that a foreign enterprise transfer technology
- A requirement that a foreign enterprise conduct R&D in China
- A requirement that a foreign enterprise satisfy performance requirements relating to exportation or the use of local content, or make valuable, deal-specific commercial concessions.

Because of China's importance to the global electronics value chain and the size of the Chinese market, U.S. semiconductor firms accept these restrictions while attempting to mitigate them. As a result, most leading semiconductor firms in the United States engaged in greenfield FDI or a joint venture in China between 2014 and 2018. Table 2 details inbound FDI announced by select leading U.S. semiconductor firms since the National IC Plan was instituted in 2014.

National, provincial, and local funding made available through the National IC Plan and Made in China 2025 has incentivized multinational corporations (MNCs) to establish joint ventures or expand existing partnerships. Intel (U.S.), SK Hynix (South Korea), and Samsung (South Korea) are all taking advantage of subsidized loans from the Chinese government to expand their existing operations in China, while the world's three leading foundries—GlobalFoundries (U.S.), TSMC (Taiwan), and UMC (Taiwan)—have announced their intention to set up new fabrication facilities in the country.[94]

In spite of these considerable investments, leading semiconductor firms have not chosen to locate their leading-edge operations in the country. In fact, while Intel, SK Hynix and Samsung all have large operations devoted to meeting the Chinese market's demand for memory chips, the great majority of their advanced production still occurs in their home country. Part of the reason for this decision is that semiconductors are generally traded tariff free. This means that as long as

[92] OECD, FDI Regulatory Restrictiveness Index, May 16, 2018.
[93] USTR, "National Trade Estimate Report," March 30, 2018, 93.
[94] Fuller, "Limited Catch-Up in China's Semiconductor Industry," May 2019, 436. Note that the GlobalFoundries facility is currently on hold.

firms have well-managed supply chains, supplying advanced products to the Chinese market from overseas facilities has few added costs. Another reason is that, as will be discussed in the next section, large MNCs are wary of investing in high-value manufacturing in China for fear of theft.

Table 2: Select U.S. semiconductor firms' foreign direct investments in China, 2014–18

Announced date	Non-Chinese company	Chinese company
Jan-14	IBM	Suzhou PowerCore
Mar-14	IBM	Teamsun
Sep-14	Intel	Tsinghua Unigroup
Nov-14	Texas Instruments	Existing Texas Instruments facility expansion
Dec-14	Micron	PowerTech (Taiwan)
Jan-15	Qualcomm-IMEC	SMIC, Huawei
May-15	Hewlett-Packard	Tsinghua Holdings (Unisplendour)
Jun-15	Broadcom	H3C Technologies Co.
Sep-15	Cisco Systems	Inspur Group
Dec-15	Qualcomm	SJ Semi (SMIC & Jiangsu Changjiang Electronics Technology JV)
Jan-16	Qualcomm*	Guizhou Province (Huaxintong)
Jan-16	Intel	Tsinghua University and Montage Technology Global Holdings
Apr-16	AMD	Tianjin Haiguang Advanced Technology Investment Company
May-16	Brocade	Guizhou High-Tech Industrial Investment Group
May-16	Dell	Guizhou YottaCloud Technologies
May-16	VMWare	Sugon Information
Sep-16	Western Digital	Tsinghua Unigroup (Unisplendour)
Feb-17	GlobalFoundries	Chengdu Municipality
Mar-17	IBM	Wanda Internet Technology Group
Jul-17	Nvidia	Baidu
Feb-18	Intel	Tsinghua Unigroup (Spreadtrum & RDA)
May-18	Qualcomm	Datang Telecom Technology Co.

Note: * = Since dissolved.

Source: Compiled by author.

