PRICEWATERHOUSECOOPERS

China's Impact on the Semiconductor Industry*

*connectedthinking

A Technology Forecast Publication

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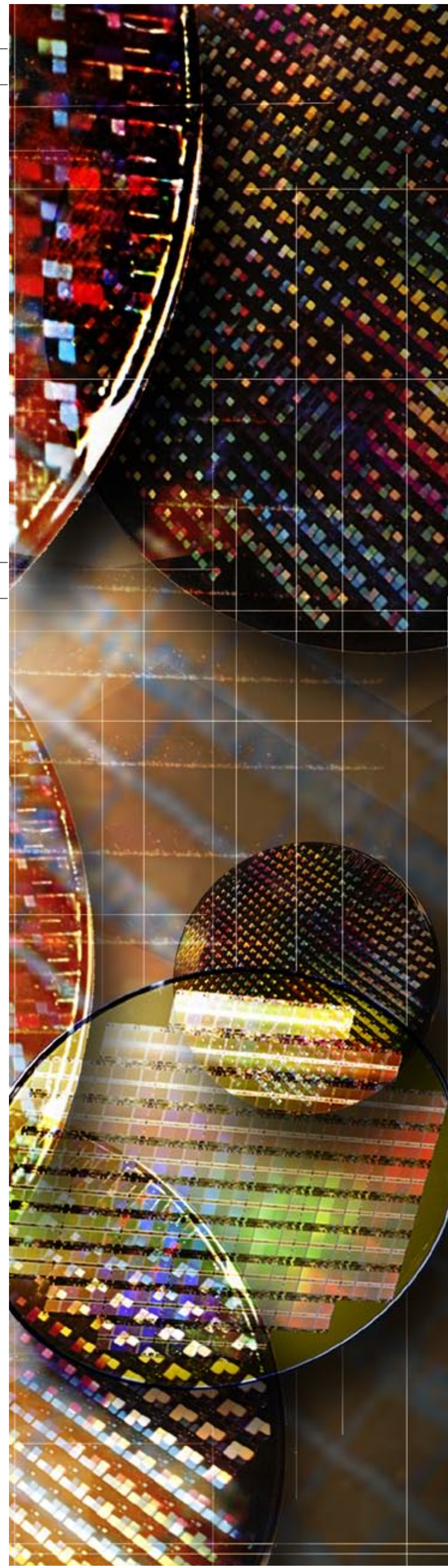

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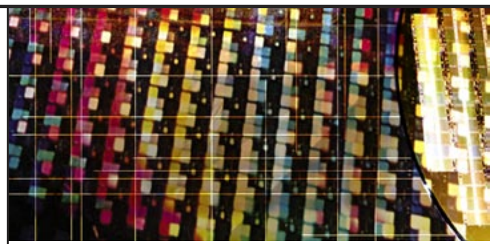


Since the late 1990s, a variety of factors have combined to trigger the beginnings of a massive migration of semiconductor plant capacity to China. Often noted is the appeal of the low cost of labor in many parts of China, but another equally important factor has been the previous migration of electronics production to China and the associated need for chip suppliers to be close to their original equipment manufacturer (OEM), original design manufacturer (ODM), and electronics manufacturing services (EMS) customers. Also of fundamental importance are the attractive tax, loan, and land incentives provided by Chinese governments at all levels.

The downturn of 2000 through 2003 brought the closure of many unprofitable facilities in the West and accelerated plant migration to Asia-Pacific. This was an opportune time for China to offer new incentives to companies seeking to locate plants in the country. The rise of outsourcing and the fabless/foundry model created in Taiwan was yet another factor that accelerated plant migration to China. As of August 2004, more than a dozen foundries were operating in China that could generate greater than $1.5 billion in annual revenues by year's end. Plant relocation was not limited to wafer fabs. By the end of 2003, 78 semiconductor packaging, assembly and test (SPA&T) facilities had been established in China, which produced 9 percent of the world's value of SPA&T.

The Chinese government continues to attract new manufacturing business, and the semiconductor industry is particularly favored by governments in many areas because of the prestige associated with advanced technology. Additional capacity on the mainland is being added rapidly, and not all of it is purely economically motivated. This situation has caused some in the industry to voice concerns about China's impact on oversupply.

During the next year, oversupply caused by the growth of plant capacity in China is not likely to be a serious concern for the industry at large, but could be a problem for the foundry market. Over the long term, other concerns for the established industry include the size and scope of industry changes that will affect the competitive landscape and the way companies do business. At a minimum, China's growing importance to the industry will bring additional risk and opportunity to business relationships, increase the importance of cost efficiency, and usher in a number of other unpredictable changes.

Cost Efficiency as a Competitive Weapon

The most significant change China will bring to the industry relates to cost. Cost efficiency has long been the focus of many chip suppliers, particularly those with a presence in Asia-Pacific, but circumstances in China will create a different dimension to this competition. In China, the deverticalized, fabless/foundry model is the rule rather than the exception, and more competitors could emerge there than in the rest of Asia-Pacific combined. Domestically owned companies will likely spend less to protect worker health and safety, and these companies can avail themselves of other cost advantages not available to companies headquartered outside China.

Most manufacturing companies in China compete aggressively on cost. Many are bankrolled by state-owned financial institutions that have the ability to defer loan repayment indefinitely, indeed to subsidize operating losses for years with loan support. Incentives for semiconductor companies to locate in China are even greater than they are in Taiwan, and in fact, China has matched and improved Taiwan's list of incentives.

Incentives for semiconductor companies to locate in China are even greater than they are in Taiwan, and in fact, China has matched and improved Taiwan's list of incentives.

The deverticalized industry makes lower cost structures possible. Foundries have more flexibility, and they can use plant capacity more efficiently than integrated device manufacturers (IDMs) can. Many semiconductor assembly and test services (SATS) companies, similarly, are highly efficient and have become the first alternative for companies seeking new SPA&T capacity. Rather than build new assembly and test facilities, IDMs are outsourcing the SPA&T function in part or in whole. Contract design companies can produce new designs for a fraction of the cost of in-house design, although good design capability is scarce. Nonetheless, the growth of foundries and associated development policy has spawned hundreds of design companies, and it will require several more years to determine whether or not China can be successful in this area as well.

Two main cost-reduction strategies are used by the semiconductor industry, but only one of these has been used in China. The first is to focus solely on the total cost of plant, equipment, labor, and materials. This is the approach employed in China and is common among suppliers of multi-source standard products. The most aggressive of these suppliers in China—ON Semiconductor is a primary example—have moved west, where costs are lowest and government incentives are highest. SPA&T facilities appeared first in these locations, but wafer fabs in these locations have begun to appear as well. Some companies may even move design and marketing functions there during subsequent phases of development. Many manufacturers can use variations of this lowest total cost strategy.

The second main cost-reduction strategy in the semiconductor industry can be used only by top-tier manufacturers that can make the enormous capital investment required. This method involves production using the largest wafer sizes and smallest linewidths that are feasible. Producers that run 12-inch (300mm) wafers and achieve linewidths of 90nm or less with high yields can achieve cost-per-die savings over the comparable costs of suppliers that do not have this advanced capability. Achieving next-generation linewidths alone can yield cost-per-die savings of

30 percent. This approach has been used most notably by the world's largest IDMs, but also to great effect by leading-edge foundries and their fabless customers. Successful users of this strategy can invest more; sell better, more valuable products at a lower cost; and achieve better margins than their competitors. Here China is, for the moment, slowed by investment and technology transfer restrictions on the part of other countries that are sources of capital, equipment, and know-how. Because finer linewidths are associated with more advanced design and higher value intellectual property (IP), China's IP track record gives pause to prospective customers for the most advanced foundry technology.

China's Second Phase—Take Taiwan, Then Add Korea and Singapore

IDMs have been cautious about using the most advanced technologies in China because of well-known intellectual property risks, but some are preparing to do so in the near future. Hynix, for example, has obtained permission from its creditors to build a wafer fab in China, and plans an 8-inch (200mm) production line with a 90nm process in 2006 and a 12-inch (300mm) line using a 70nm process in 2007, according to World Fab Watch. Other memory suppliers such as Infineon may follow, and microprocessor vendors are not far behind.

Of all the industry participants in China, foundries have been the most aggressive in pursuing 12-inch (300mm), 90nm capability. Semiconductor Manufacturing International Corporation (SMIC) seeks to emulate Taiwan Semiconductor Manufacturing Corporation (TSMC), a leading-edge foundry and one that can command high average finished wafer prices because of its advanced capabilities.

"Companies that go to China only for labor cost reasons are shortsighted."
—Harry Rozakis, ASAT

SMIC and Hua Hong NEC, both of which have sizeable capacity in China, have grown rapidly in the past year, according to IC Insights, which forecasts that SMIC's revenue will exceed $1 billion in 2004. Both SMIC and Grace Semiconductor, another foundry provider in China, plan to build 12-inch (300mm) wafer fabs by 2006. SMIC has managed to equip its current fabs and avoid export controls in the process, obtaining good used equipment from an advanced lab in Belgium. SMIC and others likely will obtain leading-edge equipment for facilities in China despite the Wassenaar Arrangement established by the U.S. government and its allies.

Once a critical mass of 12-inch (300mm), 90nm or better capability is established in China—possibly after 2010—the equation will change. The first phase of China's semiconductor development will have ended. The preponderance of the value chain will be integrated (excepting design and equipment, which are limited in China), and IDMs and foundries in China will be able to exert more price pressure on a wide range of semiconductor product categories. At that point, China could have the semiconductor production capabilities of Taiwan, Singapore, and Korea combined.

Scope of This Report

This report evaluates the current status of the semiconductor industry in China and its prospects through 2010. After a summary of findings, implications, and recommendations, the report assesses specific motivations behind the industry migration to China, reviews each major step in the value chain, provides a detailed look at semiconductor demand in the country, and concludes with a consideration of three different production scenarios. Other issues surrounding the industry in China, including the value-added tax, IP protection, and social, environmental, and political concerns, will also be covered.

DEFINITIONS

In this report, the term Chinese semiconductor market refers to the total quantity of semiconductors purchased or consumed in China. In other words, it refers to demand. As discussed shortly, this market has two distinct segments: the domestic Chinese market, which is the quantity of semiconductors used in China for goods that remain in China, and the Chinese export market, which consists of the semiconductors consumed within China in products that are subsequently exported (as in consumer devices, PCs, and the like). By comparison, the term "Chinese semiconductor industry" refers to all companies in China that design, develop, manufacture, package, or test semiconductors. Therefore, the term "industry" refers to entities involved in semiconductor supply or production. Generally speaking, IDMs have their own wafer fabrication and in most cases their own SPA&T facilities, while fabless companies outsource these functions to merchant foundries and SATS.

FINDINGS AND IMPLICATIONS

The following is a summary of our findings and what the findings imply. This report is based upon secondary and primary research, including PricewaterhouseCoopers interviews with semiconductor industry executives.

MODERATE POTENTIAL FOR NEAR-TERM OVERSUPPLY

Findings: Capacity will not be added fast enough in China to exacerbate worldwide oversupply during the next year. Semiconductor production in China in 2003 reached $8.3 billion, accounting for 5 percent of worldwide production, still a relatively small percentage of the worldwide total. Although many fabs are planned in China, many companies building the fabs there are only adding production lines incrementally.

Merchant foundry capacity has been rising more rapidly than capacity as a whole. IC Insights reported that the capacity of foundry companies other than Chartered Semiconductor Manufacturing, Taiwan Semiconductor Manufacturing Corporation (TSMC), and United Microelectronics Corporation (UMC) grew 50 percent in 2003 over 2002 levels. Much of this new capacity is in China. China could make up more than 6 percent of worldwide pure-play foundry revenues in 2004, judging by estimates from IC Insights. China's share of total worldwide foundry capacity could increase to 20 percent by 2006. Gartner Dataquest forecasts that foundry production revenues in China will increase from $770 million in 2003 to $4.1 billion in 2008, a compound annual growth rate (CAGR) of nearly 40 percent.

Implications: China's impact on industry supply over the short term will be greatest on foundries. The rapid growth of Hua Hong NEC, Semiconductor Manufacturing International Corporation (SMIC), and other foundries in China could affect finished wafer price volatility. Commoditized product categories could suffer from penetration pricing strategies.

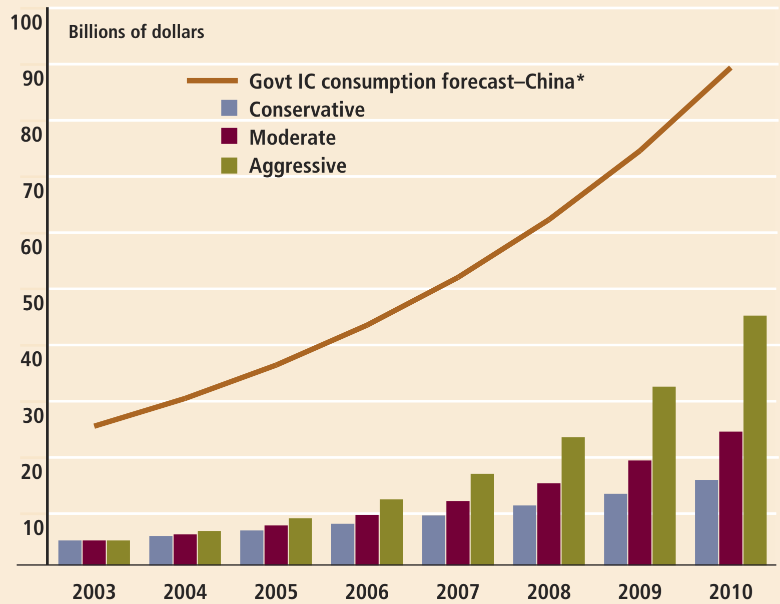
SIGNIFICANT POTENTIAL FOR LONG-TERM OVERSUPPLY AND INCREASED VOLATILITY

Findings: Enough fab capacity will exist in China after 2006 to affect the world integrated circuit (IC) market significantly. Figure 1 illustrates scenarios based on government plans to increase IC production so it will grow faster than IC consumption there by 2010.

The aggressive scenario requires that domestic IC supply increase at a rate of 40 percent through 2010 to $44.8 billion. Although the 2004 growth rate could come close to 40 percent, it is unlikely this rate will be sustainable through 2010.

The moderate scenario would require production of $24.1 billion by 2010, a CAGR of 28 percent over 2003; all fabs with a World Fab Watch probability of 0.45 or greater would be operational and fully utilized. China's share of worldwide IC fabrication would be 11.5 percent by that point.

FIGURE 1: CHINESE IC PRODUCTION SCENARIOS VERSUS CONSUMPTION



*Assumes 20% CAGR for 2003–2010

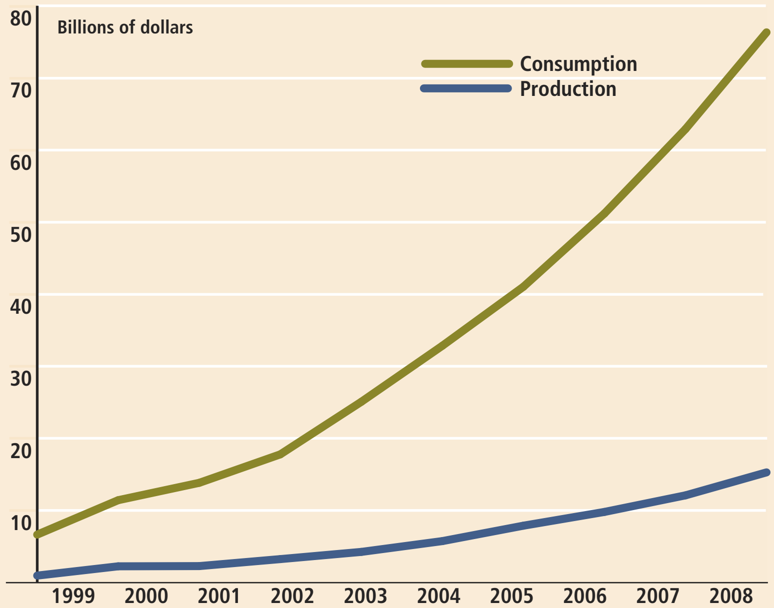
Source: CSIA, World Fab Watch, PricewaterhouseCoopers, 2004

FINDINGS AND IMPLICATIONS (CONTINUED)

The conservative scenario would achieve production revenue of $16.1 billion by 2010, a growth rate of 20 percent; China would still have 9 percent of total worldwide fab capacity by the year-end.

Implications: China's influence on worldwide production will be significant in wafer fabrication and semiconductor packaging, assembly and test (SPA&T). Foundry capacity could exceed 20 percent of worldwide capacity by 2006, as stated earlier. An equilibrium in wafer fabrication—one that shows China's capacity and that of the rest of the world growing at more or less the same rate—will not be reached until the following decade. China's emphasis on foundries will accelerate the growth of the fabless/foundry business model and outsourced SPA&T, and will increase price volatility in those areas.

FIGURE 2: CHINESE DOMESTIC IC CONSUMPTION VERSUS PRODUCTION, 1999-2008



Source: CCID Consulting, PricewaterhouseCoopers, 2004

RISING DEMAND FOR DOMESTIC SOURCES OF SUPPLY

Findings: China's domestic IC consumption/production gap—the difference between what it consumes and produces within its own borders—has grown from $5.7 billion in 1999 to $20.8 billion in 2003, according to CCID Consulting. The gap between consumption and production has widened substantially since 2001, which has likely strengthened the Chinese government's resolve to increase domestic production. (See Figure 2.)

Implications: As the semiconductor value chain in China develops, demand increases for local sources of supply. Assembly and test facilities as well as wafer fabs in the country seek to shorten their supply lines, encouraging their outside materials suppliers to locate plants in China. Demand for maintenance, customer support, and training from equipment suppliers will increase.

VARYING IMPACT ON PRICES

Findings: The addition of foundry and semiconductor assembly and test services (SATS) plant capacity in China will place some pricing pressure on many chip categories, but high-volume, low-mix products that are producible with well-established process technologies will experience the most intense pricing pressure. Product categories most affected could include standard logic, microcontrollers, low-density memory, analog ICs, and discretes. Less affected will be high-density memory, microprocessors, and application-specific products.

