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Challenges to Foreign Investment in High-Tech Semiconductor Production in China

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Abstract

This article seeks to explain the limited level of high-tech semiconductor production by foreign investors in China. First, the article briefly summarizes the evolution and current state of China's policy efforts to promote foreign investment in its semiconductor industry. Second, the article shows that foreign front-end semiconductor production in China remains relatively small, despite the lure of the government's promotional policies and the fact that China is the world's largest market. The article concludes by identifying two major factors discouraging foreign front-end semiconductor production in China: (1) China's uncertain business environment for front-end semiconductor production, punctuated by lax intellectual property rights (IPR) protection and enforcement; and (2) restrictive investment and export control policies by foreign governments.

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Introduction

Two developments over the past several years contributed to the expectation that foreign high-tech semiconductor wafer fabrication production, known as front-end production, would soar in China, commensurate with the rapid development of other high-tech sectors.[2] First, in 2000 the Chinese government dramatically reoriented promotional policies and incentives for its semiconductor industry to attract foreign semiconductor investment, recognizing that foreign investment and relocation are vital to the development of China's domestic high-tech semiconductor industry. Second, in 2005 China became the world's largest single-country semiconductor market.

Despite these two developments, foreign front-end semiconductor production in China still accounts for a very small share of global production. In 2008, foreign front-end firms in China represented only around $1 billion of the $227 billion total in global integrated circuit (IC) production (McClean, Matas, and Yancey 2009, 2-54).[3] In addition, within China, domestic semiconductor firms, not foreign firms, continue to represent the majority of front-end semiconductor production, with domestic firms accounting for, on average, over 80 percent of China's annual semiconductor production from 2003 to 2008 (McClean, Matas, and Yancey 2009, 2-54). By the end of 2007, only two foreign semiconductor firms had established front-end production in China (SEMI 2008a, 2-4).[4]

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[2] Production growth in China's advanced technology sectors is explained in Preeg 2005. Preeg argues that China is rapidly becoming an "advanced technology superstate." Sigurdson 2005 also argues that China's technological power will continue to rapidly increase.

[3] Semiconductors are commonly referred to as integrated circuits (ICs), microchips, or simply "chips." This article uses these terms interchangeably. Technically, the semiconductor market comprises two major subsets, the IC market and the optoelectronics, sensor, and discretes (O-S-D) market. Since ICs represent the larger share of the semiconductor market (84 percent in 2008) and comprise semiconductors that are harder to manufacture, more advanced, and more expensive, IC production is often used as a proxy for semiconductor production. Based on data availability, this article uses both semiconductor and IC production data.

[4] However, China continues to be a leading location for foreign firms to establish low value-added, labor intensive "back-end" semiconductor production. When comparing the total (i.e. foreign plus domestic) number of front-end and back-end production facilities in China, back-end facilities far outnumber front-end. Currently, an estimated 200 back-end facilities are operating in China compared with an estimated 30 front-end fabs (SEMI 2008a, 2-4; and McClean, Matas, and Yancey 2009, 15-4).

The lack of foreign front-end production investment has helped to keep China from its stated goal of becoming one of the major semiconductor production centers in the world (State Council Circular 18 2000).[5] Becoming a leading location of the more high-end, capital- and knowledge-intensive front-end production process would establish China as a major force in the global industry (along with the EU, Japan, Taiwan, and the United States).[6] Clearly, such a change would have significant implications for the balance of economic and high-tech power throughout the world, as well as for trade flows.

This article seeks to highlight some factors limiting the level of foreign front-end semiconductor production in China. First, the article briefly summarizes the evolution and current state of China's policy efforts to promote its semiconductor industry. Second, the article describes China's evolving role in the global semiconductor manufacturing process over the past few years. Investment, production, and trade data demonstrate that, despite growth in certain segments of China's semiconductor industry (e.g., foreign and domestic back-end and domestic front-end production), foreign front-end semiconductor investment and production in China remain relatively small. Finally, the article identifies factors influencing foreign investment. Despite the draw of government incentives and the size of China's market, foreign firms face two major obstacles that have discouraged investment: (1) China's uncertain business environment for front-end semiconductor production, punctuated by lax intellectual property rights (IPR) protection and enforcement; and (2) restrictive investment and export control policies by foreign governments. Based on their behavior over the past several years, the majority of foreign firms seem to have determined that the potential risk associated with these two factors outweighs the potential reward of locating their front-end production in China.

[5] In 2000, the stated goal of the Chinese government for its semiconductor industry was to become one of the major semiconductor production centers in the world, meet most domestic demand, and export in large quantities within 5 to 10 years (State Council Circular 18 2000). These goals are far from being met.

[6] China's ambition for its semiconductor industry is typical of most semiconductor-producing countries; it seeks progressive development up the high-tech production chain, from engaging in labor intensive back-end production to more capital and knowledge intensive front-end production and design. For China, this ambition is strengthened by its desire to supply its vast domestic market rather than to rely on foreign imports.

Evolution of Policies to Attract Foreign Investment

The Chinese government's efforts to develop its semiconductor industry have evolved to feature foreign investment as a cornerstone for developing the industry. By contrast, earlier government promotional plans restricted foreign investment and allowed the government to actively manage the industry (table 1). Prior to 2000, semiconductor firms in China were either state-owned enterprises or joint ventures in which the Chinese partner was a government entity.