Technology Transfer Requirements

Tacit and explicit requirements that compel semiconductor firms to engage in joint ventures with Chinese counterparts and transfer technology in return for market access are not new phenomena, but they form part of China's current strategic plans for the semiconductor industry. Technology transfer requirements[95] imposed on U.S. semiconductor companies are rarely aired publicly, given their sensitive nature. However, a 2017 survey by the U.S.-China Business Council found that 19 percent of responding companies had fielded at least one request to transfer technology to China in the past year and, of that number, one-third of those requests came from a central government

[95] "Technology transfer is a process by which technology developed in one organization, in one area, or for one purpose is applied in another organization, in another area, or for another purpose." Schacht, "Technology Transfer," December 3, 2012, 1.

authority.[96] The U.S. Department of Commerce's Bureau of Industry and Security, which conducted a survey of the IC design and manufacturing industry in the United States in 2017, found that 25 companies in the U.S. industry indicated they would have to form joint ventures with Chinese entities and/or transfer IP in order to maintain market access.[97] Notably, the responding companies were not minor players in the industry, but rather generated $25 billion in total sales and manufactured 26 percent of all ICs made and sold in the United States.[98]

A good example of the challenges faced by U.S. semiconductor firms operating in China is the recent history of Micron, the Idaho-based memory chip company that holds 20–25 percent market share for dynamic random access memory chips.[99] After fielding and rejecting an unsolicited $23 billion takeover bid from China's Tsinghua Unigroup in 2015, Micron then had the head of its Taiwan-based joint venture poached by Tsinghua Unigroup. Not long thereafter, several employees of Micron's Taiwan-based joint venture were charged by Taiwanese prosecutors with stealing Micron IP (valued at $8.75 billion) and sharing it with Tsinghua Unigroup and Fujian Jinhua Integrated Circuit Company (a firm owned by the Chinese province of Fujian) to aid in their own development of DRAM. When Micron sued Fujian Jinhua for IP theft, Fujian Jinhua responded by suing Micron's subsidiaries in China for infringing on their patents, the very patents which were based on Micron's stolen technology.[100] A Chinese court ruled in the Chinese firm's favor in July 2018. Simultaneous to this litigation is an ongoing antitrust investigation being conducted by China's regulatory authorities into price fixing in the memory chip market, which implicates Micron. This same regulatory authority, the National Development and Reform Commission, earlier fined Qualcomm, the largest fabless chip firm in the United States, $975 million for overcharging for patent royalties.

Conclusion

The Chinese government's efforts to promote a commercially viable domestic semiconductor industry have met with mixed success. China's reliance on semiconductor imports, due to both its increasing domestic consumption and its centrality to the global electronics value chain, continues to motivate government plans to support the development of an indigenous industry. The 2014 Guidelines to Promote a National Integrated Circuit Industry and Made in China 2025 announced in 2015 represent the latest attempts by the Chinese government to realize this goal. A review of the history of China's semiconductor industrial planning demonstrates the ongoing tension between state planning and the industry's ability to compete internationally. In spite of this tension, China's most recent plans, which incorporate lessons learned from the past, stand a greater chance of success than any previous iteration.

[96] USTR, *Section 301 Report*, March 22, 2018, 22.
[97] USTR, *Section 301 Report*, March 22, 2018, 23.
[98] USTR, *Section 301 Report*, March 22, 2018, 23.
[99] This narrative is taken in part from USCC, *July 2018 Trade Bulletin*, July 9, 2018, 9–11.
[100] Demers, "China's Non-Traditional Espionage," December 12, 2018, 5–6.

Bibliography

Bailey, Brian. "The Impact of Moore's Law Ending." Semiconductor Engineering, October 29, 2018. https://semiengineering.com/the-impact-of-moores-law-ending/.

Brandt, Loren, and Eric Thun. "The Fight for the Middle: Upgrading, Competition, and Industrial Development in China." *World Development*, 2010. http://groups.chass.utoronto.ca/brandt/wp-content/uploads/Brandt-and-Thun_WD.pdf.

Cadell, Cate. "China Cuts Tax Rates for Chipmakers amid Trade Tensions." Reuters, March 30. 2018. https://www.reuters.com/article/us-china-semiconductors-taxbreaks/china-cuts-tax-rates-for-chipmakers-amid-trade-tensions-idUSKBN1H60JM.