Foundries and SATS suppliers outside China, regardless of product category, are primarily located in other places in Asia. Because of the sharp rise in foundry and SATS capacity in China, these companies will feel the impact of price competition most, particularly if they themselves compete mainly on price.

Implications: Manufacturers in China, regardless of ownership, will contribute to pricing pressure. However, domestically owned manufacturers will be able to operate with a cost structure different from foreign-owned manufacturers and could impose the most pressure. They can force their labor costs down further because of the absence of the Occupational Safety and Health Administration (OSHA) in the United States and some other requirements foreign-owned companies must adhere to. Domestically owned companies also are better able to find and negotiate low prices for materials and fixed assets locally.

These companies may be able to price products below cost for longer periods so they can gain market share. In addition, production at Chinese companies will be susceptible to a range of non-market forces that could negatively affect pricing, including government production quotas. These circumstances could cause established makers of low-end products outside China to shift the balance of their production to midrange product categories.

SUBSTANTIAL SHIFT IN SALES BY GEOGRAPHY

Findings: China's share of IC sales—consumption, rather than production—has risen from 2.2 percent in 1996 to 17.9 percent in 2003. By 2008, its share will rise to 25.6 percent, according to IC Insights.

Implications: China will become an even more attractive IC market, one that will require substantial marketing and product support. IC industry companies that do not provide adequate service in China will be at a disadvantage. Similarly, adequate distributor presence in China will be essential.

SHIFTS IN PRODUCTION LOCATION IMPLY CHANGES IN COMPETITIVE LANDSCAPE

Findings: As the value chain in China integrates, the relative balance of manufacturing continues to shift from other places to China.

Implications: Production location changes will cause unpredictable shifts in market share, value chain, profit pool distribution, application markets, research and development (R&D), patents, and intellectual property.

SHIFTS IN PRODUCTION LOCATION ATTENDED BY CHANGES IN BUSINESS MODEL

Findings: In design and wafer fabrication, a higher percentage of China's capacity is fabless/foundry rather than integrated device manufacturing (IDM). In SPA&T, a higher percentage of capacity is outsourced SATS.

Implications: The industry's adoption of a deverticalized model is being accelerated by the growth of China's presence. The integration of foundries, SATS vendors, original design manufacturer (ODM) or electronics manufacturing services (EMS) companies, and other elements of the value chain will be important for effective operations and business development.

RELATIVE LACK OF CAPABLE SEMICONDUCTOR DESIGNERS

Findings: By the end of 2003, 463 fabless and contract design companies existed in China, according to the Chinese Semiconductor Industry Association (CSIA). However, there were only 500 qualified IC designers in the entire country, according to Advanced RISC Machines (ARM). China produces only 400 semiconductor design graduates annually, according to iSuppli. Concerted government efforts to encourage semiconductor product development in very specific areas such as PC microprocessors have not had any significant effect on this situation to date.

Implications: Chinese innovation in semiconductor design will be hampered by the lack of sufficient designers through 2010, and demand for foreign semiconductor designs will be high. Derivative designs will be prevalent. A few research institutes and startups in China will be responsible for the bulk of real design innovation there, and this innovation will continue to be dependent on the assistance of returning expatriates.

FINDINGS AND IMPLICATIONS (CONTINUED)

SMALL MARKET TO DATE FOR NEW SEMICONDUCTOR EQUIPMENT

Findings: New equipment sales are low in China, considering the high level of plant migration to the country, amounting to 7.5 percent of the total equipment market in 2003. Demand for less-expensive used equipment is high, and good used equipment is widely available because of the severity of the 2000 to 2003 downturn.

Implications: Many semiconductor manufacturing ventures are undercapitalized and unable to purchase new equipment. Only a few companies in China (12-inch [300mm] foundries, for example) will have the latest equipment. Most will focus on mature, commoditized segments of the market, placing more price pressure on these segments. Support and maintenance will make up a larger percentage of equipment company revenues in China than in other leading semiconductor-producing countries.

AGGRESSIVE POSTURE ON SEMICONDUCTOR-RELATED STANDARDS

Findings: Asian governments have moved to address the issue of high royalty payments that primarily benefit Western companies. China in particular has taken steps to establish its own standards. Some of these standards will not be successful, but the country's attempts to influence standards will continue.

Implications: Standards-setting efforts by the Chinese government will be difficult to ignore. Companies that have invested R&D capital in standards development will have to modify their own strategies in response.

LESS THAN 10 PERCENT OF WORLDWIDE 12-INCH (300MM) FAB CAPACITY IN CHINA BY 2010

Findings: As of April 2004, there were three 12-inch (300mm) fabs in China (all owned by SMIC) being equipped for production by 2004, 2005, and 2006, according to World Fab Watch. These will constitute less than 10 percent of total Chinese semiconductor production by 2010. At least one other 12-inch (300mm) fab (planned by Grace Semiconductor) could begin production by 2006.

Implications: Technological advantage in Chinese foundries will reside in a few companies that have the wherewithal to invest in advanced wafer fab equipment. Wafer size and linewidth advantages could allow these foundries to proceed down the cost curve more rapidly.

HIGH UNIT VOLUMES, LOWER PERCENTAGE OF VALUE IN PACKAGING

Findings: By 2008, China will account for 35 percent of worldwide discrete and 28 percent of IC SPA&T production capacity in unit terms, rising from 25 and 11 percent respectively in 2003. However, the value of SPA&T production in China was only 9 percent of worldwide in 2003.

Implications: China will strongly influence SPA&T pricing for high-volume, low-cost discretes and ICs. Companies will increasingly seek out less-expensive parts of the country for plant location as price competition intensifies and low-cost labor in coastal cities becomes scarcer.

DOMESTIC DEMAND COMPARABLE TO THAT OF MUCH SMALLER ASIAN COUNTRIES

Findings: China, with 21 percent of the world's population, accounted for just 4 percent of world gross domestic product (GDP) in 2003. Assuming a CAGR of 7.5 percent from 2003 to 2010, China will produce $790 billion more in GDP in 2010 over 2003 levels, or $1,246 more per person. Wealth will continue to be unequally distributed. Fewer than 100 million people live in China's principal cities, and fewer than 50 million live in cities in the wealthiest provinces. China's most significant impact on the world market, therefore, will continue to be as a manufacturer of exported products, rather than as a consumer of end-user products.

Implications: Discretionary spending in China continues to be restricted to a very small subset of the overall population. Although the domestic market is growing rapidly, its impact on the world market will be comparable to that of Japan's impact in the 1950s and 1960s, and possibly somewhat more than South Korea's in the 1980s and 1990s.

ELECTRONICS PRODUCTION REFLECTING MORE ODM AND EMS INFLUENCE

Findings: Revenue from electronics production in China will triple by 2010, rising at a CAGR of 17 percent from 2003 and reaching $285 billion, according to IC Insights and PricewaterhouseCoopers. By contrast, worldwide production will rise 6 percent during the same period. ODM production will rise 22 percent, followed by EMS production and other contract manufacturing.

Implications: The importance of the ODM channel for semiconductor sales increases. Chipset and module makers will find it necessary to develop reference designs and perform more system design in general.

HIGH MOBILE PHONE, CONSUMER DEVICE, NOTEBOOK PC PRODUCTION LEVELS

Findings: By 2007, China's share of worldwide video game console production will exceed 50 percent, according to Gartner Dataquest. Color TV and notebook PC production will exceed 40 percent, and mobile phone production will reach 40 percent. By 2010, 3G phone production alone will consume semiconductors valued at $20 billion.

Implications: Electronics production in these product categories will increase demand for locally produced semiconductor content.

EMPHASIS ON LOGIC, ASSPS, AND MEMORY

Findings: Chinese consumption of memory and application-specific standard products (ASSPs) will exceed that of microcomponents through 2008, according to Gartner Dataquest.

Implications: Handheld and consumer electronics devices are constituting a larger percentage of total electronics production in China, which will favor companies that are well positioned in these application categories.

EMERGENCE OF A MAJOR CHINESE IDM

Findings: An IDM ranked in the top 25 in worldwide sales will emerge in China by 2010 or shortly thereafter, probably serving the second source, mid-market, and commodity products segment for high-volume applications. The Chinese government's active role in nurturing the domestic semiconductor industry will have a number of other unpredictable effects on the competitive landscape, but the motivation to create a high-ranking, globally competitive IDM is strong. The growth of such an IDM will arise from the sale of products designed for Chinese needs.

Implications: One possible consequence of the development of a major IDM encouraged by the Chinese government would be the lack of a level playing field in this product area, favoring the Chinese IDM over others. The IDM may gain additional advantages through special relationships with electronics original equipment manufacturers (OEMs), or by working through EMS or ODM companies.

SOME CHINESE DESIGNS AT 0.18μm AND BELOW

Findings: One-third of Chinese IC designs were at the 0.18μm node or below in 2003. Some Chinese designs at 0.13μm were beginning to be produced in July 2004.

Implications: The capable Chinese designers will become more globally competitive soon, particularly in the area of logic ICs. ■

RECOMMENDATIONS

As noted in the preceding Findings and Implications section, China's growing influence on the semiconductor industry will have broad-ranging effects. The following recommendations provide some preliminary guidance to companies seeking to take advantage of new business opportunities in China or anticipate changes that will result from the country's new role as a major semiconductor producer.

PROTECT INTELLECTUAL PROPERTY

The following best practices provide some initial guidance in this area:

Avoid exposing any information that could jeopardize competitive advantage. Ventures in China based on older technology can still be profitable, and can offer a way to establish a presence now that can be expanded with better technology later. Consider keeping intellectual property (IP), even if developed in China, outside the country.

Conduct a risk assessment before any venture in China. The level of risk of new ventures in China can be high, but excessive security measures can waste resources and reduce efficiency. It is important to have detailed knowledge of where the highest risk lies and what the level of the risk is.

Design and implement physical and IT security systems that are appropriate for the risk. An assessment of business requirements and risk will determine the nature of additional IT security considerations. Further restrictions on information access could be necessary, and these restrictions will tend to reduce the operating efficiency of the company as a whole.

A company's IT security strategy must consider fully the extra risk a venture in China adds. The most valuable intellectual property should receive the highest level of protection, while older, less-essential IP will warrant a lower level of protection.Make appropriate legal arrangements and develop strong documentation. In joint venture arrangements, make use of the arbitration clauses in contracts. Enforce remedial action through arbitration courts outside of China. This approach will not help with employees, with whom there is only a contract appeal via a Chinese court.

Establish close relationships with employees and educate them on the best IP protection methods. Best employment practices and employee education will improve employee awareness, increase loyalty, and reduce the risk of IP loss.

Establish alliances with companies and government entities that can benefit from protecting intellectual property. Make it in the government's interest to protect IP, or at least remove any incentives for the government to encourage the undermining of intellectual property. For example, remove the government's motivation for import substitution.

Proactively monitor IP and pursue violators. Initially notifying a company of an infringement accompanied by a demand to discontinue the violation can sometimes be sufficient. Injunctions on end products in countries that protect IP can be effective, but are costly and time-consuming. Strong legal action is sometimes necessary, and high-profile actions taken in China can encourage better legislation and enforcement in the future.

Avoid underestimating Chinese R&D capabilities. Accept and integrate into business strategies the following facts: the absolute level of science and technology in China has taken a quantum leap during the past decade; many well-equipped and well-staffed advanced research and development (R&D) institutes have sprung up; and many hundreds of thousands of Chinese scientists and engineers have been educated and trained to world-class levels.

PREPARE FOR INCREASED VOLATILITY WITH CONTINGENCY PLANNING

As electronics manufacturing in China grows during the next several years, an increase in market volatility for the worldwide semiconductor industry is likely. When new companies enter the market and maneuver for position in China, competition will intensify and periods of oversupply will result.

At other times, shortages will occur. A supplier, for example, could withdraw suddenly, creating a shortage situation, or demand for some products could rise suddenly as consumer preferences change, resulting in shortages of specific parts or materials.

Other areas of the broader economy will also have an impact on semiconductor market dynamics. The rising price of oil and other imported commodities, for example, could decidedly change what China manufactures and for whom, particularly in the case of low-value, high-weight products such as major appliances and large-format televisions. Many such changes could affect the investments of semiconductor industry companies that hope to benefit from an increased presence in China.

Beyond better forecasting, the best way to prepare for increased volatility in demand and supply is to conduct scenario planning exercises. In this way, companies can decide before a crisis occurs how best to respond should a particular situation develop. After considering the scenarios and the consequences that could result, managers can begin to develop a comprehensive set of contingency plans that can be periodically maintained and updated.

USE PERIODS OF OVERCAPACITY

Buyers of foundry services or semiconductor assembly and test services (SATS) may be able to negotiate very favorable deals during periods of overcapacity, when Chinese production facilities may be anxious to maintain some level of throughput. Buyers should monitor capacity changes closely to anticipate excess supply situations. Such a strategy can be complicated, of course, by the need to qualify each supplier carefully.

IDENTIFY AND FOCUS ON SPECIFIC, STRONG CUSTOMERS AND THEIR REQUIREMENTS

Customer assessment is more important to a successful semiconductor market strategy in China than in many other locations because of the rapidly changing competitive landscape and the relative lack of good, readily available company information there. A small number of original design manufacturer (ODM) and electronics manufacturing services (EMS) companies hold a large share of the high-volume consumer electronics, PC, and communications market, but their requirements can change quickly as the landscape of their own original equipment manufacturer (OEM) customers shifts. Companies that are less familiar with the Chinese market would do well to seek out more stable customers to begin with.

EVALUATE NEW PARTNERS AND SUPPLIERS THOROUGHLY

The biggest single cause of failure and loss in China is the failure to know enough about partners, suppliers, or customers before commitments are made. Assume the need to conduct a very thorough due diligence when considering partnering, merger, or acquisition possibilities.

MARKET LEADERS: OUTFLANK THE EXTERNAL COMPETITION

Some Western companies seeking to protect market share have successfully outspent or outmaneuvered their competition in China, sometimes recruiting many of the most talented personnel in the process. For example, VIA Technologies acknowledged that it had hoped to recruit 1,200 personnel for its Beijing R&D Center, but had hired only 60 by December 2001. VIA noted: “Most Chinese headquarters of Western corporations are located in Beijing. They are all competing for good people, and it is relatively difficult for Taiwanese companies to recruit.” Intel, for instance, has made extensive investments in education funds in China, which may have contributed to its success against its rivals.

RECOMMENDATIONS (CONTINUED)

LOW-COST AND HIGH-VOLUME PRODUCERS: JOIN THE INDIGENOUS COMPETITION

Over the long term, manufacturers of older, multi-sourced standard product lines may be able to achieve lower cost structures by engaging in joint ventures with Chinese partners. This strategy could involve the transfer of equipment from aging facilities to a facility in China that has a contemporary, optimized layout. Or, this strategy could involve the purchase of used equipment at low cost. In some cases, management, design, and marketing responsibility may be transferred to the Chinese partner, which could result in a favorable classification of the plant as a local facility, depending on the rules of the provincial government in question.

Joint design ventures can provide companies a means of entry into the Chinese domestic market. Texas Instruments, for example, partnered with Hua Hong IC Design, Ningbo Bird, Xiamen, and ZTE in 2000 to jointly develop 2.5G handsets in a project overseen and funded by the Ministry of Information Industry. Ningbo Bird shipped 10 million handsets in 2003, according to Gartner Dataquest. Also in 2000, Texas Instruments established a joint digital signal processor (DSP) applications laboratory with Midea Group, an air conditioner manufacturer to which it sold DSPs.

Companies considering such a venture should be aware that the different branches and levels of the Chinese government can be inconsistent in their approaches to foreign companies. One part of the government may cultivate these relationships at the same time another actively pursues ways to decrease dependence on foreign semiconductor design sources. As mentioned previously, any partnering arrangements should be evaluated closely beforehand.

INTRODUCE NEW PRODUCTS SELECTIVELY

Competition promises to become much more severe as a result of China's increased prominence in manufacturing. The recent experiences of systems vendors, even those that normally compete on price, can be a leading indicator for the semiconductor industry. Dell, for example, announced in August 2004 that it would exit the market for low-end PCs in China after Lenovo Group led a price war in the product segment. Dell maintains a strong presence in the mid-market there, and continues its main focus in China on business customers.

Semiconductor companies in China should not underestimate the willingness of their competition to revert to price wars. At a minimum, companies need to consider the strength of the competition in the segment, the willingness of customers to substitute one product for another, the margin necessary to survive in the segment, segment dynamics, and future trends. Some companies accustomed to competing on price may not fare well with the same strategy in China. Higher-margin products associated with higher barriers to entry may provide a stronger opportunity in such a case.

PROVIDE DEVELOPER SUPPORT TO THE LOCAL MARKET

Providing solid support for products is crucial to successful market penetration. Texas Instruments, for example, is known for its development support for its DSP products, and other companies such as Advanced Micro Devices (AMD), Intel, and STMicroelectronics have succeeded in the Chinese market in part by establishing centers in China to assist with reference designs and development platforms. ODMs tend to require more extensive support than OEMs that conduct their own design work.

Companies should make product collateral available in Chinese, including data books, application notes, and reference designs. Screens and interfaces for all equipment should also be in the Chinese language. Chinese speakers on staff are essential, and at least some of these employees should have local knowledge of individual market, government, and logistics conditions. Companies need to identify the requirements that products must meet to be competitive locally, and companies should design, manufacture, and market the products to these requirements.

ESTABLISH AND PROTECT BRAND IDENTITY IN CHINA

Even in lower-cost areas, perceptions of brand quality can allow a price premium. Intel has been very active in this area through advertisement and university influence.

PROMOTE AND ADHERE TO BEST HEALTH, SAFETY, AND OTHER PRACTICES

Occupational health and safety practices in China are substandard in many places, and intense price competition may discourage the use of proper procedures. Companies should promote the application of established common industry standards and practices throughout China to make the playing field more level.

INVEST EARLY IN ASIAN STANDARDS DEVELOPMENT

Large integrated device manufacturers (IDMs) have the wherewithal to invest early in product development areas in China. STMicroelectronics, for instance, licensed Time Division-Synchronous Code Division Multiple Access (TD-SCDMA) technology from Datang and offered a TD-SCDMA platform for developers in 2003, anticipating mass market introduction of an SoC in 2005. Smaller semiconductor companies may have the opportunity to partner with local companies that may have obtained licenses on favorable terms. Companies should be selective about these opportunities and consider the drain on resources that standards developments can have. Only a few of the many standards being developed will see large-scale adoption.