Several factors prompted the central government to develop this new promotional model. First, the government realized that the previous set of policies were not effective. Most notably, the Chinese government's "command-economy" model, in which the state directed the industry and

TABLE 1 Changes in China's promotional policy model for its semiconductor industry

Policy	Pre–2000	2000–Forward
Corporate structure	State-owned enterprise	Private; government holds passive minority share
Foreign direct investment	Heavily restricted	Liberalized
Promotion of IC design industry	Emphasis on state-owned research institutes	Privatization of government research institutes; financial assistance to private companies
Government as direct investor in leading firms	100 percent government ownership of semiconductor enterprises	Government passive minority equity stake
Tariffs on semiconductors	6–30 percent	0
Industrial parks	Over 100 "high-tech parks" scattered throughout the country	Bigger, more concentrated clusters. 1 flagship park (Zhangjiang), 2–3 others emerging (Suzhou, Beijing)
Major financial incentives to individuals	None	Major tax benefits
Government controls enterprise decision-making	Yes	No
Government promotion of venture capital sector	No	Yes

Source: Reprinted in part from Howell et al. 2003, figure 11.

controlled major enterprises, proved a bad fit with the semiconductor industry, which flourishes in an innovative and entrepreneurial environment often associated with private enterprise (Howell et al. 2003, 22–23). Despite much investment over several decades and the implementation of several long range plans with specific goals, by the end of the 1990s the semiconductor industry in China significantly lagged behind those of the leading global producers (United States, EU, and Japan) in both production quantity and technology advancement. The Chinese industry was several technological generations behind the global leading edge, was not a major presence in foreign markets, and only supplied around 15 percent of its own market (Howell et al. 2003, 27). [7]

Second, the Chinese government learned how the Taiwanese government successfully implemented promotional policies in the 1980s and 1990s that made its industry a global leader by the end of the 1990s. One expert describes the divergent paths taken by the two governments.

> Chinese planners built their industry on a foundation of state-owned enterprises, laboratories and research institutes, withpervasive control over decisionmaking by government ministries. By contrast, the government of Taiwan utilized incentive policies intended to create and strengthen a vibrantprivate sector and did not attempt to exert influence over individual enterprise management. China sought to control inward foreign investment to such a degree that most foreign semiconductor producers were deterred altogether from major investments in China; Taiwan welcomed inward foreign investment with relatively few restrictions (Howell et al. 2003, 30).

To a large degree, the Chinese government's current policies are modeled after Taiwan's, aiming to achieve similar success.

Third, China's entry into the World Trade Organization (WTO) in 2001 forced the government to bring their methods for promoting industry into compliance with WTO rules. For example, prior to WTO entry, the Chinese government engaged in a development strategy of "trading markets for technology," in which foreign firms were permitted to invest in China and sell into the Chinese market in exchange for technology transfer and other

[7] For more information on the development of the Chinese semiconductor industry prior to 2000, see Chase, Pollpeter, and Mulvenon 2004, 101–103.

benefits (Howell et al. 2003, 39). Since WTO rules prohibit such promotional strategies, China developed new promotional policies in line with those of other WTO member countries, such as subsidies, tax incentives, and science, education and training programs (Howell et al. 2003, 39).

Current Policies and Incentives

Circular 18 and the 10th Five-Year Plan. The Chinese central government designated the semiconductor industry as an encouraged industry, promulgating a full menu of policies to promote its growth. State Council Circular 18, "Some Policies for Encouraging the Development of the Software and the Integrated Circuit Industry," is the principal document that defines the central government's policy for the semiconductor industry.[8] Issued in June 2000, Circular 18 implements the broad vision of the development of the semiconductor industry in China as part of the government's 10th Five-Year Plan. Circular 18 specifically lays out the goal of making China a leading design and manufacturing center for ICs by 2010, which includes ensuring that ICs produced in China will "match most demands from the domestic market and be exported in large quantities" (Circular 18 2000, art. 2). Circular 18 also outlines specific promotional policies for the IC industry (box 1). These policies are available to both foreign and domestically owned firms that qualify (Circular 18 2000, art. 52). By promoting greater foreign investment through FDI liberalization, tax incentives, and easing of government ownership requirements (among other things), the promotional policies for the semiconductor industry envisioned in the 10th Five-Year Plan and articulated in Circular 18 mark a major departure from Chinese government promotional policies of the past.[9]

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[8] Other policies exist for the development of high-technology industry in China, but Circular 18 is the only directive that specifically targets the semiconductor industry. For a full discussion of policies aimed at high-technology industry and R&D development, see USITC 2007a. Notably, semiconductors is one of only two sector-specific industries in China provided its own policy documents by the government (the other being the automobile industry) (Howell et al. 2003, 45; industry official, interview by Commission staff, Shanghai, China, January 15, 2008).

[9] Since the 1950s, the Chinese government has sought to develop a semiconductor industry, but with limited success. For a detailed description of China's various policies and programs to promote the semiconductor industry (and the high-tech, R&D, and electronics sectors, in general), see Howell et al. 2003, 22–27; Sigurdson 2005, chaps. 2 and 3; and USITC 2007a, 103–117.

Box 1. Major Promotional Policies in Circular 18

The major promotional policies in Circular 18 include:

- Tax holidays and reductions—eligible IC manufacturers can receive a five-year tax holiday from corporate income tax starting on the first year that a firm earns a profit. The five-year tax holiday is followed by five additional years in which the corporate tax rate is halved.
- VAT exemptions on imported equipment and machinery—IC manufacturers are exempt from paying the 17 percent value-added tax applied on imports of machinery and equipment.
- Import duty exemption on equipment and machinery—IC manufacturers are exempt from import duties on IC production equipment. In joining the WTO in 2001, China agreed to eventually eliminate tariffs on these goods.
- Exemption on import duties and VAT on raw materials—IC manufacturers are exempt from import duties on “raw materials and consumables for their own use.”
- Capital construction/infrastructure investment—Under article 3(2), “some direct budgetary funds for the capital construction shall be allocated to provide the financial supports for the infrastructure construction and industrialization of IC industries.” According to one observer, however, in practice the vast majority of infrastructure support is provided to firms by local governments at the local level (Howell et al. 2003, 46).
- Facilitated customs clearance—IC manufacturers shall be granted an “easier customs clearance.”
- Foreign currency retention—Under article 45, “In an aim to evade the exchange rate risks, [IC manufacturers] are allowed to deposit the after-tax profits in the special accounts in the form of foreign currency if the profits are to be used for reinvestment in China.”
- Capital—Under articles 3(1) and 51, “the State shall provide the generous assistance for establishing the risk investment [venture capital] companies and setting up the risk investment [venture capital] funds.”