Chen, Donghua, Oliver Zhen Li, and Fu Xin. "Five Year Plans, China Finance and Their Consequences." *China Journal of Accounting Research* 10, no. 3 (September 2017). https://www.sciencedirect.com/science/article/pii/S1755309117300199.

China Development Bank. "Integrated Circuit Investment Strategies," 2015. http://www.cdb-capital.com/GKJR/integrateden/list.

Crichton, Danny. "China Closing in on Massive New Chip Fund in Bid to Dominate US Semiconductor Industry." TechCrunch, May 7, 2018. https://techcrunch.com/2018/05/07/china-chip-fund/.

Demers, John C. "Statement Before the Committee on the United States Senate Judiciary Committee for a Hearing on China's Non-Traditional Espionage Against the United States." United States Senate, December 12, 2018. https://www.justice.gov/sites/default/files/testimonies/witnesses/attachments/2018/12/18/12-05-2018_john_c._demers_testimony_re_china_non-traditional_espionage_against_the_united_states_the_threat_and_potential_policy_responses.pdf.

Feng, Kaidong. *Catching Up or Being Dependent: The Growth of Capabilities Among Indigenous Technological Integrators During Chinese Development*. Doctoral dissertation, University of Sussex, 2010. http://sro.sussex.ac.uk/6277/.

Fuller, Douglas B. "China's National System of Innovation and Uneven Technological Trajectory: The Case of China's Integrated Circuit Design Industry." *Chinese Management Studies* 3, no. 1 (2009). https://papers.ssrn.com/sol3/papers.cfm?abstract_id=1342752.

Fuller, Douglas B. *Creating Ladders Out of Chains: China's Technological Development in a World of Global Production*. Doctoral dissertation, Massachusetts Institute of Technology, June 2005. https://dspace.mit.edu/handle/1721.1/33681.

Fuller, Douglas B. "Growth, Upgrading and Limited Catch-Up in China's Semiconductor Industry." *Policy, Regulation and Innovation in China's Electricity and Telecom Industries*. Cambridge, UK: Cambridge University Press (May 2019): 262−303 .

Fuller, Douglas B. *Paper Tigers, Hidden Dragons: Firms and the Political Economy of China's Technological Development*. Oxford, UK: Oxford University Press, July 2016.

Fuller, Douglas B., Akintunde I. Akinwande, and Charles G. Sodini. "The Globalization of R&D's Implications for Technological Capabilities in MNC Home Countries: Semiconductor Design Offshoring to China and India." *Technological Forecasting and Social Change* 120 (2017): 14–23. https://www.sciencedirect.com/science/article/pii/S0040162517304080.

Gilli, Andrea, and Mauro Gilli. "Why China Has Not Caught Up Yet." *International Security* 43, no. 3 (Winter 2018/19). https://www.mitpressjournals.org/doi/abs/10.1162/isec_a_00337.

Goodrich, Jimmy. "China's 13th Five-Year Plan: Opportunities and Challenges for the U.S. Semiconductor Industry." Written testimony submitted to the U.S. China Economic and Security Review Commission, April 27, 2016. https://www.uscc.gov/sites/default/files/Jimmy%20Goodrich_Written%20Testimony%20042716.pdf.

Hanemann, Thilo, and Daniel H. Rosen. "Chinese Investment in the United States: Recent Trends and the Policy Agenda." Rhodium Group, December 2016. https://rhg.com/research/chinese-investment-in-the-united-states-recent-trends-and-the-policy-agenda/.

Harwitt, Eric. *China's Telecommunications Revolution*. Oxford, UK: Oxford University Press, May 2008.

Hong, Junjie. "WTO Accession and Foreign Direct Investment in China." *Journal of Chinese Economic and Foreign Trade Studies* 1, no. 2 (2008): 136–47. https://econpapers.repec.org/RePEc:eme:ceftpp:v:1:y:2008:i:2:p:136-147.

Huang, Yasheng. *Selling China: Foreign Direct Investment During the Reform Era.* Cambridge, UK: Cambridge University Press, 2003.