LEVERAGE OTHER SUCCESSFUL VENTURES IN CHINA

Multinational corporations can take advantage of previous ventures in other industries in China and transfer the knowledge gained to a new semiconductor industry undertaking. Several of the most prominent foreign-owned or joint-venture operations in China have a history of doing business there, and their semiconductor-related operations are only their most recent effort in the country. These companies have a cadre of experienced employees who have moved from one successful venture to another.

ANTICIPATE LOGISTICS PROBLEMS AND PLAN FOR EFFECTIVE PRODUCT DELIVERY

Companies should assume that logistics in China will be complicated. Products to be used there will need to be effectively delivered, and just-in-time capabilities will be essential. A plant in China, or solid third-party logistics support at a minimum, will be necessary to accomplish product delivery.

ADOPT A LOCALIZED PROCUREMENT STRATEGY EARLY

At least a dozen foundries exist in China. Semiconductor companies pursuing a fabless or fab-lite business model might consider establishing relationships with one or more of these foundries. In so doing, they may be able to obtain a preferred position. Fabless companies, in addition, may find it easier to qualify with new foundries. One of the downside risks of any fabless/foundry relationship is IP leakage, however, and this risk is higher in China than in many other countries.

WORK CLOSELY WITH LOCAL GOVERNMENTS

Administrative procedures are very complicated in China, and each locality may have special requirements and incentives. Enlisting the help of local governments can help streamline administrative processes. Semiconductor companies that have established plants in China have made mistakes about where to locate these facilities. Companies should be aware of all the major national and local requirements that apply and incentives that might be available.

While leveraging Chinese government incentives and subsidies to the extent possible, companies should know that government attitudes and policies can change unexpectedly. Different provinces

RECOMMENDATIONS (CONTINUED)

offer different incentives, and it is important to evaluate the pros and cons of particular locations. Some companies have mistakenly located in one place, only to find it necessary to relocate.

Local governments in places like western China can be more receptive to aggressive proposals, and the national government provides extra incentives for the region. ON Semiconductor's assembly and test facility in Leshan is an example of a successful plant operation in the Sichuan province of western China. Motorola, the predecessor company establishing the plant, negotiated an advantageous agreement with the local provincial government and began packaging discrete devices (mainly switches and diodes) there. Over time, this plant's capabilities grew, and the facility now claims the lowest cost and best quality of any plant ON operates for the products manufactured. Currently, ON plans to expand its presence in Leshan with a wafer fab. It remains to be seen if other functions can be successfully moved from the coastal centers of technical education, higher standards of living, and international culture to these lower-cost areas.

Establishing efficient operations in western China requires even more extensive site evaluation and planning than comparable efforts in developed coastal areas might. Risks can be high. Infrastructure concerns in western China continue despite efforts to improve it. Transportation can be unreliable, and the trucking industry, for instance, consists of many small companies that enjoy government protection to the detriment of overall efficiency. Governments may initially be supportive, and then change course and undermine a company's efforts later. ■

There are three principal reasons to be in China: cost savings, participation in the local supply chain, and proximity to participation in the local semiconductor market. These three factors often overlap. In every decision, however, one reason tends to be dominant, while the others provide supporting incentives for a presence in China.

Cost Savings

Locating in China provides direct savings to semiconductor manufacturers. These savings are derived primarily from reduced labor, capital, and operating costs due to government incentives and certain tax benefits, particularly those associated with China's differential value-added tax.

LABOR COSTS

Wages in China are significantly lower than in Europe and North America, and they are somewhat lower than wages in other Asian countries. Although lower labor costs were at one time the principal motivation for establishing facilities in China, savings garnered from labor costs have been steadily decreasing. The root cause is upward wage pressure being exerted by white-collar workers (such as designers, managers, and executives) in large cities, such as Shanghai and Beijing. This wage pressure is due to the comparative shortage of workers who have semiconductor-related skills and the increasing demand for them. Eventually, China will deliver more skilled engineers—either through its own educational system or exposure to skills imported by foreign manufacturers. The advent of these skills might dampen wage pressure, but until that time, wage inflation will undercut labor savings.

Wages in China are lower in the central and western provinces. To avail themselves of these lower labor costs, semiconductor manufacturers are increasingly building new plants farther inland from their current operations in the eastern provinces. Intel and Motorola (later ON Semiconductor) both established new plants in the west with this specific benefit in mind. This trend is likely to continue.

The cost savings that can be realized by a favorable pay scale varies widely with the nature of a company's business. The following ranking indicates (in descending order) the dependence on labor of various segments of the semiconductor value chain.

- Design (most)
- Some materials
- Assembly and test
- Fabrication plants (fabs) and foundries
- Materials with low labor components

Savings due to labor costs are expected to continue diminishing over time, and the westward movement will provide only a stopgap solution. Eventually China's wage scale will be comparable at all points with those of other Asian countries (notably India, Thailand, and the Philippines), and it will disappear almost entirely as an impetus for setting up operations in China. Says Jean-Philippe Dauvin, group vice president and chief economist at STMicroelectronics, "By 2008, this cost advantage will not be much of a reason to be in China, but the domestic market will be."

GOVERNMENT INCENTIVES

To attract investment in semiconductor manufacturing, the Chinese government provides a wide variety of special incentives. These incentives typically include land subsidies, loan subsidies, significant discounts on utilities and logistical support, and preferential tax treatments. These incentives are put in place by the national government for large plants such as fabs, and by the regional governments for smaller operations. Interviews with foreign organizations operating in China indicate that these incentives have been consistently delivered as promised.

Participation in the Local Supply Chain

Customers in China, particularly companies that are designing products for export, are notoriously cost conscious and, as a result, have a strong preference for a local supply chain. These customers are disinclined to wait for imported inventory to be manufactured, shipped, and cleared through customs before fulfilling the orders they have on hand. In almost all cases, a wait of this kind will force the customer

VALUE-ADDED TAX

In China, as in other countries that employ this taxation instrument, the value-added tax (VAT) is an alternative to sales tax. It consists of a tax on the amount of value added by each vendor in the product chain as raw materials progress into a finished product. Nations that use the VAT tend to prefer it to the model of a flat sales tax, because they can stimulate or moderate individual sectors of the economy by changing the tax rate or offering tax rebates at various stages in the manufacturing and distribution process.

The VAT does not affect all segments of the value chain equally. For example, imported raw materials in some cases and equipment for semiconductor manufacture are both exempt from any taxation. In the case of integrated circuit (IC) makers, those that have investments of more than 8 billion RMB or have processes capable of linewidths of 0.25m or less are exempt. As a result, vendors that meet the qualifications for this overall exemption in these segments are unaffected by VAT-related issues.

Effects and Resolution of the Differential VAT

China's VAT of 17 percent is imposed on most products manufactured domestically and on most imported products. It is generally collected by the seller as part of the purchase price of the product and then remitted to the local tax authorities. As part of China's Tenth Five-Year Plan (issued by the State Economic and Trade Commission in 2001 for the years 2001–2005, but with a valid period for the incentive of 2002–2010), a differential VAT was established by which domestic semiconductor manufacturers could apply and receive a rebate of 14 percent of the total 17 percent VAT, leaving an effective VAT rate of 3 percent. (In certain cases, discussed shortly, the effective rate was higher.) Imported semiconductors, however, did not qualify for the rebate, and so their VAT rate remained pegged at 17 percent.

Other countries protested this differential treatment, saying it lacked conformance with the World Trade Organization's (WTO) requirements as spelled out in the General Agreement on Taxes and Tariffs of 1994 (GATT). In March 2004, the United States requested formal consultations with China, the first step under the WTO's dispute resolution procedure. In July 2004, the Chinese government agreed to eliminate the rebate for domestic manufacturers.

One of the principal reasons for having a presence in China is the domestic semiconductor market, which is expected to expand significantly between now and 2010. To sell into this market, non-Chinese semiconductor vendors must be price-competitive with their domestic counterparts. In view of the differential VAT, this created a significant challenge. As a result, many manufacturers established facilities in China, so they could gain access to the domestic market at prices that benefited from the VAT rebate. To qualify, companies to look for local alternatives. Hence, to compete, vendors in the electronics supply chain must have manufacturing plants on the ground in China.

Despite this pressure for local supply chain support, many parts of assembled products are still imported because no domestic equivalents are available. This phenomenon is particularly visible in the auto industry: Despite lower labor costs and the availability of inexpensive domestic parts, cars in China cost the same as they do in the United States. This pricing parity is almost entirely due to the cost of imported parts.

Local Participation in the Chinese Market

A frequent saying among companies setting up businesses in China is: "If you want to be a player in China, you have to be in China." This dictum encapsulates a widely recognized reality: Participation in the Chinese semiconductor market is granted primarily to companies that are willing to make the investment of a manufacturing operation in the country. It is important to add that operations in Hong Kong do not fulfill this requirement. Hong Kong remains a zone apart, even though it has been officially part of China since mid-1997. Today, for example, Hong Kong maintains a separate legal system and a separate currency.

Proximity to the Chinese market requires a definition of that market. The "Chinese market" is a term that generally refers to the use of semiconductors both in exported items and for domestic consumption. The different size of these two segments is discussed later in this document.

began joint ventures with Chinese businesses or wholly-owned subsidiaries (known as wholly foreign-owned enterprises, or WFOEs) in China because these entities were viewed on a par with domestic businesses for purposes of VAT calculation.

The VAT was widely seen as the proverbial straw that broke the back of Taiwan Semiconductor Manufacturing Corporation's (TSMC's) resistance to establishing operations in China. Morris Chang, the company's CEO and an outspoken opponent of the differential VAT, observed that "Our U.S. customers who have either joint ventures or wholly owned subsidiaries in China have indicated to us that sooner or later, we have to be there, because it costs them a lot in taxes to import our goods."

The stimulus provided by the VAT for foreign investment was not the only consequence of the differential VAT. The differential enabled the local vendors to grow by undercutting imports, thereby stimulating the indigenous semiconductor industry.

The VAT in Practice

A common way companies have dealt with the VAT is to do what is called the Hong Kong turnaround. This process enables companies to leverage exceptions in the VAT law to their favor. The primary principle is that unfinished products that are imported into China are not subject to the VAT. So, a foundry shipping finished wafers to a local semiconductor assembly and test services (SATS) company will in fact ship them to Hong Kong and bill a Hong Kong company for them. Because the product is technically exported, no VAT is charged. Then the SATS company will import the same wafers to its plant in China. Because the wafers are considered unfinished materials for the SATS, no VAT is imposed upon them as they cross the border into China. This turnaround can occur several times in the development of a single product. Companies that specialize in handling the billing, paperwork, turnaround, and re-export in Hong Kong can complete the process in as little as 28 hours.

This operation has one other advantage: It facilitates payment in foreign currency rather than in Chinese currency—a benefit for most, if not all, vendors. For purposes of industry analysis, this turnaround creates difficulties because it leads the Chinese authorities to double and triple count semiconductors, as they cannot recognize that previously counted wafers are now complete ICs. The problem of double counting—an ongoing difficulty in analyzing business in China—has been compensated for, to the extent possible, in the numbers presented in this report. ■

For more information about growth predictions, see page 55.

Proximity to this market confers several advantages, mostly competitive. It enables companies to establish themselves as a player in a market that is becoming more competitive (and it enables them to respond with agility to changing market needs). In view of the substantial growth predicted for the Chinese semiconductor market, companies want to be established early and position themselves against domestic and transnational competitors as early as possible. Manufacturers such as Dupont, Intel, and Motorola that came to China early have already recognized the benefits of establishing their names and their presence in the domestic market.

Beyond the competitive benefits, a manufacturing presence in China provides obvious logistical benefits for serving customers. Companies can derive additional advantages from Chinese regulations, specifically those governing levels of local content. In January 2003, a new Government Procurement Law (GPL) went into effect. This new law was designed to provide greater transparency to government procurement—an activity previously seen as rife with corruption and favoritism—and to comply with China's obligations under the World Trade Organization (WTO). The GPL requires government entities (excluding the military and many of the provincial governments) to purchase products of which at least 50 percent of the added value is locally made.

For purposes of this law, foreign companies with wholly owned subsidiaries in China are viewed as local companies and are therefore acceptable vendors. Given the size of the national government and its current willingness to invest heavily in infrastructure, qualifying as a local company can create opportunities for significant contracts.

THE CHINESE CONSUMER MARKET

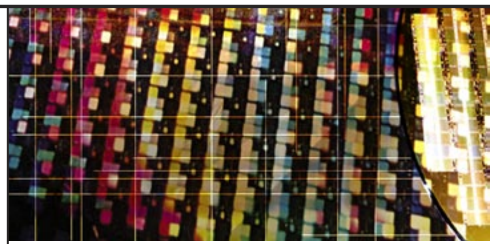
The vast Chinese consumer market has been a hoped-for golden opportunity to foreign corporations for more than two centuries. As early as 1840, British companies looked enviously at China's market as a destination for many of their goods. A century later, American advertising executive Carl Crow, who marketed pharmaceuticals in China, wrote a famous book *400 Million Customers*, promoting the dynamics of this market. In it, he made the following observation, which neatly encapsulates a mercantile fantasy of long standing: "No matter what you're selling, your business in China should be enormous, if the Chinese who should buy your goods would only do so." Yet, despite 25 years of work in China, Crow's agency never launched a successful product.

His failure and those of many other entrepreneurs in China can be attributed, in part, to misunderstanding the Chinese consumer market. The principal misunderstanding is the belief that the Chinese market is homogeneous. In fact, it is not. On a macroeconomic level, for example, Chinese consumers fall into two distinct groups: the roughly 800 million rural poor, who subsist on less than $1 per day, and the remaining 500 million who, on average, live on approximately four times that amount. Of these "richer" Chinese, only the top 20 percent earn as much as $2,000 per year, which remains significantly below the $5,000 threshold at which true disposable income becomes a reality.

As a result, the number of Chinese who can truly purchase items beyond the basics needed for day-to-day living is significantly below 100 million. This scenario is somewhat compounded by the Chinese savings rate, which historically has been extremely high, due to the absence of a widespread pension system and health-care protection in China. In fact, this high rate of savings has fueled a significant portion of the capital investments made by Chinese banks during the last decade.

Additional non-economic factors complicate the possibility of a unified Chinese market. These include poor distribution channels, the conflicting laws and regulations of the different provincial governments, and the use of different languages. Consequently, it is important to recognize the Chinese consumer market for what it is: a potentially large market that will grow slowly over time and will need to be viewed not as a single, monolithic entity, but as a collection of individual markets. ■

SEMICONDUCTOR VALUE CHAIN DYNAMICS



Value chains are groups of companies that in a sequence of design and production events contribute value to an end product. China's function as a catalyst for change in the semiconductor value chain is best understood within the context of overall worldwide change. This section provides an overview of the current dynamics of the worldwide semiconductor value chain. The following section then compares and contrasts it with the semiconductor value chain in China.

Value Chain Deverticalization

At the heart of the traditional semiconductor value chain are device companies that own their own wafer fabrication plants (known as fabs) and, in a number of cases, their own semiconductor packaging, assembly and test (SPA&T) facilities. These vertically integrated device manufacturers (IDMs), led by Intel, Renesas, Samsung, STMicroelectronics, Texas Instruments, and Toshiba, continued to hold more than 85 percent of the integrated circuit (IC) market through the end of 2003, according to IC Insights. Traditional semiconductor companies view production capability as a core competency to be closely guarded, particularly with respect to fabrication of their most sophisticated products.

The deverticalized semiconductor value chain, by contrast, consists of companies that specialize in one or a small number of functions. A function or group of functions is deverticalized when it is decoupled from and thus able to operate independently of other functions. Fabless companies such as Broadcom and Nvidia, for instance, specialize in chip design, marketing, and sales, but outsource wafer fabrication and SPA&T. Some semiconductor intellectual property (IP) companies such as Advanced RISC Machines (ARM) and Rambus sell only the IP cores of devices, not the devices themselves. Foundries such as Taiwan Semiconductor Manufacturing Corporation (TSMC) and United Microelectronics Corporation (UMC) provide wafer fabrication services to fabless companies, while semiconductor assembly and test services (SATS) providers such as Amkor and Advanced Semiconductor Engineering (ASE) perform back-end packaging and test services.

The deverticalized sector of the industry has grown rapidly during the past decade and continues to grow faster than the vertically integrated, traditionally organized sector. This trend is in evidence even within the largest IDMs, many of which now pursue a fab-lite business model by outsourcing to SATS vendors entirely and to foundries for some product lines. The high cost of capital equipment and the difficulties inherent in using plants efficiently, given only a single captive customer, have combined to encourage the adoption of the fab-lite model. Partnering arrangements have also become more common (Renesas, a joint venture of Hitachi and Mitsubishi, is an example) as a way to assert greater control than might be possible with purely outsourced manufacturing.

A few companies in specialized niches may still be purely integrated, even making their own substrates or photomasks, but the general deverticalization of the value chain continues. Fabless companies are growing faster than their vertically integrated counterparts, and the latter often decide to outsource larger and larger percentages of the production functions they had previously performed in-house. By 2008, 20 percent of worldwide IC revenues will be generated by fabless companies, according to IC Insights. The other promising segments of the chain are the result of deverticalization. The Chinese emphasis on foundries, inspired by the popularity of the Taiwanese foundry model pioneered by TSMC, should encourage a further elaboration of this trend.

Value Chain Dynamics and Semiconductor Demand

The source of some of the value in one chain can come from an adjacent chain, and it is equally true that more than one industry can contribute value to one or more value chains. In the case of the semiconductor value chain, for instance, electronic design automation (EDA), a software industry segment, and semiconductor equipment, a manufacturing automation equipment industry segment, may not strictly be considered part of the semiconductor industry, but each has a decided impact on the semiconductor value chain.