Source: State Council Circular 18 2000.

Regional and Local Policies and Practices. While Circular 18 is often cited as the definitive roadmap set forth by the central government for the development of the industry, implementation is left up to provincial and local governments (Howell et al. 2003, 47).[10] Given the number of provincial and local governments in China and limited data, comprehensive details about how these governments have implemented the State Council’s vision, communicated via Circular 18, for the semiconductor industry remain elusive.

[10] According to Howell et al., most of the provisions in Circular 18 are not self-implementing; thus, full implementation depends on (1) provincial and local authorities’ implementing regulations, and (2) clarifications from the state level.

Some provincial and local governments have devised strategies of their own as well. For example, starting in 2005, provincial and local governments have adopted a new strategy not specifically outlined in local policies and regulations for attracting investment in front-end fabrication. The strategy, known as a "virtual fab" strategy, entails a local government largely or fully funding the construction of a fabrication plant (fab) for a semiconductor firm to manage. Under this arrangement, the local government owns the fab while the contracted semiconductor firm manages it for a fee and a share of the profits. Two regional governments reportedly adopted this strategy—the Wuhan local government, which began construction of a 300 mm fab in 2006, and the Chengdu municipal government, which set up a 200 mm fab in 2005. Both fabs are managed by Semiconductor Manufacturing International Corporation (SMIC), the largest China-headquartered semiconductor firm according to 2008 IC sales (LaPedus 2008).[11]

Semiconductor Production in China

Summary

- Semiconductor production in China represented less than 2 percent of world production in 2008.
- From 2003 to 2008, foreign firms accounted for less than 20 percent of front-end production annually in China, while domestic firms accounted for over 80 percent.
- By the end of 2008, two foreign firms had established front-end production in China, while many more had established the more labor-intensive and less capital-intensive back-end semiconductor production.

Despite China's promotional incentives and its status as the world's largest semiconductor market (box 2), semiconductor production in China still accounts for a very small share of the global total. In 2008, total IC production in China accounted for less than 2 percent of total worldwide IC production, and foreign-based IC production in China accounted for 25 percent of

[11] Because this strategy is not based on a written policy, it is unclear whether both foreign and domestic firms can participate. Thus far only SMIC has participated in the strategy.

total IC production in China (figure 1). For perspective, each of the top 19 global IC companies in 2008 had a greater share of the world market than all Chinese-based IC companies combined, and production by the world's leading IC company, U.S.-headquartered Intel Corporation (Intel), accounted for more than eight times that of all Chinese-based IC companies (McClean, Matas, and Yancey 2009, 3-2). The average annual growth rate of Chinese-based production from 2004 to 2008, however, exceeded that of overall global production (36 percent compared with 9 percent, respectively),[12] principally due to the growth of Chinese-owned firms, and not foreign-invested firms (McClean, Matas, and Yancey 2009, 2-54).

Semiconductor production in China has historically involved labor-intensive processes. For example, China's participation in the three stages of semiconductor production—design; front-end fabrication; and back-end testing, assembly, and packaging—has tilted more toward the back-end stage, which requires more labor and less capital and knowledge than front-end production and chip design (table 2).[13] Compared to the other stages of production, back-end production in China is well-established and robust.[14] Also, China's large market provides a convenient location for back-end production, because once chips finish back-end production they are ready for consumption by the numerous downstream semiconductor consumers located in China.

Currently, an estimated 200 back-end assembly and test companies exist in China (McClean, Matas, and Yancey 2009, 15-4). Several major foreign firms operate back-end facilities in China, including the world's largest semicon-

[12] It should be noted that the higher average annual growth rate for Chinese-based production likely reflected a catch-up to production leaders and the fact that Chinese-based production started from such a small base. The faster growth of Chinese-based semiconductor production during this period increased China's share of global production from 1.17 percent in 2004 to 1.81 percent in 2008 (McClean, Matas, and Yancey 2009, 2-54).

[13] Semiconductor design is the first and most R&D-intensive stage of semiconductor production. Because this article focuses on the location of the front-end fabrication, it does not address semiconductor design in detail. In general, around 500 design firms (or "fabless" firms) currently exist in China, although their capabilities are limited and their output is small vis-à-vis their U.S.- and Taiwanese-based competitors. Of the top 50 global semiconductor suppliers in 2007, none was a Chinese-based firm. There are very few foreign-based design firms operating in China (Industry official, interview by Commission staff, Beijing, China, January 14, 2008; McClean, Matas, and Yancey 2009, 3-5–3-7).

[14] According to one Chinese industry official, back-end testing and assembly semiconductor activities in China account for 40–50 percent of total current semiconductor production in China (Industry official, interview by Commission staff, Beijing, China, January 14, 2008).

Box 2. Semiconductors: Uses, Global Industry, and Market

Semiconductors, the building blocks of the Information Age, are found in virtually all electronic products today. They perform a wide range of functions in a variety of end-use products, from simple children's toys to sophisticated computers. In 2008, the most common end uses for semiconductors were estimated to be personal computers, consumer electronics, cell phones, industrial/military applications, automotive applications, and wired communications.

The global semiconductor industry had total worldwide sales of $249 billion in 2008. Over the long term, the industry has grown tremendously, registering a compound annual growth rate of 10.2 percent from 1987 to 2008, fueled by demand from a growing and increasingly diverse market. For most of its history, the industry has experienced distinct boom/bust cycles occurring on average every four years, though the industry's recent performance has bucked this trend with positive growth from 2002 to 2007.

Semiconductors are consumed in all major regions of the world, though Asia-Pacific (excluding Japan) is by far the largest regional market, accounting for 51 percent of the global IC market. China is the largest country market in the world, accounting for 25 percent of the global IC market. The Asia-Pacific region's status as the world's largest semiconductor market stems from the vast majority of semiconductor consumers—electronic systems producers—that have production located there.