IC Insights. "Nine Top-15 2018 Semi Suppliers Forecast to Post Double-Digit Gains," November 12, 2018. http://www.icinsights.com/news/bulletins/Nine-Top15-2018-Semi-Suppliers-Forecast-To-Post-DoubleDigit-Gains-/.

IHS Markit. "With Its Highest Growth Rate in 14 Years, the Global Semiconductor Industry Topped $429 Billion in 2017, IHS Markit Says." Press release, March 28, 2018. https://technology.ihs.com/601432/with-its-highest-growth-rate-in-14-years-the-global-semiconductor-industry-topped-429-billion-in-2017-ihs-markit-says.

Intel Corporation. "Comments Concerning Proposed Determination of Action Pursuant to Section 301: China's Acts, Policies, and Practices Related to Technology Transfer, Intellectual Property, and Innovation—Docket Number: USTR-2018-0018," July 23, 2018.

Intel Corporation. "Intel Supports American Innovation with $7 Billion Investment in Next-Generation Semiconductor Factory in Arizona." News release, February 8, 2017. https://newsroom.intel.com/news-releases/intel-supports-american-innovation-7-billion-investment-next-generation-semiconductor-factory-arizona/.

Jiang, Kun, Wolfgang Keller, Larry D. Qui, and William Ridley. "International Joint Ventures and Internal vs. External Technology Transfer: Evidence from China." NBER Working Paper No. 24455, March 2018. https://www.nber.org/papers/w24455.

King, David. "Size Matters: Barriers to Entry in the Microelectronics Industry." National Defense University, January 2003. https://apps.dtic.mil/docs/citations/ADA422057.

Klaus, Michael. "Red Chips: Implications of the Semiconductor Industry's Relocation to China." *Journal of Asian Affairs* 29, no. 4 (2003): 237–53. https://www.tandfonline.com/doi/abs/10.1080/00927670309601508.

Lewis, James A. "Learning from the Superior Techniques of the Barbarians: China's Pursuit of Semiconductor Independence." Center for Strategic and International Studies, January 2019. https://www.csis.org/analysis/chinas-pursuit-semiconductor-independence.

Li, Yin. *From Classic Failures to Global Competitors: Business Organization and Economic Development in the Chinese Semiconductor Industry*. Master's thesis, Fudan University, August 2011. https://www.researchgate.net/publication/304581717_From_Classic_Failures_to_Global_Competitors_Business_Organization_and_Economic_Development_in_the_Chinese_Semiconductor_Industry.

Li, Yin. "State, Market, and Business Enterprise: Development of the Chinese Integrated Circuit Foundries." Chap. 7 in *China as an Innovation Nation*, edited by Yu Zhou, William Lazonick, and Yifei Sun. Oxford, UK: Oxford University Press, April 2016. https://www.researchgate.net/publication/281455103_State_Market_and_Business_Enterprise_Development_of_the_Chinese_Integrated_Circuit_Foundries.

Lin, Yatang, Yu Qin, and Zhuan Xie. "Technology Transfer and Domestic Innovation: Evidence from the High-Speed Rail Sector in China." CEP Discussion Paper No. 1393, Centre for Economic Performance, December 2015. https://qinyurain.weebly.com/uploads/4/7/2/8/47280099/hsrtt_april17.pdf.

Lu, Yi, Zhigang Tao, and Lianming Zhu. "Identifying FDI Spillovers," *Journal of International Economics*, 2017. https://ideas.repec.org/a/eee/inecon/v107y2017icp75-90.html.

Mays, Susan K. *Rapid Advance: High Technology in China in the Global Electronic Age*. Doctoral dissertation, Columbia University, 2013. https://academiccommons.columbia.edu/doi/10.7916/D8HQ464Q.

Moore, Thomas G. *China in the World Market: Chinese Industry and International Sources of Reform in the Post-Mao Era*. Cambridge, UK: Cambridge University Press, March 2002.