Table 1 details the activities in the worldwide semiconductor value chain and their prospects for growth through 2010. This table does not include distributors or demand chain customers such as original equipment manufacturers (OEMs), electronics manufacturing services (EMS) providers, or original design manufacturers (ODM). Less mature or deverticalized links of the value chain show the highest growth prospects, while the IDM portion of the chain is forecast to grow more

TABLE 1: WORLDWIDE SEMICONDUCTOR VALUE CHAIN REVENUES, 2000 VERSUS 2010 (IN BILLIONS OF DOLLARS)

Value chain activity	2000	2010	CAGR	China's role
Electronic design automation	3.8	7.8	13%	Software user, not producer
Semiconductor intellectual property	0.7	2.3	11%	Licensee, not licensor
Equipment	52.5	43.3	-2%	Buyer, not manufacturer; used equipment favored
Materials	26.6	35.7	3%	First-tier buyer, second- or third-tier producer
IDMs	184.0	291.7	5%	Plant location for large IDMs, domestic source of smaller IDMs
Fabless device companies	20.4	44.6	9%	Small domestic presence; good supply chain opportunities for other fabless companies
Foundries	7.4	49.6	21%	Substantial: 20% of worldwide capacity by 2006
SATS	10.9	26.0	9%	Substantial: More than 14% of worldwide SATS employees already in China

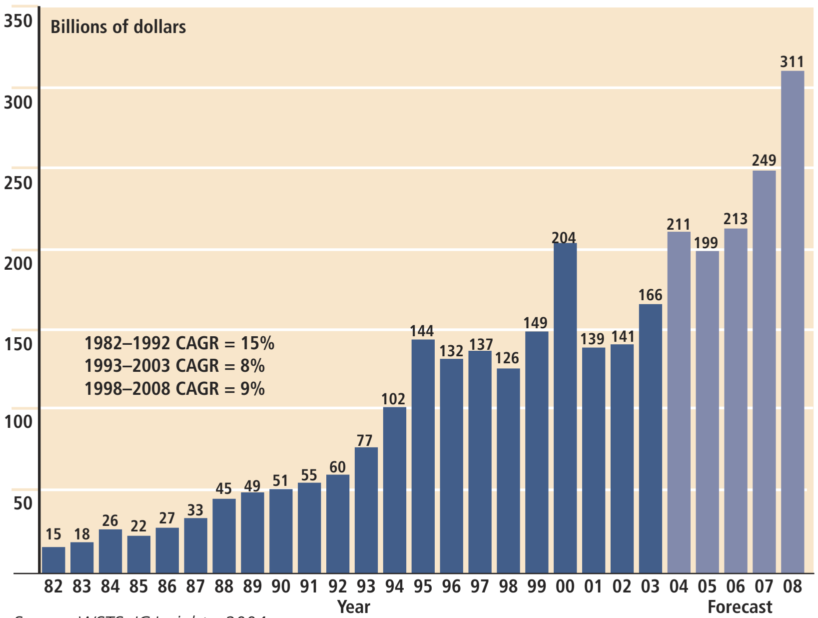
Source: Gartner Dataquest, IC Insights, PricewaterhouseCoopers, 2004 slowly. Equipment, as it is affected by capital spending volatility, shows a negative growth rate for the period because of a very high spending peak in 2000.

China's role on the supply side of the current semiconductor value chain is most significant in foundry, SATS operations, and IDM assembly and test facilities. Its role to date on the demand side has been as a buyer of materials, a licensee of design IP, a user of equipment (much of which is secondhand) and, first and foremost, as a consumer of semiconductors, two-thirds of which are built into products for export. The establishment of EMS and ODM facilities in China, not domestic consumer product demand, was the main reason semiconductor industry companies began to see the need for packaging and assembly facilities and wafer fabs to be located in the country. These companies felt pressure to be close to their customers, and that requirement is more pressing now than ever.

Changing Effects of the Semiconductor Business Cycle

The semiconductor industry follows a mature but cyclical pattern, a pattern that continues despite periodic efforts by industry groups to reduce volatility. (See Figure 3.) Overall industry growth during the past two decades has been high by comparison with many other mature industries, but boom and bust has diminished the health of the industry for years at a time.

FIGURE 3: WORLDWIDE SEMICONDUCTOR MARKET HISTORY AND FORECAST, 1982–2008



Source: WSTS, IC Insights, 2004

Swings in global semiconductor business cycles have previously been affected when Japanese, and then Korean and Taiwanese, production levels grew rapidly.

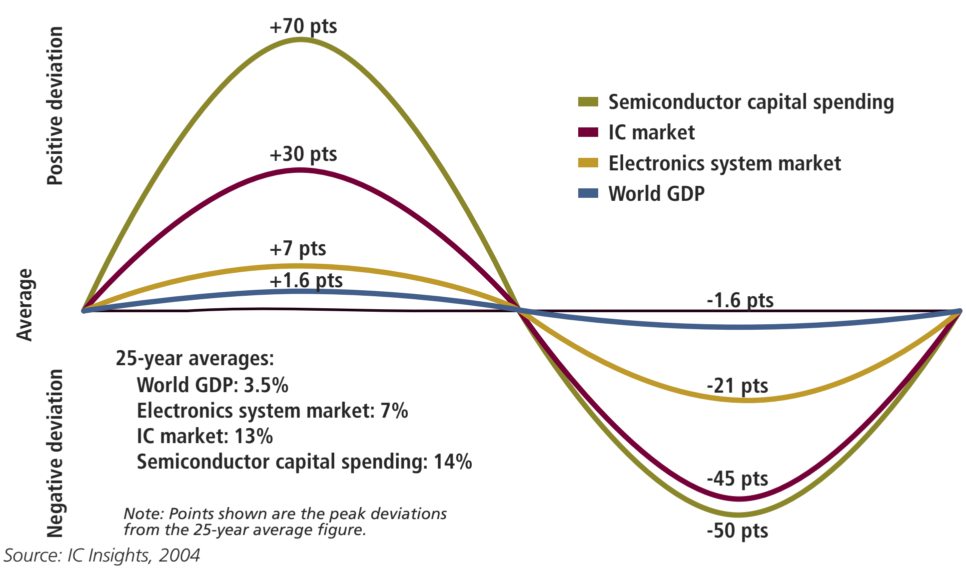
Part of the problem in damping the peaks to reduce the troughs of business cycles is the lack of ability to forecast demand accurately. Chip demand forecasting is a difficult task because demand in many high-volume semiconductor product areas is so closely tied to consumer spending patterns for electronics goods, and shifts in consumer preferences and behavior are not always possible to anticipate.

However, adding supply without an adequate business rationale has also occurred from time to time, another factor that causes volatility. Government use of subsidies and tax breaks to attract new industry, for example, has resulted in too much capacity being added at one time. New entrants to the market—which tend to be overly optimistic at times, are not aware of the level of global demand, or think they can win share from incumbents—contribute to this propensity to add capacity without regard for the true worldwide demand for it. As a result, a situation of excess capacity is created that undermines prices, sending the industry into a tailspin.

Maturing industries inevitably suffer from the effects of increased competition, and the semiconductor industry is no exception. Since the 1970s, the chip industry has experienced waves of new competition, first from Japan, then from Korea and Taiwan, and now China. Increased competition from consumer electronics manufacturers in those countries has added to consumer product industry volatility, exacerbating the volatility of semiconductor business cycles in a bullwhip effect. This bullwhip effect is felt most by equipment and materials suppliers at the opposite end of the supply chain from the electronics manufacturers. Equipment suppliers, which must endure wildly fluctuating capital spending patterns, experience the greatest degree of volatility. Figure 4 contrasts the relative volatility of gross domestic product (GDP), the market for electronics systems, the market for integrated circuits, and semiconductor capital spending.

Capital spending cycles exacerbate volatility in the semiconductor equipment business cycle. By contrast, IC and electronics system vendors suffer less from this bullwhip effect.

FIGURE 4: SEMICONDUCTOR BUSINESS CYCLE AMPLITUDE COMPARISONS



Source: IC Insights, 2004

China has come later to this era of increased competition, but has already had the largest impact of all the Asian countries on consumer electronics manufacturing. As with Taiwan, the nature of Chinese competition can be characterized by efficient manufacturing and the pursuit of lowest cost in the least-expensive product categories.

In the semiconductor area, China's current impact is still small, as Table 2 illustrates. The segments of the industry with the highest revenue were packaging and testing and foundries. Many of the major semiconductor manufacturers in China produce discrete devices—the least-complicated, lowest-cost device type. Chinese IDMs and design companies also generated some revenues, but their revenues are not comparable to revenues of the major IDMs or design companies elsewhere.

TABLE 2: MAJOR SEMICONDUCTOR MANUFACTURERS IN CHINA, 2003

Rank	Name	Revenue (100 M. Yuan)	Revenue ($ millions)	Sector	Reference
1	Motorola (China) Electronic Semiconductor Tianjin FAB	79.85	962	Packaging and testing	CCID 03-04
2	SMIC	29.05	350	Foundry	CCID 03-04
3	RENESAS Stone IC	16.16	195	Packaging and testing/Discrete	CCID 03-04 + CSIA 04
4	Shanghai Hua Hong NEC Electronics	15.61	188	Foundry	CCID 03-04
5	Leshan Radio	12.34	149	Discrete	CSIA 04
6	Shenzhen Sai STMicroelectronics	10.35	125	Packaging and testing/Discrete	CCID 03-04 + CSIA 04
7	Intel	9.08	109	Packaging and testing	CCID and PwC
8	Jianxin Xinchao Technology	8.97	108	Discrete	CSIA 04
9	ASMC	7.84	94	Foundry	CCID 03-04
10	Nantong Fujitsu Microelectronics	7.64	92	Packaging and testing	CCID 03-04
11	Jiangsu Changjiang Electronics Technology	6.96	84	Packaging and testing	CCID 03-04
12	Datang Microelectronics Technology	6.23	75	Designing	CCID 03-04
13	ChipPAC	6.05	73	Packaging and testing	PwC
14	Shougang NEC Electronics	5.62	68	IDM	CCID 03-04
15	Hangzhou Shilanyouwang Electronics	5.35	64	Designing	CCID 03-04
16	Shanghai MATSUSHITA Semiconductor	5.01	60	Packaging and testing/Discrete	CCID 03-04 + CSIA 04
17	Jiangsu Yiyuan Microelectronics Technology	4.65	56	Designing	CCID 03-04
18	Huayue Microelectronics	3.64	44	IDM	CCID 03-04
19	Jiling Huaxing Electronics Group	3.64	44	Discrete	CSIA 04
20	CSMC Technology	3.50	42	Foundry	CCID 03-04
21	Amkor Technologies	3.40	41	Packaging and testing	PwC
22	GOOD-ARK (Suzhou) Electronics	3.29	40	Discrete	CCID 04
23	Wuxi Huayue Microelectronics	3.28	40	IDM	CCID 03-04
24	Wuxi China Resources Microelectronics	2.93	35	Discrete	CSIA 04
25	Shanghai Belling	2.84	34	IDM	CCID 03-04
26	Spansion Semiconductor (Xuzhou)	2.69	32	Packaging and testing	CCID 03-04
27	Tianjin Zhonghuan Semiconductor	2.63	32	Discrete	CSIA 04
28	Shanghai Simconix Electronics	2.51	30	Discrete	CSIA 04
29	Shaoxing Wafer Valley Microelectronics	2.39	29	Designing	CCID 03-04
30	Millennium Microtech (Shanghai)	1.63	20	Packaging and testing	CCID 03-04
	Total	290.74	3,503		

Souce: CCID, CSIA, company sources, 2004

REGIONAL POLITICAL FACTORS

Regional political factors could influence some scenarios presented in this report. Primarily, these factors consist of China's relationships with Taiwan and with Hong Kong.

Taiwan

Relations with Taiwan have been uncomfortable and even testy for a long time. China views Taiwan as a renegade province that will one day be reunited with the mainland. Meanwhile, Taiwan has ambivalent perceptions of its large neighbor: Some politicians want tighter bonds with China, while others stoke nationalist sentiments by claiming the need for full independence and complete sovereignty. In 2003, China moved ahead of the United States and Japan to become Taiwan's largest trading partner, and had a trade volume totaling $46.3 billion. Hence, relations between the two has important economic implications for both countries, most especially in the semiconductor industry, where Taiwan has already made substantial investments in China.

China's displeasure with the possibilities of independence are well known. And, at times, it has threatened military action to underscore this point. Each time Taiwan has stepped back from the brink when confronted with shows of force.

Should the situation in Taiwan deteriorate, the specific nature of the escalation of tensions will be crucial to forecasting the result. Clearly, if armed conflict eventuates, the repercussions will be very grave. Not only will it have a dramatic effect on the nature of the two countries' semiconductor industries, but it is sure to distress foreign investors, who will have important concerns about their presence in China. If the United States or the European Union were to impose punitive sanctions on China for its actions, the consequences on the semiconductor industry could be serious.

Lesser problems between the two countries could make foreign investors wary of continued investment in China. If this perception is allowed to flourish and China comes to be viewed as unreliable, this too will slow further investments in semiconductor manufacturing.

Relations with Taiwan could improve during the forecast period. Given China's new prominence in Taiwanese trade, this scenario is likely. In such a case, export controls between the two countries might loosen and imports from Taiwan might receive more favorable tax treatment. As a result, the semiconductor investments by Taiwanese companies will continue to grow apace and play a significant part in the expansion of semiconductor manufacturing on the mainland.

Hong Kong

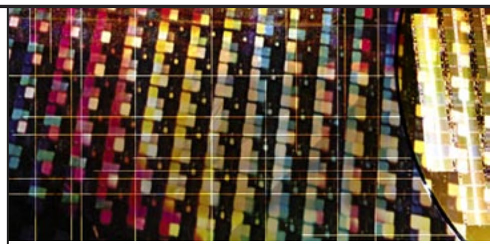
Hong Kong is not a significant player in semiconductors and so its effect on the Chinese market is unlikely to be significant. Relations between the mainland and the island province have deteriorated somewhat as Hong Kong's citizens have bridled under the constraints of Chinese-style democracy. A visit by the Chinese armada along the Hong Kong coastline in 2004 tamed a flare-up of protest on this issue. Only a heavy-handed response by the Chinese to cries for greater autonomy in Hong Kong could undermine China's semiconductor market. Such a response, if excessively forceful, could unsettle investors. It is less likely, however, that any such response would elicit sanctions from Western nations because Hong Kong's fate will be viewed primarily as an internal Chinese matter. Improved relations with Hong Kong, in contrast, are unlikely to have any material effect on semiconductor manufacturing in either country.

Disruptions in Hong Kong might have more of an effect on financial markets. Hong Kong's stock exchange is the preferred outlet for Chinese companies that are traded publicly. This preference for Hong Kong is attributable to its greater experience in public offerings and its historically longer integration with world financial systems.

Forecast

Relations with Taiwan will not seriously decline, because both countries want to avoid any direct confrontation. We expect that the current tensions between the countries represent a low point and that the possibility of improved trade relations between the two Chinas is strong.

Relations with Hong Kong will remain more or less the same: The island province will continue to test the limits of its democratic freedoms and China will continue to enforce the limits it expects. Unless military force is directly applied to Hong Kong, little of what happens there is likely to affect the dynamics of the Chinese semiconductor market. And even in the latter case, any repercussions are unlikely to be long-lasting. ■



This section analyzes each segment of the value chain to compare and contrast the status of the semiconductor industry in China with that of the rest of the world. A forecast through 2010 predicts how each segment of the value chain will develop in China.

IC Design

At present, the Chinese semiconductor industry value chain is heavily weighted toward the production end of the chain. SPA&T is the most significant value chain activity. Foundry activity, as the press frequently points out, is growing rapidly, but from a very small base. Design activity in China, by contrast, is in evidence, but does not significantly influence the worldwide industry. Design is particularly important because of the substantial percentage of value design adds to the chain as a whole.

CURRENT STATUS

Semiconductor device design activity in China involves hundreds of different entities, most of which are quite small. To date, the total activity has not had a significant impact on the worldwide industry, but the potential for this to change is high, especially considering the rise of innovation in China in related industries such as IT. IDM design centers, fabless device companies, contract design companies, and university research labs have all contributed to the variety of IC design activity in China.

When weighing their importance to the current industry, the design centers run by major foreign-owned IDMs are perhaps most notable, but the prospects for long-term change may depend on IC designers employed at domestically owned companies. To date, the latter have not fared well as a group, but a few have established themselves in the marketplace with significant design wins. Over time, some companies could prove to be standouts.

Foreign-Owned Design Activities

Most first-tier and many second-tier IDMs and fabless device companies already operate semiconductor design centers in China. IDMs that established wholly owned or joint venture design facilities in the country as early as 1996 included AT&T (now Agere), Motorola (now Freescale), NEC, Philips, and SGS Thomson (now STMicroelectronics). Foreign-owned design center activity in China intensified in 2003, when facilities such as those of Hitachi and Mitsubishi (now combined to form Renesas) expanded and new facilities of others were established.

Many foreign IDM-run IC design centers in China are principally focused on research and development (R&D) for products intended for the domestic market,

STRIDES IN EDUCATION

Educational reform in China began as part of a broad-ranging modernization program instituted under Deng Xioping in 1978. This program of education reform has been consistently aggressive, as shown in Table 3.

TABLE 3: CHINESE GOVERNMENT ACTIONS BENEFITING TECHNOLOGY EDUCATION, 1986–2002

Date	Activity
1986	7th Five-Year Plan: Defense spending reduced from 13 to 9 percent; minimum of nine years of education mandated for all school-age children.
1990	8th Five-Year Plan: Mandated an updated technology infrastructure for education.
1996	9th Five-Year Plan: Set a target of 4 percent of the country's gross national product to be spent on education, reported at 2.6 percent in 1994. At this point, 45 percent of education funding was private. Also initiated Project 211, a plan to foster research and development at 100 Chinese colleges and universities.
2000	10th Five-Year Plan: Expanded the entrance rate of education at each level, including a higher education entrance rate of 15 percent by 2005. Began to diverge even more from the rigid Soviet model of education adopted in 1949.
2001	Expenditures on Project 211 since 1996 reached 18 billion RMB ($2.2 billion).
2002	A further 6 billion RMB ($731 million) was earmarked for Project 211.

Source: People's Daily and other Chinese government sources

Efforts to achieve these objectives have resulted in real improvements to technology education and the increase of the higher education entrance rate. China now has a number of highly respected research universities and has more than tripled the number of science and engineering college graduates it has produced since 1984. (See Figure 5.) In 1997, it surpassed the United States as the largest source of university-trained engineers of any country worldwide. In 2003, the annual number of technician and engineer graduates combined reached two million in China, according to Gartner Dataquest. Demand for skilled engineers and technicians continues to outpace supply by a large margin, and salaries for those in highest demand are rising rapidly, but the long-term prospects for increased supply of an educated workforce are good.