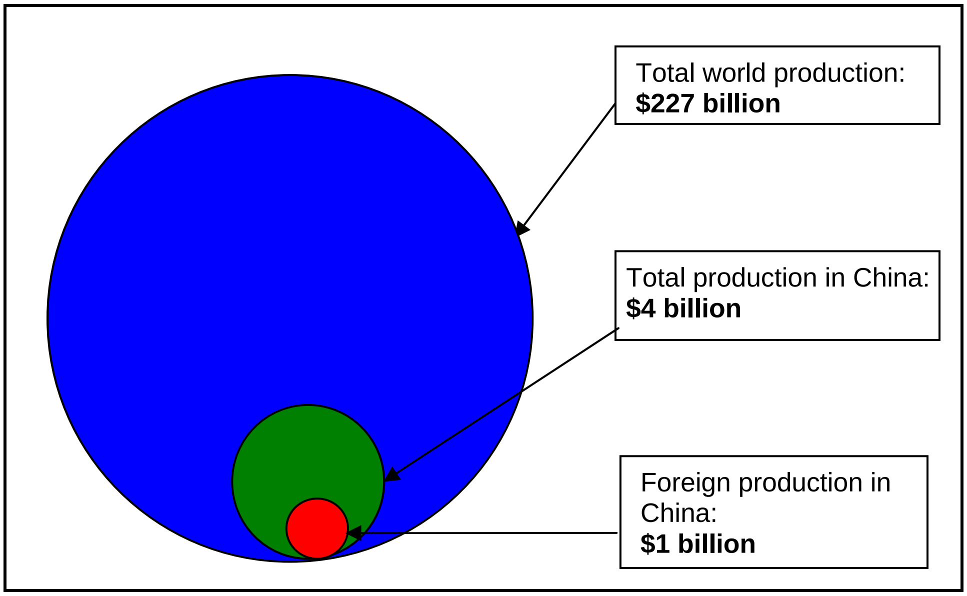
The majority of leading semiconductor producers are headquartered in five countries: the United States, the EU, Japan, Korea, and Taiwan. Many firms, however, maintain production in several countries. With the emergence in recent years of the Asia-Pacific region as the world's largest market, many semiconductor firms headquartered in other parts of the world have increased their presence (in some cases, shifting or establishing some level of production) in the region, including in China.

Sources: Montevirgen 2008, 17; SIA 2008; McClean, Matas, and Yancey 2009.

ductor firm, Intel (Intel Corp. 2008, 20). In addition, many Chinese and foreign-owned firms that focus exclusively on back-end production (also known as open-market assembly and test (OSAT) service providers, or simply back-end contract manufacturers) operate in China (table 3). For example, one of the world's biggest OSAT service providers, U.S.-headquartered Amkor Technology Inc., has its largest facility (based on factory floor square footage) in Shanghai (Amkor Technology Inc. 2008, 27). Furthermore, in recent years, many notable foreign companies, both integrated device manufacturers (IDMs)[15] as well as OSATs, have established or increased back-end production in China (table 4).

[15] IDMs are semiconductor firms that operate in all three stages of semiconductor production. As the three stages of production have become more specialized, three other types of firms have developed in the industry: design or "fabless" firms which operate exclusively in the design stage; pure-play foundries, which operate exclusively in the front-end stage; and OSATs, which operate exclusively in the back-end stage.

Figure 1 Foreign IC production in China, total IC production in China, and total world IC production, 2008



Source: McClean, Matas, and Yancey 2009, 2-54.

TABLE 2 Three stages of semiconductor production and the extent of China's participation

Stage	Description of activity	Characteristics	Leading locations
Design	Design of the semiconductor	- R&D intensive - Abundant high-skilled labor - Strong IPR environment	United States, Taiwan **China's participation: limited**
Front-end fabrication	Construction of semiconductors on silicon wafers using highly sophisticated machinery	- Capital intensive, very expensive - Some low-skilled labor - Strong IPR environment	United States, Korea, Japan, EU, Taiwan **China's particpation: limited**
Back-end testing, assembly, and packaging	Testing, assembling, and packaging of semiconductors for final sale to end customers	- Less capital intensive and expensive than front-end fabrication - More labor intensive than front-end fabrication	China, Singapore, Malaysia, Taiwan, the Philippines **China's participation: established and robust**

Source: Compiled by author.

TABLE 3 Types of semiconductor firms by production stages and description of their presence in China

Design	Front-end fabrication	Back-end testing, assembly, and packaging
Fabless Firms Leading firms have yet to emerge in China. Chinese domestic firms exist but are not major producers.	**Pure-Play Foundries** These firms account for the majority of front-end production in China. Most firms are Chinese domestic firms.	**Back-end Contract Manufacturers (or OSATs)** These firms have an established presence in China.
Integrated Device Manufacturers (IDMs) These firms operate in all three stages of production. Most maintain a presence in China, usually in the form of back-end operations or sales offices, but they have been reluctant to locate front-end production in China.		

Source: Compiled by author.

Front-end fabrication, the most capital- and technology-intensive stage of semiconductor production is done in China by Chinese-owned foundries and foreign-owned IDMs. Chinese domestic firms, not foreign firms, are the leading source of front-end semiconductor production in China (table 5). From 2003 to 2008, Chinese domestic production accounted for an annual average of at least 83 percent of total semiconductor production in China (McClean, Matas, and Yancey 2009, 2-54).[16] Of Chinese-owned foundries, SMIC is by far the leading producer, accounting for 33 percent of total Chinese-based IC production in 2008 (McClean, Matas, and Yancey 2009, 2-54).

The establishment of front-end semiconductor fabrication in China by foreign firms in recent years has occurred sparingly. Of the roughly 180, 200 mm fabs in operation worldwide in 2008, only one foreign-owned facility existed in China, a plant operated by Taiwan Semiconductor Manufacturing Company (TSMC) of Taiwan (McClean, Matas, and Yancey 2009, 14-69). Of the 70 more advanced 300 mm fabs in operation worldwide in 2008, one foreign-owned facility existed in China, a joint venture between Hynix Corporation of Korea and STMicroelectronics NV of the EU (Hynix-STMicro JV)

[16] Though specific data for foreign-based production in China are not available, Chinese domestic production accounted for at least 80 percent of total production in 2003 and at least 70 percent in 2008. For most of the intervening years, Chinese domestic production was greater than 80 percent (McClean, Matas, and Yancey 2009, 2-54).