Mozur, Paul. "Germany Withdraws Approval for Chinese Takeover of Aixtron." *New York Times*, October 24, 2016. https://www.nytimes.com/2016/10/25/business/dealbook/germany-china-technology-takeover.html.

Mozur, Paul. "Obama Moves to Block Chinese Acquisition of a German Chip Maker." *New York Times*, December 2, 2016. https://www.nytimes.com/2016/12/02/business/dealbook/china-aixtron-obama-cfius.html.

Mozur, Paul, and Jack Ewing. "Rush of Chinese Investment in Europe's High-Tech Firms Is Raising Eyebrows." *New York Times*, September 16, 2016. https://www.nytimes.com/2016/09/17/business/dealbook/china-germany-takeover-merger-technology.html.

Organisation for Economic Co-operation and Development (OECD). FDI Regulatory Restrictiveness Index. http://www.oecd.org/investment/fdiindex.htm (accessed May 16, 2018).

President's Council of Advisors on Science and Technology (PCAST). *Ensuring Long-Term U.S. Leadership in Semiconductors*, January 2017. https://obamawhitehouse.archives.gov/sites/default/files/microsites/ostp/PCAST/pcast_ensuring_long-term_us_leadership_in_semiconductors.pdf.

PwC. "China's Semiconductor Market: 2017 Update," 2017. https://www.pwc.com/gx/en/industries/technology/chinas-impact-on-semiconductor-industry/china-semiconductor-market.html.

Schacht, Wendy H. *Technology Transfer: Use of Federally Funded Research and Development*. U.S. Congressional Research Service (RL33527), December 3, 2012. https://www.nist.gov/document/technologytransferuseoffederallyfundedresearch-developmentpdf.

Semiconductor Industry Association (SIA). *2017 FactBook*, May 2017. http://go.semiconductors.org/2017-sia-factbook-0-0-0.

Semiconductor Industry Association (SIA). *2018 FactBook*, June 2018. http://go.semiconductors.org/2018-sia-factbook.

Semiconductor Industry Association (SIA). "Beyond Borders: The Global Semiconductor Value Chain," May 2016, https://www.semiconductors.org/document_library_and_resources/trade/beyond_borders_the_global_semiconductor_value_chain/.

Semiconductor Industry Association (SIA). "Comments Concerning Proposed Determination of Action Pursuant to Section 301: China's Acts, Policies, and Practices Related to Technology Transfer, Intellectual Property, and Innovation—Docket Number: USTR-2018-0018," July 20, 2018.

Simon, Denis, and Detleft Rehn. *Technological Innovation in China: The Case of the Shanghai Semiconductor Industry*. Pensacola, FL: Ballinger Publishing Company, 1988.

State Council of the People's Republic of China. "Made in China 2025 Technical Area Roadmap" (in Chinese), October 29, 2015. http://www.cae.cn/cae/html/files/2015-10/29/20151029105822561730637.pdf.

State Council of the People's Republic of China (State Council). "Notice of the State Council on Printing and Distributing 'Made in China 2025'" (in Chinese), May 8, 2015. http://www.gov.cn/zhengce/content/2015-05/19/content_9784.htm.

State Council of the People's Republic of China (State Council). "The National Outline of the Development of the Integrated Circuit Industry Officially Announced" (in Chinese), June 24, 2014. http://www.gov.cn/xinwen/2014-06/24/content_2707360.htm.

Statista. "Share of Mobile Phone Users That Use a Smartphone in China from 2013 to 2019,*" 2018. https://www.statista.com/statistics/257045/smartphone-user-penetration-in-china/.

Taiwan Semiconductor Manufacturing Company Limited. (TSMC). "TSMC Breaks Ground on Fab 18 in Southern Taiwan Science Park." News release, January 26, 2018. http://www.tsmc.com/tsmcdotcom/PRListingNewsAction.do?action=detail&language=E&newsid=THGOHITHTH.

Tao, Li. "How China's 'Big Fund' Is Helping the Country Catch up in the Global Semiconductor Race." *South China Morning Post*, May 10, 2018. https://www.scmp.com/tech/enterprises/article/2145422/how-chinas-big-fund-helping-country-catch-global-semiconductor-race.