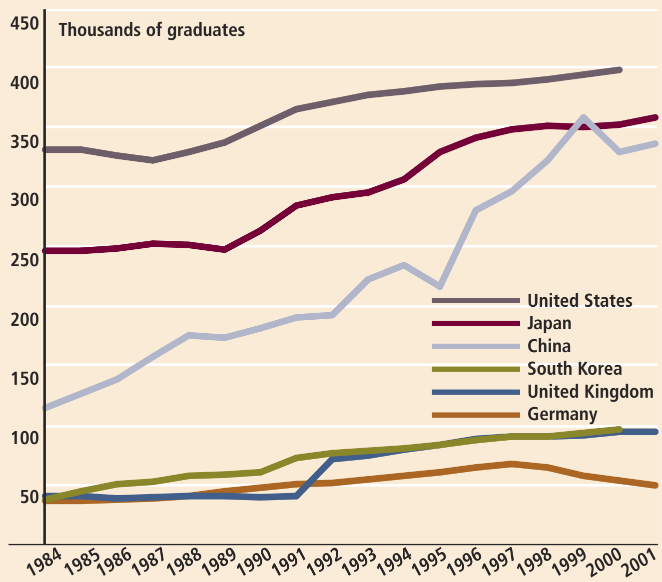
In addition to improving education in the country, the Chinese Ministry of Education has supported study abroad for university students, and noted that 580,000 students had studied abroad between 1978 and 2002. As of January 2003, 150,000 of these had returned to China, and 270,000 remained abroad as students, with the rest presumably employed or living abroad, but not attending college.

The Chinese government is well aware that returning students are a primary source of talent for business startups and scientific research. By January 2003, the *People's Daily* reported "more than 60 start-up business parks for returned overseas students" had been established. According to the paper, 81 percent of the membership of the Chinese Academy of Sciences and 54 percent of the Academy of Engineering consisted of former overseas students who had returned to China.

In companies, blending former expatriates with engineers educated abroad and new graduates of China's upgraded universities should accelerate the dissemination of knowledge throughout the semiconductor value chain in the country. Former expatriates who have key positions in semiconductor industry companies in the country bring knowledge of detailed requirements and proven business processes gained from their previous employers, often large companies that have invested heavily in research and development (R&D). When they begin work in China, they begin transferring that knowledge to others who have not had the benefit of working at a company that participates in leading-edge design, process, packaging, or test R&D, for example.

Over time, this knowledge transfer should stem the rise of wages for engineers who are versed in the techniques of Western and Japanese semiconductor companies. As the quality of life in Chinese cities improves, fewer Chinese will be likely to leave the country for a better lifestyle elsewhere. ■

FIGURE 5: SCIENCE AND ENGINEERING UNIVERSITY FIRST-DEGREE GRADUATES, SELECTED COUNTRIES



Source: U.S. National Science Foundation, 2004 and a number of these collaborate on R&D with research universities in the country. In addition, these companies often promote engineering education at these universities. When it announced a design center in Xi'an, Infineon, for example, also announced it would establish a National IC Talent Incubation Base with Xi'an Jiaotong University and Xidian University through support of scholarships and training laboratories.

Domestically Owned Design Activities

iSuppli estimated in 2003 that there were more than 400 Chinese fabless and contract semiconductor design companies, but noted that few of these companies generated significant revenues. Gartner Dataquest in May 2004 estimated a total of 600 design houses in China, and the Chinese Semiconductor Industry Association (CSIA) at the time estimated this number at 463. Some companies in this category have been in business since the mid-1990s and were established under Project 909, a state-funded $1.2 billion semiconductor IC initiative. Most were more recent startups founded by returnees who were trained or employed outside China; these companies are often affiliated with or even partially funded by universities or state-owned research institutes. Some large appliance or system vendors such as Datang and Haier Group fund semiconductor design activities.

IC design bases, funded by the Ministry of Science and Technology, municipal governments, and universities since 2001, have allowed startup design companies to begin work more easily, according to the U.S. Information Technology Office (USITO). These entities license EDA tools, provide access to IP libraries, and help with training, marketing support, and job candidate searches.

Current financing of some design activities in China reflects other kinds of government support as well. Chinese government smart card initiatives, for example, provide the opportunity for contracts to domestic design companies. Some design activities generate revenue through commissions on agency IC sales, according to the USITO.

In such an environment, it is important to try to ascertain which design entities in China might be commercially viable. Table 4, on page 28, details a select number of the fabless and contract IC design companies that appear to have competitive product lines and documented design wins. Of the few companies on this list that reported revenue in 2003, no company's revenue exceeded $74 million.

This proliferation of IC design startups in China began and continues without an adequately skilled indigenous semiconductor industry workforce. Dr. Jun Tan, president of ARM's China operations, estimated in October 2003 that only 500 of 4,000 IC designers in the country were truly qualified to do the task. iSuppli estimated that a total of 7,000 chip designers were in the country in 2003, of whom 60 percent had fewer than four years of experience. In mid-2003, iSuppli forecast a demand for more than 20,000 chip designers in China by 2006 and noted that the country was producing semiconductor design engineering graduates at a rate of only 400 each

"The proportion of Chinese core technology in cellular, and most electronics segments, is actually dropping as electronics become more sophisticated."

—Anne Stevenson-Yang, U.S. Information Technology Office

TABLE 4: SELECT CHINESE FABLESS AND CONTRACT IC DESIGN COMPANIES

Company	Category/Status	Main products/IP licensed from other companies
Actions Semiconductor	Fabless device company with foreign funding	Audio codec ICs and SoCs
Apexone Microelectronics	Fabless device company with foreign funding	Analog and mixed-signal products, including liquid crystal display (LCD) driver and Universal Serial Bus (USB) ICs
ARCA Technology	Privately owned fabless device company	Central processing units (CPUs) for Wyse network computers, 32-bit embedded processors
Beijing LHWT Microelectronics	Fabless device/contract IC design	Wideband Code Division Multiple Access (WCDMA), Wi-Fi, and Wireless Local Area Networking Authentication and Privacy Infrastructure (WAPI) wireless local area networking baseband ICs
BLX IC Design	Fabless device company spun off from the China Academy of Sciences	Godson (Dragon) 32- and 64-bit multiple processing units (MPUs)
China Electronics subsidiaries: China Integrated Circuit Design, Shanghai Electronics Smart Card, CEC Huada Electronic Design	Project 909 state-funded fabless or contract IC design	Subscriber Identity Module (SIM) card, wireless, digital set-top box, and point-of-sale terminal ICs
Datang Microelectronics	Vertically integrated systems/fabless device company; $74 million in revenue in 2003, up from $25 million in 2002	SIM card ICs; licensed ARM and LSI cores for SCDMA baseband signal processors
Shanghai Fudan Microelectronics	Fabless company collaborating with Shanghai Fudan University; $11.8 million in revenue in 2003, up from $7.5 million in 2002	Smart card ICs (60%), power, multimedia, communications ICs; licensed ARM7 core
Haier IC Design	Fabless device company funded by Haier Group	Set-top box ICs
Hangzhou Silan Microelectronics	IDM with $45 million in revenue reported in 2003, up from $32 million in 2002	8-bit microcontroller units (MCUs), local area network (LAN) communication ICs
Huajie IC Technology	Contract IC design; foreign/domestic joint venture	Analog and digital application-specific ICs (ASICs) for communications and consumer electronics
Jiangsu Yiyuan Technologies	Fabless device/contract IC design	IT security and smart card ICs
Nanjing Micro One Electronics	Project 909 state-funded fabless device company	DC/DC converters, complementary metal oxide semiconductor (CMOS) image sensors, DPTV video processors
Qinghua Tongfang Microelectronics	University-funded fabless device company	Smart ID card ICs
Shenzhen State Microelectronics	Project 909 state-funded fabless device company	Motion Picture Experts Group (MPEG)-2 decoders
Vimicro	Fabless device company initially state-funded; plans an initial public offering (IPO) in fall 2004	Imaging processors for handhelds and digital cameras
Wuxi China Resources Semico Microelectronics	Fabless device company; wholly owned by China Resources Semiconductor (Hong Kong) since 2002; before that, a joint venture	Consumer electronics and telecommunications ICs
ZTE Integrated Systems	Vertically integrated systems/fabless device company	Licensed ARM CPU cores for networking ICs

Source: Press reports, company Web sites, CSIA, CCID Consulting, Fabless Semiconductor Association, iSuppli

year. Gartner Dataquest reported after a 2003 survey of EDA tool users that only 4 percent of electronic design engineers in the country were engaged in IC design.

Demand for design talent inside the country and undercapitalization of most Chinese fabless and IC design companies may create high employee turnover and an increase in attempts to acquire the small number of companies that do have talented and able designers. Acquisitions of Chinese fabless and IC design companies noted since 2001 have included the following:

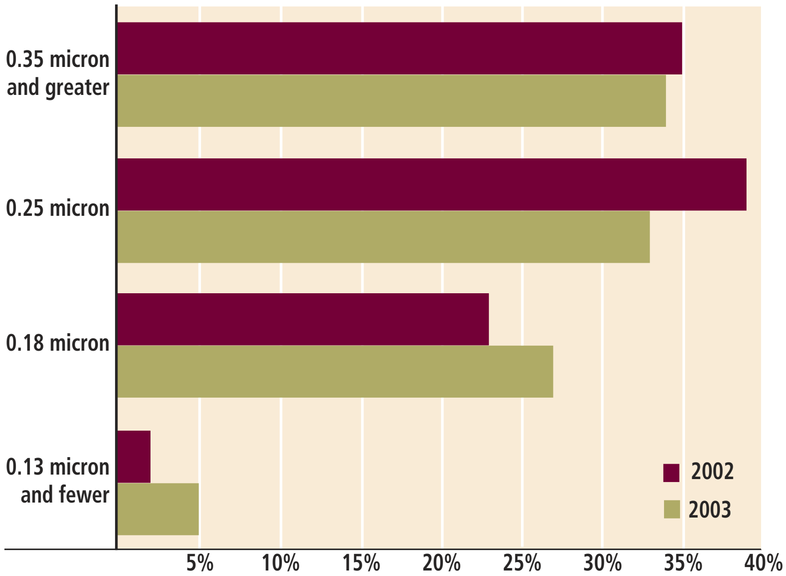
- Integrated Device Technology acquired Newave Technology, a Shanghai-based analog and mixed-signal telecom IC design company with 70 employees, in April 2001.
- Semico Microelectronics, a China Resources Semiconductor of Hong Kong wholly-owned subsidiary, purchased China Huajing's stake in Wuxi China Resources Semico Microelectronics in August 2002 for $1.6 million to become sole owner of the telecommunications and consumer electronics IC design company.
- NEC acquired Beijing Hua Hong Integrated Circuit Design's stake in Beijing Hua Hong NEC IC Design, a joint venture between the two that received funding through Project 909, in December 2003.

Process Technology in Use

China still produces most semiconductor designs at or above 0.25μm, but as of 2003, 32 percent of designs were produced using the 0.18μm node or below, with 5 percent at 0.13μm and below, according to a Gartner Dataquest EDA tool user survey. (See Figure 6.) Survey results for China in response to these process technology questions were comparable to those gathered for Taiwan. China reported only a few percentage points less at the smaller nodes and a few more at the larger nodes than did Taiwan.

In other respects, design in China is slanted toward relatively low levels of integration, reflecting a focus on smaller analog, mixed-signal, and low-gate-count digital ICs for communications, consumer electronics, and automotive applications. In 2003, 98 percent of IC designs in China had transistor counts of five million or fewer; 72 percent of designs incorporated 20,000 or fewer transistors, according to Gartner Dataquest. Just 6 percent of IC designs had a clock frequency of 500 MHz or more.

FIGURE 6: DESIGNS BY PROCESS TECHNOLOGY IN CHINA, 2002–2003



Source: Gartner Dataquest, 2003

Designs at smaller nodes were nearly as prevalent in China as in Taiwan in 2003.

FORECAST

China should begin to reap the benefits of its expanded higher education system and decrease its dependence on imported semiconductor designs and former expatriate designers soon. By 2010, skilled designers who have not had experience outside the country will be much in evidence.

In spite of this trend, demand for skilled designers in China could continue to outpace demand elsewhere by a large margin. From the single perspective of labor cost, able IC designers could command a premium for their services. This expense will diminish the cost benefit of using designers in the country, who are generally in cities that have a high cost of living. However, proximity to customers and the supply chain will still provide a strong incentive for designers to locate in China.

Most designs produced in China will continue to be for communications and consumer electronics products. Many of these designs will continue to be derivative, and reverse engineering will still be a serious problem for companies outside China through the end of the decade. However, the occurrence of reverse engineering will not overshadow real innovation that will occur in China as the domestic market begins to thrive and new designers gain expertise. The mobile phone market in particular should see substantial change as the result of increased Chinese demand. This dynamic offers an opportunity for companies in Asia-Pacific generally, but particularly for companies with a solid presence in China that participate in an integrated demand chain and have a good understanding of how Chinese market demands differ from those elsewhere.

Reverse engineering will not overshadow real innovation that will occur in China as the domestic market begins to thrive and new designers gain expertise.

China's aggressive standards posture could change the landscape for standards development, thereby affecting how R&D is conducted outside the country as well as internally. Strategic plans should assume that China will have at least some influence on standards requirements and technology selection, and that Asia-Pacific generally will wield more power in standards development. These factors will not only affect what products are produced, but will also increase the scope of strategic marketing efforts inside China to consider the inclusion of a standards-oriented R&D presence.

By 2010, China will be close to Taiwan in its ability to generate new IC designs at advanced process nodes. Improved R&D capability, higher domestic industry revenues, and a more highly skilled workforce will all contribute to an increase in globally competitive IC designs from China.

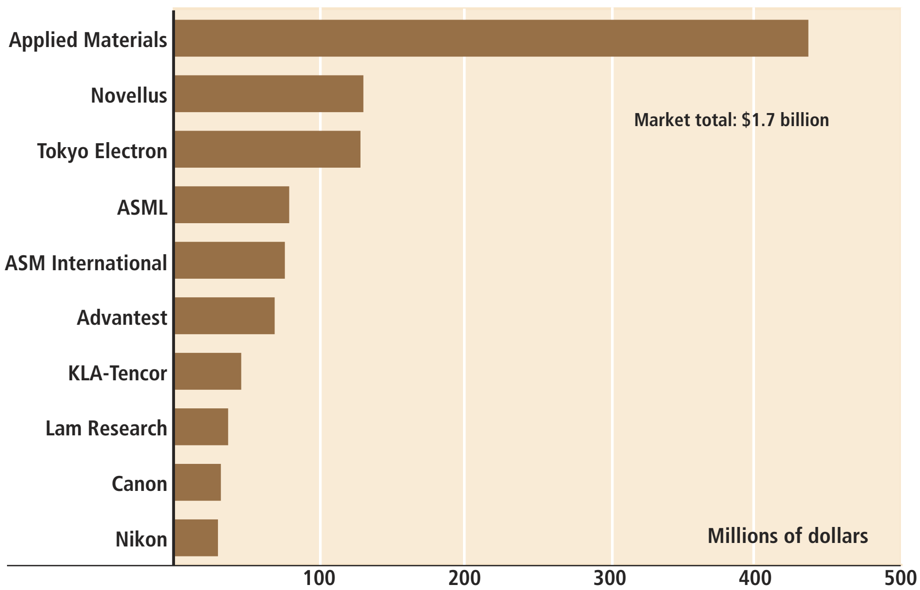
Equipment

The Chinese government's primary initiatives related to the semiconductor industry have focused on building production facilities and a more educated workforce. Consequently, domestic efforts to design and build semiconductor equipment have not received significant government attention to date. This is not surprising, considering that a number of other major semiconductor producing countries in Asia such as Korea, for example, continue to lack a strong domestic semiconductor equipment capability long after other portions of the value chain in these countries have been developed. Given the relative lack of domestic supply and the rapid growth of semiconductor production lines in China, foreign-owned equipment suppliers have had high hopes for the Chinese market for their products.

CURRENT STATUS

Demand for new semiconductor manufacturing equipment has been low in China considering the high level of fab construction and SPA&T activity there. Sales of new equipment in China amounted to $1.7 billion in 2003, according to VLSI Research, a 7.5 percent share of the total worldwide equipment market. U.S. vendors captured a 55 percent share, followed by Japan with 29 percent. Applied Materials was the top ranked vendor with 25 percent of the market. (See Figure 7.) According to SEMI, 84 percent of equipment sold was for front-end or wafer fabrication purposes.

FIGURE 7: EQUIPMENT SALES TO CHINA, TOP 10 VENDORS, 2003



Source: VLSI Research, 2004

Prospects for increased new equipment sales to China are good. SEMI reported that in the first quarter of 2004, sales to China were $573 million, indicating that actual 2004 sales to China could exceed $2.1 billion.

By contrast, demand for used equipment in China has been high for a longer period. In April 2003, iSuppli estimated that the installed base of semiconductor equipment in China was valued at $13 billion, much of it in recently constructed foundry plants. iSuppli noted that Semiconductor Manufacturing International Corporation (SMIC), for example, obtained equipment from places like the Netherlands and Sweden, and in doing so managed to avoid the U.S. export restrictions under the Wassenaar Arrangement. Some equipment was also purchased from the Interuniversities Microelectronics Centre (IMEC) in Belgium, one of the most advanced semiconductor R&D facilities in Europe. Capital expenditures of SMIC alone are expected to rise from $500 million in 2003 to $1.2 billion in 2004, according to Gartner Dataquest.

> ***"In some countries, the VAT is only 5 percent. In China, it is 17 percent for all industries. Seventeen percent is a lot of impact, especially when design houses, assembly companies, and foundries are treated as individual entities. That is a problem."***
>
> ***—Mingchuan Wang, Grace Semiconductor***

While the wafer fab equipment supplier presence in China tends to be limited to sales, support, or training offices, a number of leading SPA&T equipment vendors, including ASM, Kulicke & Soffa, and Teradyne, have established manufacturing facilities there. These vendors do a large amount of precision machining work that is labor intensive, and they established plants in the country to benefit from low wage rates as well as to be close to their customers.