TABLE 4 Selected foreign IDM and OSAT firms establishing back-end assembly and test facilities in China, 2001–08

Selected Foreign IDMs		
Company	*Headquarters*	*Year Established*
AMD	USA	2004
Fairchild	USA	2003
Hynix	Korea	2005
Intel	USA	2004
Qimonda	EU	2004
International Rectifier	USA	2005
Micron	USA	2005
National	USA	2004
Renesas	Japan	2004
Samsung	Korea	2003
STMicroelectronics	EU	2008
Toshiba	Japan	2005
Selected Foreign OSATs		
Company	*Headquarters*	*Year Established*
Amkor	USA	2001
ASE	Taiwan	2004
Carsem	Malaysia	2004
SPIL	Taiwan	2002
UTAC	Singapore	2004

Source: McClean, Matas, and Yancey 2008, 15-5.

Note: Intel and STMicroelectronics had also established back-end facilities in China prior to the years noted above.

(McClean, Matas, and Yancey 2009, 14-69).[17] By the end of 2007 two other foreign IDMs, Intel of the United States and ProMOS Technologies of Taiwan, were constructing fabs (Intel 300 mm, ProMOS 200 mm) in China,[18] and one other firm, PowerChip of Taiwan, was planning to construct a

[17] In 2006, sales from STMicro/Hynix's facility were $305 million, while sales from TSMC's facility were $160 million (SEMI 2008a, 2, 40, and 42).

[18] Intel has begun construction on a fab in Dalian that is expected to begin production in 2010 (Intel Corp. 2008, 20; SEMI 2008a, 4).

TABLE 5 Domestic and foreign IC production in China, 2003–08

	Sales in millions $					
	2003	2004	2005	2006	2007	2008
Total Chinese IC production	1,046	2,248	2,431	3,201	3,800	4,110
Estimated production from domestic firms	843	2,019	2,183	2,761	3,005	2,910
Share of total	81%	90%	90%	86%	79%	71%
Estimated production from foreign firms	203	229	248	440	795	1,200
Share of total	19%	10%	10%	14%	21%	29%

Source: McClean, Matas, and Yancey 2009, 2-54.

TABLE 6 Foreign semiconductor firms with front-end semiconductor activity in China, 2007

Company	*Headquarters*	*Status of Fab*
Hynix-STMicro JV	Korea and EU	Began production in 2006
TSMC	Taiwan	Began production in 2004
Intel	USA	Under construction
ProMOS	Taiwan	Under construction
PowerChip	Taiwan	Planning

Source: SEMI 2008a, 2–4.

(200 mm) fab in China (table 6) (SEMI 2008a, 4). The noticeable increase in foreign production from 2006 to 2008 (table 5) is attributed mainly to the ramping up of production from the Hynix-STMicro JV plant, rather than an increase in the number of foreign firms establishing production in China.[19]

Though advances in production efficiencies vary widely, the majority of fabs in China use outdated process technologies to manufacture their

[19] The Hynix-STMicro JV plant began production in June of 2006, and ended the year with $305 million in sales (SEMI 2008a, 40). Sales from the plant in 2007 and 2008 would likely be much higher, because they would include: 1) 12 months of production instead of 6 months, and 2) the ramping up of production capacity as well as a capacity expansion which occurred in 2007 (STMicroelectronics N.V. 2008, 88).

semiconductors.[20] Indeed, all but one of the major indigenous Chinese semiconductor firms currently use process technology that was considered leading edge 10–15 years ago in terms of linewidth and wafer size (SEMI 2008a, 38–42; GAO 2008, 11–12). SMIC, which produces mainly for foreign-based consumers, is the exception.[21] Regarding the two foreign firms with front-end production in China, TSMC's fab does not employ leading-edge technology (180–350 nanometer linewidths on 200 mm wafers), and while the Hynix-STMicro JV uses more advanced process technologies (90–100 nanometer linewidths on 300 mm wafers), it still does not operate at the leading- edge (SEMI 2008a, 40–42). Intel's future fab in Dalian, to be completed in 2010, will produce 300 mm wafers using 90 nanometer linewidths, which is estimated to be at least three generations behind the leading edge (LaPedus 2007).

Trade Patterns

The long-established production-sharing pattern of firms maintaining front-end production in the United States while using China as a leading location for back-end production is evident in U.S.-China bilateral trade data (box 3 and figure 2). For example, in 2006, at least 84 percent of all U.S. semiconductor exports to China consisted of unfinished semiconductors in the form of chips, dice, and wafers.[22] Semiconductors in this form have undergone front-end production but have yet to undergo back-end production. These data strongly suggest that a majority of semiconductors exported from the United States to China in 2006 underwent front-end production in the United States, and were subsequently shipped to China for final back-end production. By contrast, only 5 percent of Chinese exports of semiconductors to the United States in 2006 consisted of unfinished semiconductor chips, dice, and wafers; the vast majority consisted

[20] Semiconductor process technology is measured by linewidth and wafer size. Smaller linewidths and larger wafer sizes equate to more advanced process technology. In 2008, the most advanced process technologies achieved in the industry were linewidths of 45 nanometers and wafer sizes of 300 mm.

[21] By the end of 2007, SMIC reported in financial documents that it had three 300 mm fabs in Beijing (one operating, two constructed) and one in Shanghai (constructed) (SMIC 2008, 27–28; and SMIC 2007c). In terms of linewidth, by mid–2008 SMIC was producing semiconductors at the 65 nanometer node, which was one generation from the most advanced level at that time.