Thun, Eric. "Industrial Policy, Chinese-Style: FDI, Regulation, and Dreams of National Champions in the Auto Sector." *Journal of East Asian Studies* 4, no. 3 (September–December 2004): 453–89. https://www.jstor.org/stable/23417950.

Torsekar, Mihir, and John VerWey. "The East Asia-Pacific's Participation in the Global Value Chain for Electronic Products." *Journal of International Commerce and Economics*, March 2019. https://www.usitc.gov/publications/332/journals/east_asia-pacifics_participation_in_the_global_value_chain_for_electronic_products.pdf.

Udemans, Christopher. "Nanjing to Create $20 Billion Integrated Circuit Investment Fund." TechNode, July 18, 2018. https://technode.com/2018/07/18/nanjing-integrated-circuit-fund/.

U.S. Census Bureau, NAICS Related Party Database. https://relatedparty.ftd.census.gov/ (accessed October 30, 2018).

U.S. Chamber of Commerce. *Made in China 2025: Global Ambitions Built on Local Protections*, March 16, 2017. https://www.uschamber.com/report/made-china-2025-global-ambitions-built-local-protections-0.

U.S.-China Economic and Security Review Commission (USCC). *July 2018 Trade Bulletin*, July 9, 2018. https://www.uscc.gov/trade-bulletin/july-2018-trade-bulletin.

U.S. International Trade Commission (USITC). *The Economic Effects of Significant U.S. Import Restraints, Ninth Update 2017 (Import Restraints 9)*. USITC Publication 4726, September 2017. https://www.usitc.gov/publications/industry_econ_analysis_332/2017/economic_effects_significant_us_import_restraints.htm.

U.S. Trade Representative (USTR). *2017 Section 301 Report*, April 1, 2017. https://ustr.gov/sites/default/files/301/2017%20Special%20301%20Report%20FINAL.PDF.

U.S. Trade Representative (USTR). "2018 National Trade Estimate Report." Fact sheet, March 30, 2018. https://ustr.gov/about-us/policy-offices/press-office/fact-sheets/2018/march/ustr-releases-2018-national-trade.

U.S. Trade Representative (USTR). *Findings of the Investigation Into China's Acts, Policies, and Practices Related to Technology Transfer, Intellectual Property, and Innovation Under Section 301 of the Trade Act of 1974 (Section 301 Report)*. March 22, 2018. https://ustr.gov/sites/default/files/Section%20301%20FINAL.PDF.

U.S. Trade Representative (USTR). "Section 301 Report into China's Acts, Policies, and Practices Related to Technology Transfer, Intellectual Property, and Innovation." Press release, March 27, 2018. https://ustr.gov/about-us/policy-offices/press-office/press-releases/2018/march/section-301-report-chinas-acts.

U.S. Trade Representative (USTR). *Update Concerning China's Acts, Policies, and Practices Related to Technology Transfer, Intellectual Property, and Innovation (Section 301 Report Update)*, November 20, 2018. https://ustr.gov/sites/default/files/enforcement/301Investigations/301%20Report%20Update.pdf.

VerWey, John. "Global Value Chains: Explaining US Bilateral Trade Deficits in Semiconductors." Executive Briefing on Trade. U.S. International Trade Commission, March 2018. https://www.usitc.gov/publications/332/executive_briefings/ebot-semiconductor_gvc_final.pdf.

Wedeman, Andrew. *Double Paradox: Rapid Growth and Rising Corruption in China*. Ithaca, NY: Cornell University Press, 2012.

Wu, Friedrich, and Chua Boon Loy. "Rapid Rise of China's Semiconductor Industry: What are the Implications for Singapore?" *Thunderbird International Business Review*, 2004, https://onlinelibrary.wiley.com/doi/abs/10.1002/tie.20005.