IDMs and foundries, the customers for most semiconductor equipment, spend most of their equipment budgets on highly automated, modular equipment that accomplishes multiple steps in the wafer fabrication process in rapid sequence. The barriers to entry for this sector of the equipment market are high, and investment in Chinese equipment companies in general has been low to date. Specialized wafer fab equipment is also subject to export control, which would tend to discourage joint venture arrangements between U.S. and Chinese equipment companies that could make the transfer of intellectual property more of a possibility.

EXPORT CONTROLS

Shortly after the onset of the Cold War, a group of U.S. allies formed the Coordinating Committee for Multilateral Export Controls (COCOM) to implement a system of export controls. COCOM's concern was to limit the sale of weapons and so-called dual-use technologies (those that are civilian in design but can be employed in military applications) to Communist countries. In the mid-1990s, the participants in COCOM felt that the East-West orientation of the agreement no longer reflected the reality of the changed world order. As a result, they began talks toward a new series of agreements on export controls for weapons and dual-use technologies.

The talks, which were held in the Dutch town of Wassenaar, led to a series of agreements that were approved in 1996 and dubbed the Wassenaar Arrangement (WA). Rather than focus on the previous East-West orientation, the WA targeted so-called rogue nations as well as China. Like its predecessor, the WA is an informal arrangement, and it is not formalized by treaty documents. More precisely, the WA is a framework for coordinating national policies on export controls.

The WA specifically covers integrated circuits (ICs) and semiconductor manufacturing equipment. Although the provisions concerning ICs are rarely enforced anymore, the restrictions on semiconductor manufacturing equipment continue to play a role. Equipment vendors in the United States are required to gain an export license for chip-manufacturing equipment intended for delivery to China. (This provision extends to re-export. According to the U.S. Department of Commerce, "The re-export from Taiwan to China of U.S.-origin controlled semiconductor equipment, software, and technology is subject to U.S. re-export requirements—even if some of those items were exported to Taiwan under license exceptions. This means that a Taiwanese exporter would be required to apply for a re-export license to ship to China not only U.S.-origin equipment, but also foreign-made equipment in which 25 percent of its value consists of controlled U.S. content.")

In the past, obtaining export licenses was far from automatic. However, during the last few years, the procedure has become more of a rubber-stamp process. For example, in 2002, nine licenses were applied for and all were granted. Many analysts believe that while this more relaxed policy has helped enable sales of American equipment in China, the license-application cycle causes delays and slows the sales cycle. Other signatories to the WA have looser controls on sales of semiconductor equipment, and it is perceived that they have gained in the market due to this greater agility.

However, it is difficult to quantify the effect the WA has on the equipment market. China's domestic equipment-manufacturing capability is small, which implies that the country must import almost all of its semiconductor manufacturing equipment. Much of the equipment purchased for Chinese plants is secondhand and is two to three generations behind current leading-edge technology. Because much of the equipment is used, the potential dollar benefit of removing the WA is unclear. This situation will change once China has a fab capable of handling 12-inch (300mm) wafers, which will require more-expensive, new equipment. Such a plant is currently being built by SMIC and should be operational in 2005.

Forecast

Although the United States has removed general-purpose semiconductors from the licensing requirements of the WA, equipment sales still need deal-by-deal approval. In a speech in September 2003, U.S. Under Secretary of Commerce for Industry and Security, Kenneth I. Juster, hinted at smoothing and simplifying the license process under the WA. However, he made clear that he did not foresee that the WA would be dismantled anytime soon. We expect the WA to remain in place, but in a more efficient form. The greater rapidity of approval will lessen the competitive disadvantage suffered by U.S. vendors selling to China, but this change will not result in a significant benefit until Chinese fabs approach the leading edge of semiconductor manufacturing. ■

As a result, equipment manufacturing by domestically owned companies is low, reflecting annual sales of as little as $80 million, as discussed later. The few Chinese equipment companies that exhibited at SEMICON China 2004 in March 2004—the main trade show for semiconductor equipment and materials suppliers—were invariably manufacturers of less-automated, standalone equipment such as furnaces, small deposition systems, crystal pullers, and the like. The CSIA lists a few suppliers, but again, the revenues of these companies are likely to be small.

FORECAST

The low end of the equipment segment of the semiconductor value chain will be affected most by the increased influence of China on the industry. Overall, Chinese companies will demand less-expensive, less-customizable tools. Used equipment will continue to fulfill most needs. Demand for training and support will continue to be high.

High barriers to entry and a lack of domestic suppliers will protect first-tier equipment manufacturers from increased direct competition, but these companies will find few prospects for growth outside China. As a result, these vendors will accelerate their efforts to develop or modify more product lines to serve the Chinese market. Pressure will intensify to reduce 12-inch (300mm) equipment prices in 2006 and 2007 as more Chinese foundries upgrade their wafer fabs.

Demand from SPA&T facilities in China for equipment will increase by 2008 as the most advanced SPA&T plants in the country will need to upgrade their equipment to remain competitive. As it matures, the characteristics of the Chinese market for SPA&T equipment will begin to mirror that of the worldwide market.

"For any low-cost region, when businesses move in, the side effect is wage inflation. So for the local people, especially white-collar workers, the wage is increasing at a rapid rate. For the hourly wage workers, the wage is rising at a much slower rate."

—Wesley Chen, Solectron

Materials

Semiconductor manufacturers consume a wide variety of specialized materials. Although requirements for many wafer fab materials are demanding, requirements for packaging and assembly materials are somewhat less so. This segment of the value chain is very price sensitive, one reason that plant managers in China have a high interest in domestic sources of supply.

CURRENT STATUS

Current statistics on semiconductor materials consumption in China are difficult to find, but China's share of the worldwide materials market—that is, the dollar value of semiconductor materials that Chinese plants consumed—was less than 5 percent in 2003. In 2002, the total worldwide semiconductor materials market amounted to $23 billion after peaking at $28 billion in 2000, according to SEMI. Materials consumed in China for all of 2003 amounted to $1.15 billion according to PricewaterhouseCoopers estimates, or 5 percent of the worldwide 2002 total.

Chinese materials production for wafer fabs probably will be far less than this percentage, because European, Japanese, Taiwanese, and U.S. suppliers that do not currently have facilities in China are well entrenched. For example, production of starting silicon wafers in China may not have exceeded $163 million in 2003, according to PricewaterhouseCoopers estimates. Qualifying suppliers of starting wafers is time-consuming and difficult. Each supplier's wafers have different characteristics, and foundries must optimize their processes based on these characteristics. As a result, foundries tend to favor the wafers of their current suppliers to those of other suppliers. Even if a new supplier's wafers have better performance characteristics and significant promise, a foundry may prefer to continue the relationships with its suppliers rather than take the risk of qualifying a new one.

Changing suppliers of packaging materials, by contrast, has comparatively less risk because of the lower cost involved. The potential for suppliers located in China to gain inroads with these materials is higher. In fact, one Sino-German joint venture in the country, Heraeus Zhaoyuan, claims a 60 percent market share of the gold bonding wires consumed in China. Other international companies such as DuPont Photomask, QPL, and Fico Tooling that have plants and other facilities in China have also reported success.

FORECAST

The location of wafer fabs and SPA&T facilities in China will naturally increase already high demand for local sources of materials. Domestic sources of SPA&T already in evidence will continue to develop. By contrast, domestic suppliers of specialized wafer fab materials (such as starting wafers that seek to compete with market leaders) will have difficulty winning customer trust. International suppliers will continue to establish plants in the country when demand for volumes seems sufficient.

Materials suppliers that already have a presence in China serving other industries will exploit that advantage. Large industrial gas vendors that sell to hospitals or other industries in China, for example, can leverage their presence in gas sales to be able to sell to wafer fabs. Materials suppliers to circuit board manufacturers have been able to establish themselves in that business and then begin to serve component suppliers when those companies appeared in China.

All other things being relatively equal, semiconductor executives in China who have experience in the industry outside the country will tend to use the same suppliers they have in the past. The relative maturity of the semiconductor industry implies

TAIWAN'S ROLE IN ESTABLISHING CHINESE FOUNDRIES

The pure-play foundry model, perfected in Taiwan, has the potential to accelerate the migration of foundry capacity to China for two reasons: 1) it involves Chinese-to-Chinese transfer of know-how, and 2) the human-resource demands of the model are focused and limited to a specific, narrow swath of the electronics industry value chain.

Management and engineering talent from Taiwan functions well in China's Yangtze River delta, and the global equipment suppliers that helped build the industry in Taiwan can quickly replicate the facilities in China. Taiwan's major operators have invested in and operate many Chinese plants. Rather than being pure competitors of Taiwan's established industry, these Chinese plants are essentially conceived as the successor to Taiwan's production role in the global industry and are beneficiaries of the Taiwanese experience to date. Capital from domestic and international sources is available, particularly for foundry market leaders such as TSMC, SMIC, and UMC. With China playing a major role already in the assembly of electronics end products, the establishment of foundries there represents a strategic starting point, around which China's planners hope to fill in the remaining pieces of the value chain. ■

a well-established base of global suppliers already accustomed to serving customers that have plants in many different locations in the developing world. As long as these companies remain competitive in performance, price, and customer service, they will retain their customer base. Suppliers most threatened by upstart competitors in China will be those that sell raw materials, where barriers to entry can be low, depending on buyer requirements.

Wafer Fabrication

Wafer fabrication in China has been the subject of many press articles since 2000 because of the extensive fab construction plans and high level of activity of foundries. A primary motivating factor for locating these fabs in China was not labor cost, as frequently assumed—labor is a low percentage of the total cost of a fab—but tax, real estate, and loan incentives. The main demand-chain factor encouraging the addition of this capacity generally was the growth of wafer fab outsourcing, the result of the decline of smaller IDMs, the success of companies like Chartered Semiconductor, TSMC, and UMC, and the rise of the fabless semiconductor company business model. High fab cost and inefficient IDM fab utilization are two primary reasons fab capacity is shifting in favor of foundries.

High labor costs did not cause IDMs to close their fabs in the U.S. between 2000 and 2002. Rather, the closures resulted from the very high losses the IDMs sustained through bad market timing. Expensive plants came online just when the industry was experiencing a sharp downturn. IDMs have had trouble utilizing their fabs efficiently even during periods of growth. After the downturn, many IDMs decided either to partner and share the risk of future fab construction, or turn to outsourcing. China's investment in foundry capacity was fortunately timed to coincide with these events.

CURRENT STATUS

To date, Taiwan has been the chief beneficiary of the wafer fabrication outsourcing trend. China is well positioned to become the world's number two foundry location by 2010. At least 12 companies with plants in China offer foundry services. Most of these are third-tier providers with undisclosed revenues, but several second-tier companies, including ASMC, Hua Hong NEC, and SMIC, reported foundry revenues of between \$100 and \$366 million in 2003. Some leading foundries with no previous fabs in mainland China, including ProMOS and TSMC, now have plans to build plants there.

Because many of China's wafer fabrication plants were established within the last decade, more of its production is weighted toward 8-inch (200mm) wafers than in the rest of the world, as shown in Table 5, on page 36.

Ownership of China's wafer fabrication capabilities is noticeably different from those in most other countries. Once Motorola sold its Tianjin fab to SMIC, only four foreign IDMs with fab capacity remained in China: NEC, ON Semiconductor, Philips (a joint venture producing ASICs), and Rohm. Foundry capacity dominates China's current capabilities. When fully equipped and ramped, almost 80 percent of

"As long as there is a huge advantage in assembling and board manufacturing and other activities in China, it's going to be difficult to compete from the United States—really difficult to compete. Even though it's a capital-intensive industry, and even though the products cost very little, the supply chain still becomes an issue for flying those little chips all over the world."

—Charles Browne, DuPont China Holding

Because China's wafer fab facilities were established so recently, 48 percent of China's wafer fab capacity was below the 0.16µm node as of July 2004.

TABLE 5: WAFER FAB CAPACITY, CHINA VERSUS WORLDWIDE, JULY 2004 (IN THOUSANDS OF 8-INCH EQUIVALENT WAFER STARTS PER MONTH)

	China		World	
Geometry	**Capacity**	**%**	**Capacity**	**%**
>/= 0.7µm	105.0	16	2,052.6	20
< 0.7 to >/= 0.4µm	91.2	14	1,080.8	11
< 0.4 to >/= 0.3µm	16.9	3	799.1	8
< 0.3 to >/= 0.2µm	18.0	3	956.6	10
< 0.2 to >/= 0.16µm	62.0	10	914.9	9
< 0.16µm	307.0	48	4,013.1	40
N/A	40.0	6	208.4	2
Total	640.1	100	10,025.5	100
Wafer size				
>/= 4″	51.4	8	617.9	6
5″	30.1	5	830.3	8
6″	189.6	29	2,419.5	24
8″	369.0	58	5,031.1	50
12″	0.0	0	1,126.7	12
Total	640.1	100	10,025.5	100

Source: World Fab Watch, 2004

China's current wafer fabrication capabilities will be dedicated to foundry production, compared with just under 25 percent worldwide.

Based upon these current capabilities, China will be able to increase its share of worldwide foundry production to just under 20 percent by 2006. That increase could have a significant impact on the semiconductor industry. The 14 percent of China's current IDM wafer fab capacity dedicated to ICs and 6 percent dedicated to discretes are significantly less than the 60 percent and 14 percent worldwide. This is probably the result of the timing when China opened the semiconductor sector to foreign investments, an election to mimic the Taiwan model, and the very weak market position of China's state-owned semiconductor companies.

Although fab capacity in China is recent and relatively advanced, it has not been leading edge or lowest cost. This is because the country currently lacks 12-inch (300mm) wafer capability. Of the twenty eight 12-inch (300mm) wafer fab modules currently in production worldwide, not one is in China. A variety of geopolitical reasons can explain this fact, but the implication is that for at least the next three years wafer fab plants in other locations have the capabilities for retaining low-mix, high-volume, advanced technology (such as dynamic random access memory [DRAM], for example) wafer manufacturing cost leadership.

The absence of 12-inch (300mm) capability in China will provide only a temporary advantage to producers outside the country. By 2007, three 12-inch (300mm) wafer fabs should have been committed, which when at full capacity at mature yields will constitute 13 percent of China's wafer fab capacity. These three fabs will compose just over 5 percent of worldwide 12-inch (300mm) capacity.

As of July 2004, 16 additional new wafer fabs had been announced or planned for China, representing 36 percent of the 44 new fab plants announced or planned worldwide, but only 22 percent of their equivalent capacity. If these additional new fabs were all completed and ramped into full production at mature yields, China could increase its share of total worldwide semiconductor wafer production from the 2 percent or less realized in 2003 to 8 percent or greater by 2008. This increase could have a further significant impact on the semiconductor industry. While it is unlikely that all of these announced or planned wafer fab plants will be realized, they do provide a measure of the current enthusiasm for plants in China.

Only one uncommitted 12-inch (300mm) fab (unlike the two 12-inch (300mm) already committed plants mentioned earlier) is included among these 16 additional announced or planned new fabs. Two 6-inch (150mm) and eighteen 8-inch (200mm) fabs are also committed. The 8-inch (200mm) fabs constitute 87 percent of this possible additional capacity and most, that is, just more than 70 percent, are dedicated to IDMs producing ICs. Foreign companies are involved with 12 of these 22 possible additional wafer fabs, representing about 60 percent of the possible additional capacity. These companies include NEC for four of the 22 and Hynix, Philips (a joint venture producing ASICs), ProMOS, and STMicroelectronics for one each of the 22.

FORECAST

The high level of investment in Chinese foundries will undoubtedly intensify competition in that segment of the market. This competition will particularly affect other foundries in Asia-Pacific, especially those that compete on price and do not have 12-inch (300mm) capability. By the end of the decade, Chinese foundries should become more broadly competitive as they use 12-inch (300mm) wafers and smaller geometries. Continuing foundry price competition should benefit fabless device companies regardless of where they are located.

Continuing foundry price competition should benefit fabless device companies regardless of where they are located.

A high level of foundry competition could cause foundry services to become further commoditized, affecting a higher percentage of low- and mid-level product categories. If this occurs, commoditization could compel foundries in search of better margins to offer design services themselves or acquire design companies.

IDMs that compete on price will continue to find China an attractive location, and the need for tighter supply chain integration should compel some of the other major IDMs to locate fabs there by the end of the decade. Partnering arrangements will allow IDMs to reduce risk and facilitate the location of fab capacity in China. They can establish facilities that use older technology initially, another way to reduce risk. Intel's agreement in June 2004 to license 0.25µm and 0.35µm complementary metal oxide semiconductor (CMOS) process technology and provide equipment to Nanotech, a small Chinese foundry, could serve as the initial phase of one such arrangement.

Packaging, Assembly and Test

Semiconductor packaging, assembly and test (SPA&T) facilities gain less notice than foundries and are less well documented. One reason for this is that they are roughly five times less expensive than foundries, and take much less time to construct and begin to operate. Intellectual property security is also less of a concern for these activities than for design or foundry companies.

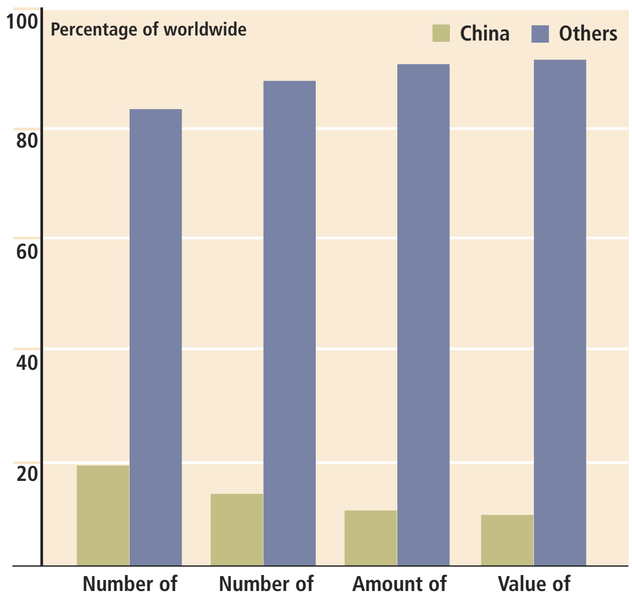
SPA&T activities benefit more from location in low labor cost areas than foundries because the proportion of labor cost for the former is higher. Additionally, the skill level required for some elements of the workforce is lower. Proximity to the EMS supply chain has compelled companies to locate SPA&T plants in low-cost areas. All of these factors have encouraged the migration of SPA&T operations to China.