[22] Changes to the Harmonized Tariff Schedule of the United States (HTS) in 2006 eliminated HTS provisions for semiconductors by "unfinished semiconductor chips, dice, and wafers." Therefore, after 2006, it is difficult to use trade data to determine the production stage of semiconductors that are traded (USITC Dataweb; GAO 2006, 28).

Box 3. The Global Nature of Semiconductor Production-Sharing

Semiconductor production is global in nature; the three stages of production often occur in different countries. Asia has historically been a popular location for back-end production, though in recent periods, some design and front-end fabrication have also occurred in the region. In the 1960s and 1970s, when back-end testing, assembly, and packaging was more labor intensive than today, many IDMs either offshored this production stage to Asia to keep costs low by taking advantage of lower labor rates, or contracted it out to Asian firms that exclusively focused on this stage of production. In the 1980s and early 1990s, as competition in the industry intensified and costs of designing and fabricating chips increased, many firms decided to specialize in either the design stage or the production stage, thus developing a new production model known as the fabless/foundry model. Most semiconductor design work tended to remain in the United States, which has long been a base and magnet for semiconductor engineering talent, while the first foundries were established in Taiwan. Today, although the majority of semiconductor design still occurs in the United States, small design clusters have developed recently in Taiwan and China.

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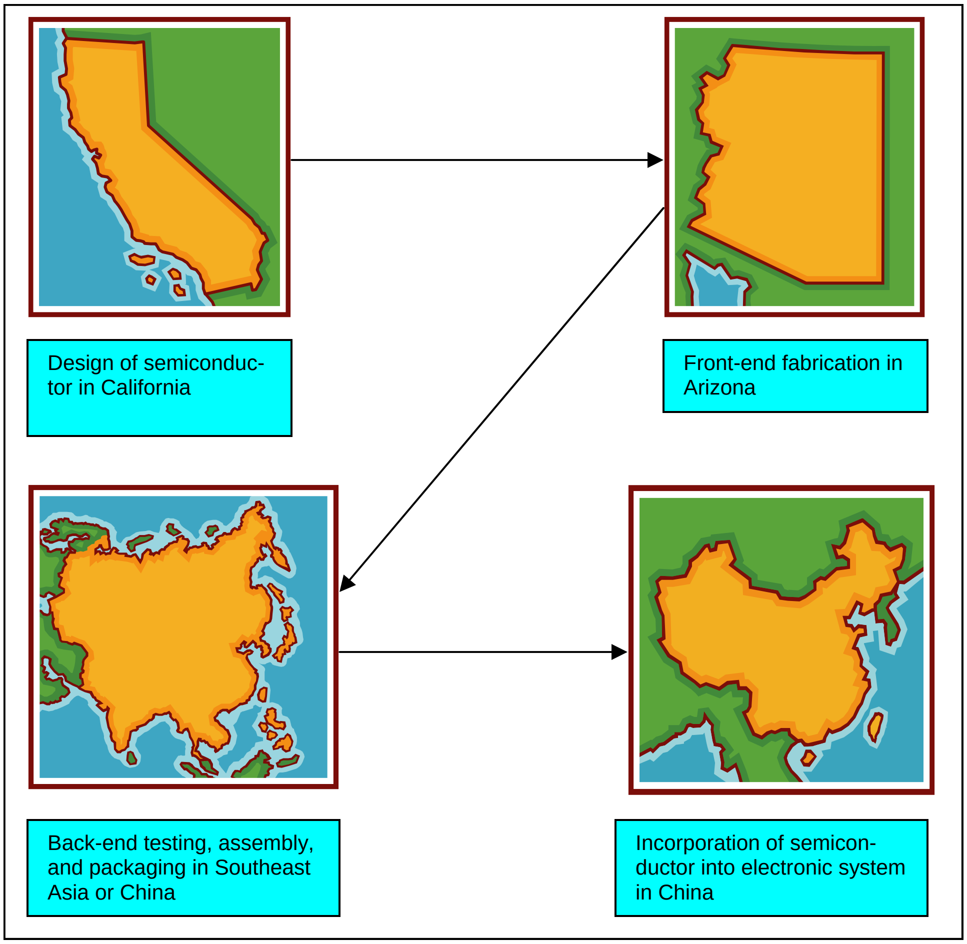
Sources: McClean, Matas, and Yancey 2009, 3-7, 16-10; industry official, interview by Commission staff, Beijing, China, January 14, 2008.

Notes: 1) One of the factors driving the development of the fabless/foundry model was the increasing cost of constructing a fab. From 1980 to 1995, the cost had risen from $100 million to $1 billion. Many firms, especially new ones, discovered that this cost was prohibitive, thus forcing them to specialize in chip design only and adopt the fabless business model. 2) It is estimated that roughly 500 semiconductor design firms currently exist in China; however, given that in 2008, 31 of the top 50 fabless suppliers were U.S.-based firms and no Chinese-based firm was in the top 50, it is likely that the vast majority of design firms in China are small suppliers.

of finished semiconductors (USITC, Dataweb). Presumably, a large number of these finished semiconductors imported from China were those sent there as unfinished semiconductor chips, dice, and wafers from the United States—and other leading front-end semiconductor producing countries—for final back-end production.

Because the location of front-end semiconductor production has remained relatively stable in recent years, U.S.-China bilateral semiconductor trade trends have remained largely unchanged. The United States maintained a surplus in semiconductor trade with China every year from 2001 to 2008, reaching a high of $3.3 billion in 2008 (USITC, Dataweb). The leading destinations for U.S. exports of semiconductors in 2008 were Malaysia, China, Taiwan, the Philippines, Korea, and Singapore (USITC, Dataweb); all of these countries except Korea are leading locations of back-end production.

Figure 2 Current typical global production-sharing pattern of a U.S.-based IDM



Source: Compiled by author.