Wübbeke, Jost, Mirjam Meissner, Max J. Zenglein, Jaqueline Ives, and Björn Conrad. *Made in China 2025: The Making of a High-Tech Superpower and Consequences for Industrial*

Countries. Berlin, Germany: Mercator Institute for China Studies, December 12, 2016. https://www.merics.org/en/papers-on-china/made-china-2025.

Xinhua News Agency. "'Made in China 2025' Is Not a Replica of German Industry 4.0" (in Chinese), April 21, 2015. http://www.gov.cn/xinwen/2015-04/21/content_2850580.htm.

Xinhua News Agency. "'Made in China 2025' Issued a Clear Road Map of Manufacturing Power" (in Chinese), May 19, 2015. http://www.gov.cn/xinwen/2015-05/19/content_2864566.htm.

Yue, Patrick C., and Tian Lu. "China's Latest Overseas M&A in the Semiconductor Industry." *IEEE Solid-State Circuits Magazine*, November 16, 2017. https://ieeexplore.ieee.org/iel7/4563670/8110862/08110893.pdf.

Zhang, Kevin. "China's Manufacturing Performance and Industrial Competitiveness Upgrading." Chapter 12 in *China's Domestic Transformation in a Global Context*. Acton, Australia: ANU Press, 2015.

Appendix A: List of Acronyms

ATP	Assembly, test, and packaging
CFIUS	Committee on Foreign Investment in the United States
DRAM	Dynamic random access memory
FDI	Foreign direct investment
FYP	Five-year plan
IC	Integrated circuit
IDAR	Introducing, digesting, absorbing, and re-innovating
IDM	Integrated device manufacturer
IP	Intellectual property
JV	Joint venture
M&A	Mergers and acquisition
MEMS	Microelectronic mechanical devices
MLP	National Medium- and Long-Term Science and Technology Development Plan
MNC	Multinational corporation
OECD	Organisation for Economic Co-operation and Development
R&D	Research and development
RF	Radio frequency
RMB	Renminbi
SIA	Semiconductor Industry Association
SMIC	Semiconductor Manufacturing International Corporation
TSMC	Taiwan Semiconductor Manufacturing Corporation
VAT	Value-added tax

Appendix B: Notable Semiconductor-Related Chinese Industrial Plans

Year	Title	Semiconductor-related provisions
1956	Outline for Science and Technology Development, 1956−1967	Identified semiconductor technology as a "key priority" for China's future.
1983	"Build Two Bases (North and South) and One Point"	Designated a "South Base" (around Shanghai, Jiangsu and Zhejiang) and "North Base" (Beijing, Tianjin, and Shenyang) where firms could share resources and develop semiconductor industry supply chains.
1982	The Strategy for the Development of China's Electronics and Information Industries	6 Strategies Outlined focused on using foreign technology to advance China's technology via joint ventures, creation of a domestic electronics supply chain with an emphasis on quality mass production and large-scale ICs.
1990	Project 908	Advocating Project 908, which sought to establish China's first world-class I.D.M. at Wuxi's #742 Factory.
1991	8th Five-Year National Economic and Social Development Plan	Called the development of the domestic IC industry a "main task" of the state. Articulated "Project 908."
1995	Project 908 Breaks ground	Goal was to establish a 150mm (6-inch) wafer fab run as China Huajing Electronics Group (IDM).
1996	9th Five-Year National Economic and Social Development Plan and 2010 Long-Term Goals	Called for development of next-generation ICs.
2001	10th Five-Year National Economic and Social Development Plan Outline	Called for the focused development of high tech industries and to "vigorously develop the IC… industry."
2005	National Medium- and Long-Term Science and Technology Development Plan Outline (2006-2020)	Articulated China's long-term technology development strategy. Of 13 key projects identified, development of core electronics (including chips) and chip manufacturing are prioritized as numbers one and two.
2006	11th Five-Year National Economic and Social Development Plan Outline	Called for the "vigorous" development of ICs and other industries at the core of the "digitization trend."
2011	12th Five-Year National Economic and Social Development Plan Outline	Inaugurated a "high performance ICs project."
2014	Guidelines for the Development and Promotion of the Integrated Circuit Industry	Called for establishing a National IC Industry Development Leading Small Group to coordinate design of the industry's development and starting a National Integrated Circuit Investment Fund.
2015	Made in China 2025	Strategy calling for accelerated advances in key manufacturing technologies, including chips.
2015	Made in China 2025: Major Technical Area Roadmap	Established specific sales values and market share targets for the IC industry to be met by domestic production.
2016	13th Five-Year National Economic and Social Development Plan Outline	Called for the active promotion of advanced semiconductor technology.