CURRENT STATUS

The rate of migration of SPA&T capacity to China has accelerated sharply since 2000. Of the 78 SPA&T facilities in China identified by Gartner Dataquest and PricewaterhouseCoopers in the first half of 2004, 35 did not exist in 1999. Nine of 12 planned new facilities worldwide as of April 2004 will be in China. Currently, nearly 18 percent of the world's SPA&T facilities are located in the country, and China's share of worldwide SPA&T employees, floor space, and value of production also approaches or exceeds 10 percent. (See Figure 8.)

Through 2003, semiconductor packaging, assembly and test facilities in China constituted a larger percentage of the world's total than any other part of the value chain in China, encouraged by the need to be close to EMS companies that had already established large facilities in the country.

FIGURE 8: SPA&T FACILITIES IN CHINA VERSUS ALL REMAINING COUNTRIES, 2003



Source: Gartner Dataquest, PricewaterhouseCoopers, 2004

Most of the merchant and captive SPA&T market leaders are already well represented in China. Of the 20 top IDMs, 15 have SPA&T facilities in the country, and the remainder of these either outsource to semiconductor assembly and test services (SATS) vendors to some extent, or have plans to build SPA&T facilities there soon. Many of the major SATS vendors themselves—including Amkor, ASAT Holdings, ASE, ChipMOS, Millenium Microtech, PSi Technologies, and STATS ChipPac—have plants in China; most of these facilities were built within the last four years, but Millennium

Microtech and Hyundai (later a facility of ChipPAC, then STATS) established facilities in Shanghai as early as 1995. The proportion of SATS activity to in-house SPA&T in China is slightly higher than in the rest of the world, as shown in Figure 9.

FIGURE 9: SATS SHARE OF PACKAGING, ASSEMBLY AND TEST CAPACITY, 2003

Source: Gartner Dataquest, PricewaterhouseCoopers, 2003

Twenty-one of the SPA&T facilities in China are owned by companies that are headquartered there. These companies are primarily a mix of joint ventures, state-run enterprises, and recent startups. Some own up-to-date equipment and offer advanced package types. Global Advanced Packaging Technology (GAPT), for example, has invested in fine pitch wire bonding and ball bonding equipment, as well as radio frequency integrated circuit test equipment, since 2001. Many long-established SPA&T facilities owned by companies in the country, however, use older equipment and offer simpler package types for low-cost chips.

"The problem with being in a remote area is that, in the end, most Chinese who have good skills want to work in a major city because the infrastructure is better, the standard of living is better, the education for kids is better.... Everything is just better."

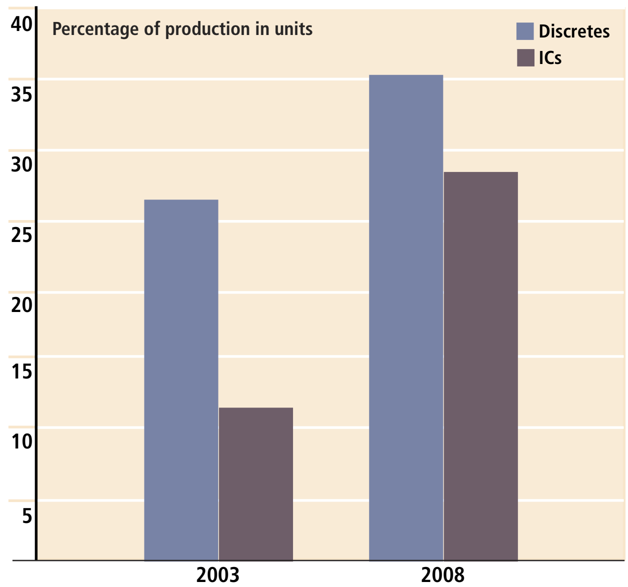
—Hock Chiang, Teradyne

FORECAST

The motivation for companies to move their SPA&T capacity to China will continue to be strong, but the focus will shift from industry leaders that have moved to protect market share to mid-market and smaller companies under price pressure that may have to move to be closer to the rest of the supply chain. The migration of EMS companies, OEMs, foundries, and materials companies to China implies that those that depend on an integrated supply chain could lose significant business by the end of the decade unless they have a presence in China.

Recently installed SPA&T plant capacity should cause much higher unit volumes in the country during the near term. More new plants likely will be established in China by mid-market and smaller IDMs and SATS companies by 2010, which will add to China's SPA&T influence on the world market. Cost will dictate that companies seek out lower-income areas in the western part of the country, and capacity in higher-cost cities such as Shanghai could remain flat or decline somewhat through the end of the decade. The product mix should diversify as the Chinese semiconductor supply chain matures, and more of the SPA&T facility output should stay in China as domestic demand grows for wireless and consumer electronics products and as income levels increase. China's share of IC production volumes should increase more rapidly than that for discretes through 2008, as shown in Figure 10.

FIGURE 10: CHINA'S SHARE OF WORLDWIDE SPA&T PRODUCTION, 2003–2008



Source: PricewaterhouseCoopers based on data from CSIA,CCID, and IC Insights, 2004

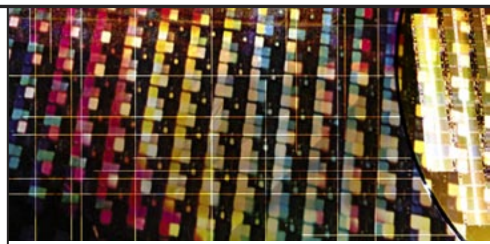
Demand for a full semiconductor industry ecosystem in China will rise as more links of the value chain become integrated in the country.

Value Chain Outlook

China's semiconductor value chain will be most affected by growth in SPA&T and foundry capacity through 2010. SPA&T facilities in China are reaching a milestone at the middle of this decade by approaching 10 percent of worldwide SPA&T production value, while wafer fabs could reach a similar point by the end of this decade with more than 11 percent of worldwide capacity in China. By then, large IDMs and foundries that do not have a plant in China could be the exception rather than the rule.

Growth in the foundry and SPA&T portions of the value chain should encourage more domestic activity in other links in the chain. The rise of China's internal consumer market should also be a contributing factor in this respect. Demand for a full semiconductor industry ecosystem in the country will rise as more links of the value chain become integrated in the country.

Inhibiting factors, however, will also come into play. Barriers to entry in the most profitable parts of the semiconductor equipment industry are high, and current equipment market leaders, for example, may feel that sales and support offices in the country are sufficient to maintain a presence there. Skilled design engineers will still primarily be located in the developed world, and design capability requires time to develop. Well-established IDMs and foundries, depending on the type of materials needed, may tend to prefer the materials suppliers they have worked with in the past. Pressure for these same materials suppliers to establish manufacturing facilities in China could increase, but low margins on materials limit the ability of these suppliers to invest in new plants.



Semiconductor demand in China will be affected by thousands of different variables, but the most fundamental variable will be worldwide gross domestic product, which creates the potential for consumers to buy electronics products that are made in China. Unlike India, which consumes 80 percent of the electronics it produces, two-thirds of Chinese electronics production is for export.

Electronics product demand is created by matching consumer needs and wants to available products that meet those needs at an affordable cost. Production levels then are determined by the level of electronics product demand, and these levels then determine the level of semiconductor consumption, as shown in Figure 11. Other important variables involve certain production factors that can change the nature of demand, such as increases in semiconductor content and outsourcing trends.

FIGURE 11: PRIMARY VARIABLES OF SEMICONDUCTOR DEMAND

Gross Domestic Product

Demand potential for products that contain semiconductors is highest in places that have the greatest wealth. Gross domestic product (GDP), which measures the economic output of countries by calculating consumption, investment, and government spending as well as net exports, is an accepted measure of wealth on a country-by-country basis.

In 2003, 86 percent of the world's GDP was concentrated in 20 countries. Most of these countries were located in North America or Western Europe. (See Table 6, on page 42.) The United States alone, with 5 percent of the world's population, accounted for 30 percent of the world's GDP. Japan alone, with 2 percent of the world's population, accounted for 12 percent of the world's GDP. China, by contrast, with 21 percent of the world's population, accounted for just 4 percent of world GDP.

On a worldwide basis, real GDP is expected to grow at an average rate of 3.2 percent between 2005 and 2010. As countries like China develop, the locus of GDP will shift more to Asia. China, for example, could outrank France in GDP by 2010, and both India and South Korea could outrank Mexico. On a regional basis, the growing

The top 20 countries in gross domestic product accounted for 86 percent of the world's total GDP in 2003. The United States alone generated 30 percent of the world's GDP. China and India will certainly move up in the rankings, but the shift will be gradual. China, for instance, will gain one percentage point in GDP share by 2010.

TABLE 6: TOP 20 COUNTRIES IN GROSS DOMESTIC PRODUCT, 2003

Rank	Country	GDP ($ trillions)	% of Total	Population (millions)	GDP per capita ($)	Gini Index (2002)
1	United States	10.9	30	293	37,139	40.8
2	Japan	4.3	12	127	34,066	24.9
3	Germany	2.4	7	83	28,924	30.0
4	United Kingdom	1.8	5	60	29,914	36.8
5	France	1.7	5	60	29,133	32.7
6	Italy	1.5	4	58	25,274	27.3
7	China	1.4	4	1,299	1,085	40.3
8	Spain	0.8	2	40	20,903	25.2
9	Canada	0.8	2	33	25,285	31.5
10	Mexico	0.6	2	105	5,963	53.1
11	Korea, Rep.	0.6	2	23	26,319	31.6
12	India	0.6	2	1,065	562	37.8
13	Australia	0.5	1	20	25,919	35.2
14	Netherlands	0.5	1	16	31,972	32.6
15	Brazil	0.5	1	184	2,676	60.7
16	Russian Fed.	0.4	1	144	3,010	48.7
17	Switzerland	0.3	1	7	44,209	33.1
18	Belgium	0.3	1	10	30,222	28.7
19	Sweden	0.3	1	9	33,422	25.0
20	Austria	0.3	1	8	31,432	31.0
21-282	Others	5.1	14	2,735	1,882	N/A
	Total	35.8	100	6,375	5,611	

Source: World Bank, 2004

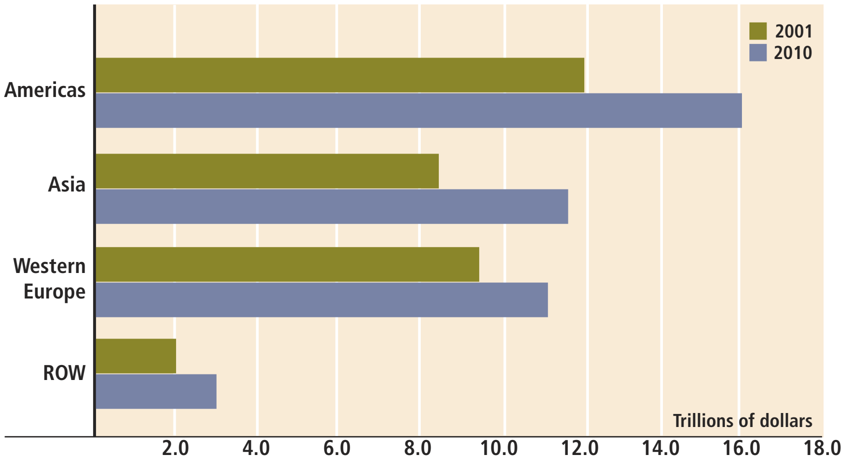
countries of Asia will shift the balance more significantly. By 2010, according to a U.S. Department of Energy forecast, Asia will generate a higher GDP than Western Europe. (See Figure 12.)

From the perspective of individual countries, the shift toward Asia will be gradual. By 2010, assuming a very healthy growth rate for China of 7.5 percent from 2003 through 2010 and moderate growth ranging from 2 to 3 percent for the more developed economies, China's share of world GDP will rise one percentage point, to 5 percent.

In Asia, the countries of China, India, South Korea, and Japan will contribute most to world GDP in 2010, together producing an increase of $1.9 trillion over 2003 levels. (See Figure 13.) By comparison, in 2010 the United States will have an increase of $2.9 trillion over its 2003 level. On its own, China will generate $790 billion more GDP in 2010 than it did in 2003, an increase of $570 per person over 2003 levels, assuming a Chinese population of 1.4 billion at that point. The 2010 worldwide GDP increase will be $8.6 trillion over 2003 levels, or $1,246 per person, assuming 6.5 billion persons.

Currency valuation has a decided impact on such a comparison. In particular, China's GDP may be understated. Many economists who have argued for China to discontinue pegging the yuan at 8.28 to the dollar (a practice it began in 1994) have asserted that the yuan is undervalued. If this is the case, then China's GDP is also undervalued. In October 2003, Nicolas Lardy of the Institute for International Economics recommended to the U.S. House of Representatives that China increase the value of its currency relative to the dollar within a range of 15 to 25 percent, and peg its currency rate to an index of a number of different currencies rather than simply to the dollar. Figure 13 displays the impact such a change would have on China's GDP alone if China's currency exchange rate were increased by 20 percent. Lardy asserts that such a revaluation would positively affect multiple Asian currencies, indicating that several country GDPs depicted in Figure 13, on page 44, may be undervalued due to the undervaluation of the yuan.

FIGURE 12: GROSS DOMESTIC PRODUCT BY REGION, 2001 VERSUS 2010



Source: U.S. Department of Energy, 2004

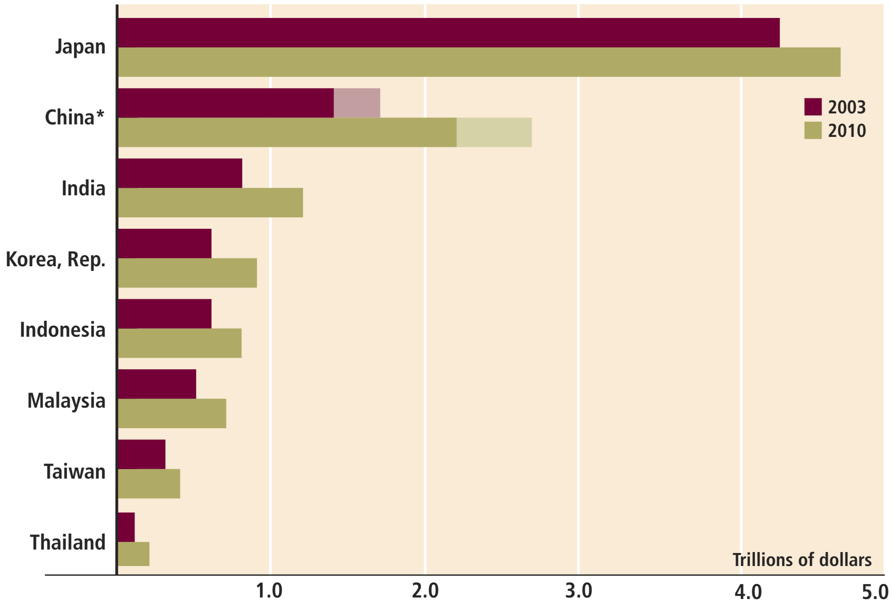
The new wealth will not be equally distributed, but will end up mostly in more affluent areas where less than 150 million people reside.

Despite the increase in GDP per person in China on a countrywide basis, 8:1 income ratios between Shanghai residents and residents of Guizhou province and a World Bank Gini income inequality score of 40.8 imply that the new wealth will not be equally distributed, but will end up mostly in more affluent areas where fewer than 150 million people reside. Although there are more than 500 million people in China's cities, only 250 million of these people can be classified as lower middle class or above. Just 100 million people live in China's principal cities, and fewer than 50 million are in the principal cities in the coastal provinces, the wealthiest region of the country.

Given the high incidence of poverty in the country and the concentration of GDP in a small segment of the total population, the impact of China's anticipated increase in GDP alone through 2010 on electronics products purchases made inside the country will likely be comparable to previous impacts of smaller Asian countries with rapidly developing economies. The history of the Japanese economy in the

China's currency is probably undervalued by at least 15 percent. Depicted is China's GDP at both the nominal and a 20 percent appreciated exchange rate.

FIGURE 13: GROSS DOMESTIC PRODUCT, SELECTED ASIAN COUNTRIES, 2003 VERSUS 2010



**Shown with current fixed-currency exchange rate and at a 20% appreciated rate*

Source: World Bank, U.S. Department of Energy, IC Insights, PricewaterhouseCoopers, 2004

1950s and 1960s (greater than 9 percent annual GDP increases between 1953 and 1965) or South Korea in the 1980s (7.5 percent annual GDP increases between 1985 and 1989) may provide a guide.