Foreign Investment Environment for Front-End Semiconductor Production in China

Summary

- Two realities discourage foreign investment of front-end semiconductor production in China:
  - An uncertain business environment marked by lax IPR protection and enforcement
  - Restrictive investment and export control policies by foreign governments
- Two incentives for foreign front-end semiconductor investment in China exist but have yet to significantly increase foreign investment:
  - Chinese government policies and practices to promote foreign semiconductor investment
  - Establishing production in the world's largest semiconductor market

Why have so few foreign firms established front-end semiconductor production in China, given its market size and the available incentives? Over the past several years, the deterrents to moving front-end production to China proved stronger than the incentives. Two factors in particular have proven effective detractors: (1) China's uncertain business environment marked most notably by lax IPR protection and enforcement, and (2) restrictive investment and export control policies by foreign governments. The strength of these two challenges has outweighed the two major incentives encouraging foreign investment in China: (1) Chinese government policies and practices to promote foreign semiconductor investment, and (2) foreign firms' desire to establish production in the world's largest semiconductor market.

China's Uncertain Business Environment

Weak IPR Enforcement

China's weak IPR protection and enforcement is recognized by the U.S. government and U.S. industry. In its 2005 "Special 301" out-of-cycle review of China's implementation of its IP protection commitments, the

United States Trade Representative (USTR) determined that IP infringement was "unacceptably high," and that China's inadequate IPR enforcement was "resulting in infringement levels at 90 percent or above for virtually every form of intellectual property" (USTR 2005, 2). In 2005, the USTR elevated China to its "Priority Watch List" of countries that do not provide an adequate level of IPR protection and enforcement, where it remains to date.[23] In addition, the USTR's 2008 report to Congress on China's WTO Compliance reported that counterfeiting and piracy in China "remain at unacceptably high levels and continue to cause serious harm to U.S. businesses across many sectors of the economy" (USTR 2008a, 5).

The U.S. semiconductor industry has also voiced concerns over China's lack of IPR protection and enforcement. The Semiconductor Industry Association (SIA) described IPR enforcement in China as "woefully inadequate in some local regions," adding that "the central government has been unable to turn its [IPR] policy objectives into action on the ground in all regions" (SIA 2005, 31). In its 2005 annual report, SIA described improving IP protection in China as a "high priority" (SIA 2005, 31).[24] SIA further notes that China "has the substantive intellectual property law required under the Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS), but enforcement remains an issue" (SIA 2004, 3).

One example of China's weak IPR environment is the existence of semiconductor counterfeiting in China. According to SIA, "counterfeiting of semiconductors is a growing problem, and China is the source of many of the counterfeits" (Dewey & LeBoeuf LLP 2007, 13). A recent two-month joint operation between the EU and U.S. Customs resulted in the seizure of over 360,000 fake computer components (including highly-valuable central processing chips), most of which originated in China (Kirwin 2008). The common counterfeiting practice with semiconductors is for counterfeiters to scrape off the label on the plastic package encasing the semiconductor, remark it with a different brand, speed, and/or part number, and sell it outside of authorized channels (Dewey & LeBoeuf LLP 2007, 13).

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[23] The USTR's most recent Special 301 Report continued to characterize overall counterfeiting and piracy levels in China as "unacceptably high" and continued to put China on its Priority Watch List (USTR 2008b, 20).

[24] For more information on SIA's view of the importance of IP protection in China, see http://www.sia-online.org/cs/issues/china and http://www.sia-online.org/cs/issues/free_fair_trade.

According to SIA, the Chinese government has taken some steps to address counterfeiting of semiconductors; however, it believes enforcement measures should be tougher (Dewey & LeBoeuf LLP 2007, 13).[25] Counterfeiting of semiconductors reinforces the notion of a business environment in China that presents investment challenges for foreign semiconductor firms, particularly on advanced front-end production. Because the semiconductor industry is highly R&D intensive, semiconductor firms' IP is their most important asset, and firms guard their IP zealously, most foreign firms have hesitated to establish front-end production in China.

Going forward, China's new Antimonopoly Law (AML) may also contribute to uncertain business risks for foreign semiconductor firms desiring to establish front-end production in China. SIA has expressed concerns that the new law, which became effective on August 1, 2008, could potentially compromise a foreign semiconductor firm's proprietary technology. According to SIA, the law may leave open the potential for highly-advanced firms to be exposed to "discriminatory and unwarranted enforcement" (Dewey & LeBoeuf LLP 2007, 10–11). It argues that under article 47 of the law,[26] foreign firms that are found to have abused a dominant position by withholding proprietary technology might confront cease-and- desist orders "directing them to transfer IPR and technology to Chinese competitors" (Dewey & LeBoeuf LLP 2007, 10–11). Such risk contributes to foreign firms' wariness about locating highly-valuable and advanced front-end production in China.

Foreign Governments' Investment Restraints and Export Controls

Two of the world's largest semiconductor-producing countries, the United States and Taiwan, maintain policies that preclude the sale or transfer of sensitive and state-of-the-art semiconductor products and technology to China, because they are considered dual-use items (products that potentially have both commercial and military uses). Similar to the effect of

[25] According to SIA, the Chinese government currently takes criminal enforcement actions on counterfeiters only when the amount of counterfeited goods exceeds a certain threshold. This enforcement practice is, in the view of the SIA, "effectively giving a safe harbor for counterfeiting below the threshold amount."

[26] Article 47 of the law states: "Where any business operator abuses its dominant market status in violation of this Law, it shall be ordered to cease doing so. The anti-monopoly authority shall confiscate its illegal gains and impose thereupon a fine of 1% up to 10% of the sales revenue in the previous year." (Antimonopoly Law 2008).

China's uncertain business environment, these policies have ostensibly limited the movement of foreign front-end production to China.