Source: USTR, *Section 301 Report*, March 2018, pp. 111−113; Lewis, ""Learning from the Superior Techniques," 2019, pp. 32−35; author's translations.

Appendix C: Announced Chinese Semiconductor-Related Investment Into the United States

Announced	U.S. target	Chinese investor	Value
Jul-06	LSI Logic- ZSR(R) Digital Signal Unit	VeriSilicon Holdings	$13 million
Jan-08	Quorum Systems	Spreadtrum Communications	$77 million
Nov-10	Creation of US subsidiary	China WLCSP Co. Ltd.	$1 million
Jun-11	MobilePeak Systems stake	Spreadtrum Communications	$27.2 million
Aug-11	Telegent Systems	Spreadtrum Communications	$92 million
Sep-11	MobilePeak Systems stake	Spreadtrum Communications	$3.6 million
Mar-15	Integrated Silicon Solutions Inc.	Hua Capital Management, SummitView Capital, E-Town Memtek	$640 million
Apr-15	FlipChip International	Tianshui Huatian Technology	$41 million
May-15	WiSpry	AAC Technologies Holdings	$10 million
May-15	Static Control Components	Apex Microelectronics	$63 million
Jun-16	Marvell Technology*	Datang Telecom	$2 billion
Jul-15	Bridgelux	China Electronics Corporation, Chongqing Linkong Development Investment	$130 million
Jul-15	Micron Technology*	Tsinghua Holdings	$23 billion
Aug-15	Micrel Technology*	Unnamed Chinese buyer	$839 million
Sep-15	Atmel*	China Electronics Corporation	$3.4 billion
Sep-15	Western Digital*	Tsinghua Unisplendour	$3.8 billion
Sep-15	Pericom Semiconductor	Montage Technology Group (subsidiary of China Electronics Corp.)	$442 million
Dec-15	Xcerra- interface board business	Fastprint	$23 million
Dec-15	Mattson Technology	Beijing E-Town Dragon Semiconductor Industry Investment Center	$300 million
Dec-15	Fairchild Semiconductor*	China Resources, Hua Capital Management	$2.5 billion
Jan-16	OmniVision Technologies	CITIC Capital Holdings, Goldstone Investment, Hua Capital Management	$1.9 billion
Jan-16	Initio	Sage Microelectronics	$40 million
Jan-16	Vivante	VeriSilicon Holdings	Not known
Mar-16	Global Communications Semiconductors	Sanan Optoelectronics	$226 million
Mar-16	GigOptix	Shanghai Pudong Science and Technology	$5 million
Mar-16	Anadigics	Unnamed Chinese buyer	$78.2 million
Apr-16	Lattice Semiconductor	Tsinghua Holdings	$41.6 million
May-16	Marvell Technology Group	Tsinghua Holdings	$78.2 million
Jun-16	Multi-Fineline Electronix	Suzhou Dongshan Precision Manufacturing	$610 million
Jun-16	Integrated Memory Logic	Beijing E-Town Chipone Technology	$136 million
Aug-16	MEMSIC	HC Semitek; China Reform Holdings Corporation	
Sep-16	Analogix	Beijing Shanhai Capital Management & National IC Fund	$500 million
Nov-16	Lattice Semiconductor*	Canyon Bridge Capital Partners	$1.3 billion
Feb-18	Xcerra Corp*	Hubei Xinyan	$580 million

Note: * = Proposed transaction terminated.

Source: Rhodium Group, compiled by author.