U.S. Export Controls

U.S. semiconductor manufacturing equipment and material exports to China are chiefly controlled for national security and antiterrorism purposes.[27] The U.S. government requires a license to export certain equipment and materials to China, and for these items, it generally is the policy to approve exports for civilian end uses and deny exports having the potential for a significant and direct contribution to Chinese military capabilities (GAO 2008, 9).[28]

According to some experts, the U.S. government generally allows semiconductor technology transfers to China if the technology is at least three generations older than the current technology in the United States (U.S.-Taiwan Business Council 2008, 10).[29] U.S. industry groups have argued that "export controls should not apply to mass market semiconductor products, or to equipment and materials available from competitors who do not share [U.S.] views on export controls." [30]

Some industry officials believe that U.S. export controls, particularly on semiconductor equipment, have slowed the growth of the semiconductor industry in China by inhibiting investment by foreign firms and technology advancement of Chinese-owned firms.[31] In 2007, the U.S. Department of Commerce (DOC) announced the creation of a new program that removes individual export license requirements for certain authorized customers in China (DOC 2007).[32] Three firms have qualified for eased U.S. export procedures for semiconductor equipment and materials under the program: Applied Materials China, Ltd., SMIC, and Shanghai Hua Hong NEC Corporation (GAO 2008, 17). A recent U.S. Government Accountability Office report found that the program has not been used as frequently as DOC had

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[27] The Export Administration Regulations (EAR) (15 C.F.R pts. 730–774) contain the requirements for export controls for dual-use items.

[28] For a list of the specific items, see GAO, "Export Controls," September 2008, app. III.

[29] On a case-by-case basis, the United States may also look into investment or technology transfer transactions.

[30] SEMI and SIA, "Joint Statement on Policy Priorities," http://dom.semi.org/web/winitiatives.nsf/0d191b3930beb33b882565ed0058880e/90a1e571d2da50b78825660c0069868e?OpenDocument (accessed March 13, 2008).

[31] Industry officials, interview by Commission staff, Beijing, China, January 14, 2008.

[32] The program is called the Validated End-User program.

anticipated. For example, after the program had been in existence for approximately one year, roughly 6 percent of the total exports of semiconductor manufacturing equipment to China occurred under the program, while 94 percent occurred using an export license. Furthermore, as of June 2008, the report found that only one of the three of the validated end-users authorized to receive semiconductor equipment and materials under the program had received any items (GAO 2008, 22–23).

Taiwanese Regulations on Investments in China

The Taiwan government regulates the type of investment Taiwan-headquartered semiconductor firms can make in China.[33] One of the main objectives of this policy is to slow the pace of investment in China and to guarantee new investments in Taiwan (U.S.-Taiwan Business Council 2008, 6). For example, Taiwanese firms are required to construct and ramp up to mass production a state-of-the-art 300 mm fab in Taiwan before constructing a less-advanced 200 mm fab in China (U.S.-Taiwan Business Council 2008, 6). Another regulation limits Taiwanese firms in China to employing 250 nanometer process technology (or apply to use 180 nanometer technology); these process technologies are several generations behind the most advanced technology. Consequently, only one Taiwanese-owned front-end fab was operating in China as of April 2008, TSMC's 200 mm facility in Shanghai (U.S.-Taiwan Business Council 2008, 8).

Foreign Firms Take Advantage of Incentives

While government incentives are not the "make or break" factor for foreign firms to establish front-end production in China as IPR concerns are, once a foreign firm decides to establish front-end production in China, it likely takes advantage of explicit or negotiated promotional policies and practices. Regarding foreign-owned firms that presently have or plan to have front-end fabs in China, press reports indicate that these projects benefited or will benefit from Chinese government incentives. For example, press reports indicate that Intel received up to $1 billion in incentives from the Chinese government to build its new front-end fab in Dalian, which is scheduled to begin production in 2010 (Nystedt 2007). Intel's CEO indicated that Chinese government support played a major role in the firm's decision to build the fab, though Intel has not disclosed the specifics of the support (Nystedt 2007). The only foreign-owned, cutting-edge fab currently

[33] Technically, the regulations expired in 2005, though new rules have yet to be written (U.S.-Taiwan Business Council 2008, 6).

operating in China, the Hynix-STMicro JV in Wuxi, reportedly was constructed with support from the Chinese government (Electronics.ca Research Network 2006), though specifics of the reported support are not mentioned in publicly available company financial information.

Importing a Viable Alternative to Production in China

Foreign firms reluctant to establish front-end production in China can still competitively supply the market from abroad, thus sidestepping the IPR risk associated with front-end production in China. First and foremost, Chinese import tariffs on semiconductors are currently zero. By joining the WTO in 2001 and becoming a signatory to the Information Technology Agreement (ITA), China agreed to reduce to zero its tariffs on all ITA products, including semiconductors. On January 1, 2005, China eliminated all tariffs on ITA products (USTR 2008a, 27). Also, due to their small size, semiconductors are relatively inexpensive and easy to transport. Finally, because of the global nature of the semiconductor production chain, foreign semiconductor firms have extensive knowledge and experience to draw upon in operating in a global production environment. An import strategy has proven viable for most foreign firms under the current competitive conditions in China. And although almost no foreign firms have front-end production in China, most have established at least some sort of “presence” in China, allowing proximity to the market.

Conclusion

Foreign front-end semiconductor production in China over the past few years can be characterized as conspicuous by its absence. Despite attractive government investment incentives, coupled with the advantages of operating in the world’s largest semiconductor market, the majority of foreign semiconductor firms have not established front-end production in China.

Investment, production, and trade data show that, despite growth in certain parts of China’s semiconductor industry in recent years, foreign front-end semiconductor investment and production in China remain relatively small. Thus, the current picture of China’s semiconductor industry seems to be that foreign and domestic back-end production continues to grow, while domestic foundries have led the way in China’s front-end production development, without significant foreign investment in front-end production.

Despite the draw of government incentives and proximity to China's market, foreign firms face two major obstacles that have discouraged investment: (1) China's uncertain business environment for front-end semiconductor production, punctuated by lax IPR protection and enforcement; and (2) restrictive investment and export control policies by foreign governments. While some increase in foreign front-end production occurred in recent years, the majority of global firms determined that the potential risk presented by these two factors continues to outweigh the advantages of locating production in China. Until these risks are mitigated or the lure of the Chinese market and policy incentives prevail, major shifts in global semiconductor production and trade patterns are unlikely.

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