New Products to Match Consumer Needs and Wants

Electronics production would be stagnant without growth applications. A number of enabling semiconductor production technologies and improved production methods are making it possible to add compelling features to end products, which will result in increased demand for semiconductors in most of the main application categories in China. These enabling technologies include the following:

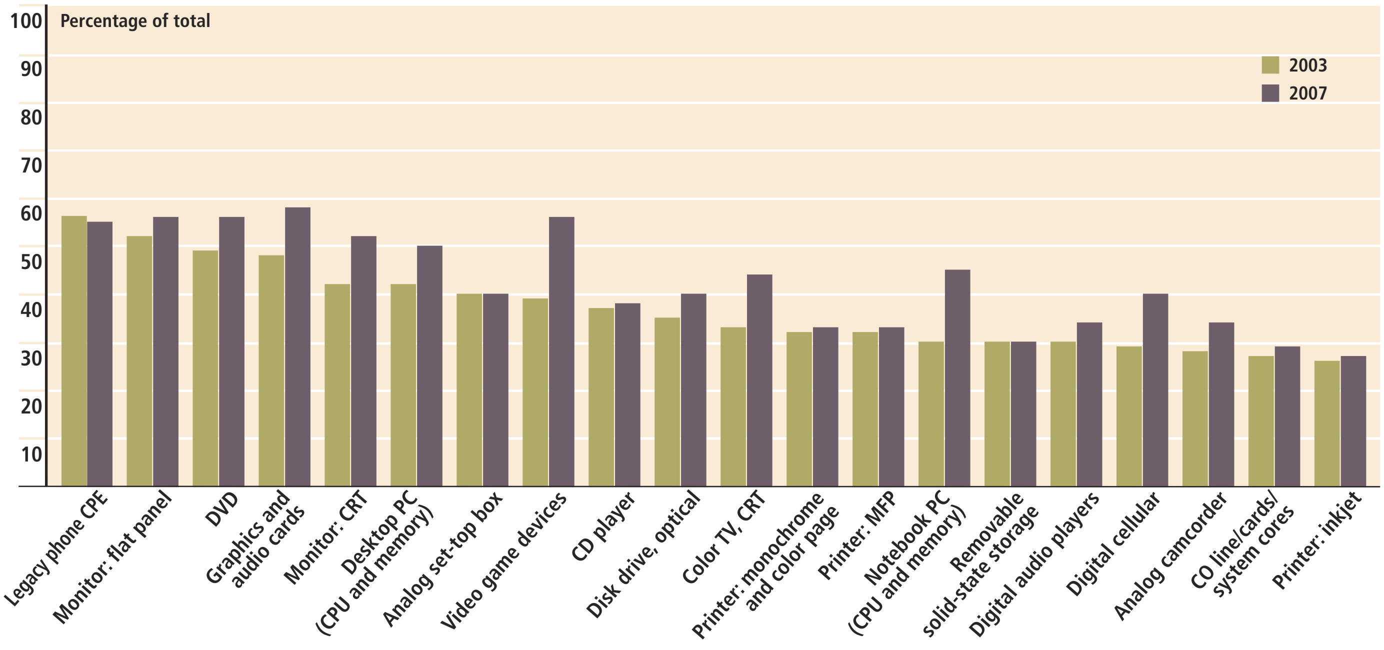
- ***Improved display components***—Liquid crystal displays (LCDs) continue to be popular, but active matrix displays based on organic light-emitting diodes (OLEDs) could begin to displace LCDs even for larger displays by 2008, according to iSuppli. Numerous other display technologies are appearing for mobile phones, other handhelds, and televisions. Flexible displays are on the horizon.
- ***Increased storage density***—Smaller hard disk drives continue to appear in handhelds like the Apple iPod, and large-capacity hard drives are appearing in standalone digital video recorders (DVRs) and set-top boxes with DVR capability. Flash cards continue to improve.
- ***Better processing capability***—Digital signal processors (DSPs) are more able to distinguish signal from noise, image processors are able to generate more detailed images more quickly, and audio processors are sampling and converting sound waves at higher rates.

- ***Reduced power consumption***—Wireless handhelds and other battery-powered devices are more capable with low-power chips.
- ***Less-expensive manufacturing***—Lower-cost componentry and assembly, as well as increased reusability, is making it possible to produce cost-effective, single-use digital cameras, according to IDC. This is merely one example. Many consumer product categories simply would not be affordable without continuous manufacturing improvement.
- ***More forms of integration***—System-on-chip continues to improve, and a variety of vendors are now producing multichip modules or system-in-package that have proven convenient for ODMs in Asia-Pacific to use.

Increased standardization has allowed products from different vendors to be interoperable, but equally importantly, it has brought a greater proportion of the aggregate knowledge of developers from various companies and research entities to bear on solving difficult problems.

Given that two-thirds of its semiconductor consumption is for export, China's demand for semiconductors mirrors that of global demand, at least in the communications, computer, and consumer electronics categories. Figure 14 illustrates the electronics products predominantly manufactured in China as of 2003 and the growth prospects through 2007 for those products, as forecast by Gartner Dataquest. The highest growth prospects indicated in China for production of these mature products are for video game devices, mobile phones, notebook PCs, and televisions. Many of these products were previously produced primarily in Taiwan or elsewhere in Asia-Pacific.

FIGURE 14: TOP 20 ELECTRONICS PRODUCTS PREDOMINANTLY MADE IN CHINA, 2003 VERSUS 2007



Source: Gartner Dataquest, 2003

THE RISE OF ASIAN STANDARDS

Asian governments perceived the rise of the personal computer, the Internet, the Web, and the mobile phone differently from governments in the West. A primary issue for Asia has been the tight control of computing and communications hardware and software markets by Western companies. Many Asian countries resented the uniform pricing policies of Western software companies; customers in much-less-wealthy Asian countries had to pay the same as customers in North America or Europe. (Some companies such as Microsoft have since begun to experiment with more flexible pricing policies.) Perceptions of Western insensitivity also surrounded the English-language-dominated Internet and Web of the 1990s, as well as cellular standards essentially controlled by European and North American equipment vendors. Control of these standards by companies in these two regions played a role in forestalling competition from other regions.

Echoing the computer and communications systems vendor landscape, a small group of North American and European semiconductor companies captured and maintained leading shares of the market for most of the high-value PC, server, and communications chips for these high-volume applications. Because of their market dominance, these companies were able to command high prices for their chips in all world regions. China, given its low per capita income, has been especially sensitive to this issue.

Responding to these circumstances, China embarked on a path in the late 1990s of becoming a leader in setting standards for electronics equipment and software. It is not alone in Asia in its efforts to assert influence over standards. Singapore has organized its own standards bodies and also participates in regional standards organizations. Korea is developing its own High-Speed Portable Internet (HPi) standard for wide-area broadband wireless systems and is encouraging international support for it. Japan, long a user of standards developed internally, is now involving other countries in Asia-Pacific as well. Japan's Communications Research Laboratory set up a wireless research lab in Singapore in 2004 to collaborate with Institute for Infocomm Research, a Singaporean government-funded research organization, as well as Nanyang Technological University, on a fourth-generation cellular standard. Asian countries generally have seen the growth of their power vis-à-vis the West for some time now and feel that current standards should reflect their actual position in the world.

Since the late 1990s, China has been the most aggressive country in Asia in setting these standards. A primary motivation behind these standards has been to reduce royalty payments to foreign companies that own the intellectual property rights for communications and computer semiconductors and equipment. It has announced its own operating system, image compression, and wireless standards.

Some Chinese standards efforts may not be successful. After attempting to require that all wireless local area networking equipment sold in the country support the Wireless Local Area Networking Authentication and Privacy Infrastructure (WAPI) standard the Chinese government decided to postpone the requirement indefinitely after Western companies strongly objected. In this case, the government's timing was bad—wireless local area networking equipment designed to internationally agreed-upon specifications was already in wide use, billions of dollars had been invested in developing the equipment since the 1990s, and millions of units were being shipped annually. To impose such a requirement on networking equipment vendors in 2004 was unreasonable.

In some other cases, however, China's timing has been better, its methods less forceful, and the prospects for success somewhat better. The Chinese third-generation (3G) cellular standard Time Division-Synchronous Code Division Multiple Access (TD-SCDMA) benefited from the delayed deployment and interoperability problems of the Wideband Code Division Multiple Access (WCDMA) standard. From 1998, when the Chinese first proposed this standard to the International Telecommunications Union, TD-SCDMA has been a more international effort than WAPI. The two principal companies involved in developing the standard have been Datang Mobile of China and Siemens of Germany. U.S.-based UTStarcom and IPWireless, among others, are also building TD-SCDMA equipment. China Putian, a communications infrastructure vendor, has collaborated with Nortel Networks on equipment for the standard, and in June 2004 signed an agreement with Nortel to develop this equipment jointly.

When the Ministry of Information announced in June 2004 that China would launch TD-SCDMA commercially by mid-2005, it noted that domestically made chips are available for dual-mode CDMA2000 or WCDMA and TD-SCDMA. Spreadtrum Communications, a company based in Shanghai, will build phones using these chips. In June 2004, the TD-SCDMA Forum signed an agreement with the Global System for Mobile Communications (GSM) Association to coordinate each other's activities, an indication that China plans to collaborate with operators and vendors in other parts of the world to refine the standard. TD-SCDMA is clearly part of a long-term, orchestrated effort to support domestic 3G cellular semiconductor, base station, and phone design in the domestic and international market, but not to the exclusion of companies headquartered outside of China.

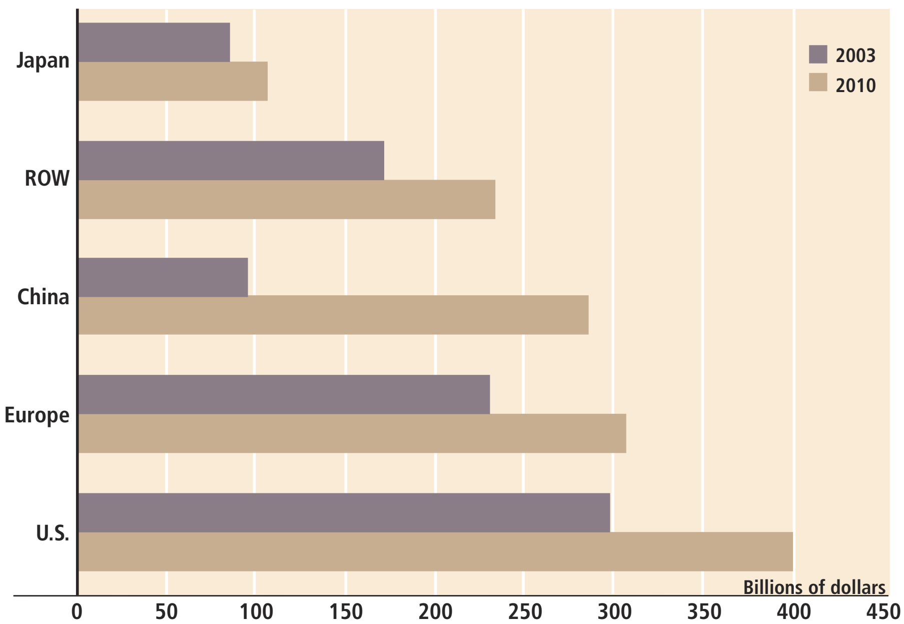
Whether the standard will be successful remains to be seen. Datang Telecom Group, quoted in a November 2004 in *China Business Weekly,* stated that R&D for TD-SCDMA has been underfunded and substantial barriers to adoption of the standard remain. Unresolved interoperability problems may cause a lag of up to one year before TD-SCDMA could be introduced by carriers in China. As a result, some industry observers expect no Chinese 3G carrier will deploy TD-SCDMA by itself, but rather only in conjunction with WCDMA.

Radio frequency identification (RFID) could be another target application for Chinese standards, given the relative immaturity of RFID technology and growing Chinese experience in short-range, low-power wireless. RFID price-tag sensitivity is high, and for that reason lowest cost manufacturing will be essential. All of these factors favor Chinese participation in future RFID standards development. ■

Electronics Production

Changes in semiconductor demand are closely tied to electronics production trends. Adjusting for currency inflation, worldwide electronics production increased just 4 percent in 2003 over 2002 levels, according to IC Insights. It is a well-known fact that electronics production is rapidly shifting to China, and to a lesser extent, other parts of Asia. Given current capacity migration levels, China's electronics production volume will nearly triple by 2010, rising at a compound annual growth rate (CAGR) of 17 percent. (See Figure 15.) Production in the rest of the world (predominantly other places in Asia), by comparison, will grow at 10 percent, while production in North America, Europe, and Japan combined will grow at 4 percent annually, slightly less than the worldwide average of 6 percent.

FIGURE 15: ELECTRONICS PRODUCTION BY REGION, 2003 VERSUS 2010



Source: IC Insights, PricewaterhouseCoopers, 2004

By 2010, China's electronics production will be nearly triple that of Japan and will approach that of Europe.

Increases in Outsourcing

Electronics manufacturing outsourcing is changing the nature of semiconductor demand. Historically, outsourcing trends have placed more power in the hands of semiconductor vendors.

Particularly in the personal computer industry, OEMs have tended to favor an outsourced manufacturing model. However, in the case of mobile handsets, outsourcing is less common. Smaller mobile handset OEMs have begun to outsource production, but the larger handset OEMs have restricted outsourcing to less than 20 percent of total production, according to IDC.

China is shifting the balance in this area. Indigenous handset OEMs such as Ningbo Bird, TCL, and Xiaxin, as well as the Japanese/Swedish Sony Ericsson joint venture, have used Taiwanese ODMs to produce handsets that have become

SOCIAL AND ENVIRONMENTAL FACTORS

During the 25 years since China opened to foreign investment in 1978, China's real gross domestic product (GDP) has grown at an average of 9 percent per year, and foreign investment has grown on average 15 percent per year. Such growth cannot occur without causing destabilizing effects on the environment and in society.

Rural versus Urban Populations

China's population of 1.28 billion is divided into two distinct groups: urban inhabitants totaling roughly 502 million and a rural population of roughly 796 million. Urban dwellers had an average per capita income of 8,500 yuan, while rural inhabitants earned 2,620 yuan per person. Because China's rural poor live on so little, a pervasive concern exists that the disparity between them and their urban counterparts might eventually lead to unrest.

This disparity is worsening despite the enormous growth enjoyed by the overall Chinese economy. For example, China's rural population, which consists mainly of farmers, saw its income increase by only half the increase of 9.1 percent enjoyed by urban residents. In 2003, China's grain harvest declined for the fifth consecutive year. If the efficiencies of modern farming methods begin to exert pressure on the inefficient farmers of China's interior, it is feared that more than 400 million workers may become displaced and unemployed—a number far larger than the cities' ability to absorb—if such a migration were permitted to happen at all. China has a system of permit laws that makes it nearly impossible for a rural worker to find employment and move his or her family to an area outside of his home province without permission. To these pressures must be added China's need to provide jobs for approximately 12 million new workers each year. In light of these issues, the population factor must be viewed with considerable concern.

One possible solution is tied to escalating labor costs. Where the semiconductor industry has flourished in the large cities, wages have been steadily rising. As a result, companies are moving new plants westward in the direction of the cheaper, rural labor. To what extent this trend will alleviate the pressures described previously is hard to gauge; it probably will be only a small mitigating factor.

Regardless of the fate of the rural Chinese, they should not be viewed as consumers of semiconductors during the forecast period. It is safer to view the domestic market as the 500 million urban dwellers, who enjoy the possibility of discretionary income. Even this group probably will not represent much of a consumer force soon: The top 20 percent of urban dwellers earn 15,400 yuan per year or about $5 a day, a number that despite China's low cost of living leaves very little for discretionary spending.

Environment and Natural Resources

Shortages of potable and irrigable water are serious problems in China. The reasons for this shortage are two-fold: water contamination and very poor use of water resources. China has the largest irrigated farmland area in the world. However, irrigation is typically not the spray or drip methods used in many countries today. Rather, farmers simply flood their farms and let the excess water drain off. This process contributes both to enormous waste and to pollution problems. According to China's own statistics, the country discharged 31 billion tons of wastewater in 1980. This number had climbed to 62 billion tons by the year 2000. In total, 80 percent of this wastewater was dumped untreated into rivers, lakes, and reservoirs. An additional aspect of the water problem is the uneven distribution of water supplies: the northern regions of China have access to receive only one-fifth of the per capita water available in other regions of the country.

China has undertaken various plans to increase recycling, to encourage conservation, and to develop desalination plants. However, as of mid-2004, 400 of China's 668 cities face water shortages, and of the 400, more than 100 are threatened with serious situations, according to the Chinese government. These shortages will have two effects on the semiconductor industry: The cost of water needed to manufacture semiconductors will continue to rise. This added cost will erode the savings garnered by locating manufacturing in China.

Electricity shortages will begin to appear. According to *The Economist*, China is already generating electricity at near-maximum capacity. Because China is so dependent on hydroelectric projects for power generation, water shortages will lead to diminished power resources. This decrease is already occurring in the northwest provinces of China. For example, power generation at the Liujiaxia Hydropower Station has dropped by 1.5 billion KwH per year—a decline of approximately one-third—due to water shortages. If electricity shortages materialize, semiconductor manufacturers will pay higher prices for the power they consume, translating again into diminished cost savings.

In addition to water shortages, desertification in China is a grave problem. China's Environmental Protection Agency reports that the Gobi Desert expanded by 20,240 square miles from 1994 to 1999—an area half the size of Pennsylvania. The edges of the Gobi Desert are now within 150 miles of Beijing. The causes of desertification are excessive deforestation and very excessive grazing. Incentives for farmers to reduce stocks of grazing animals are unlikely to be successful, because in the poor, rural areas, farm animals remain the defining form of riches, in lieu of money.

Forecast

The problem of China's poor, rural population will continue to be an important factor to track during the forecast period. However, it is unlikely to have a significant effect on semiconductor manufacturing, as long as the environmental factors, especially desertification, do not significantly worsen and thereby cause large migrations toward the cities. Such a development would overwhelm most other economic issues and its specific repercussions are hard to assess. The environmental factors of constrained water and power availability will affect the costs of semiconductor manufacture in China and consequently diminish the savings enjoyed by companies today. ■

popular domestically. (See Table 7.) Many of these ODMs have large manufacturing facilities in China and can impose significant pricing pressure on their competitors.

To date, these OEMs and their ODM providers have been dependent on the design expertise of Western chipset and module suppliers, but this too is changing. In 2003, Ningbo Bird, for example, began offering a smartphone entirely engineered in China, according to *Wired*.

TABLE 7: CHINESE HANDSET VENDORS AND THEIR SUPPLIER RELATIONSHIPS

Handset vendor	Original design manufacturer	Chipset or module supplier	2003 volume ($ millions)
Ningbo Bird	Bellwave, BENQ, Quanta, Pantech, Sewon, and Telson	Siemens, Sagem, and QUALCOMM	10.0
TCL	Foxconn, Pantech, and Compal	Wavecom, ADI, and QUALCOMM	9.7
Xiaxin	Bellwave	N/A	2.5
Keijian	Own brand and SAMSUNG	ADI, Wavecom, and SAMSUNG	2.0
Eastcom	BENQ, Compal, Sewon, LiteOn, Pantech, and Telson	Motorola, Agere, and QUALCOMM	2.0
Konka	Compal, Arima, Quanta, Bellwave, Pantech, Telson, and BENQ	Agere and QUALCOMM	1.5
Soutec	N/A	Motorola, QUALCOMM, and Wavecom	1.5
Panda	Bellwave, Arima, Foxconn, and Sewon	N/A	1.3
Haier	BENQ, Compal, Sewon, Inventec, and LiteOn	Philips, Motorola, and QUALCOMM	1.0
Legend	Arima, BENQ, Pantech, Sewon, and Quanta	QUALCOMM	1.0

Source: Gartner Dataquest, 2004

Through 2003, Chinese handset OEMs primarily used Taiwanese ODMs, but much of the core chipset technology came from Europe, Korea, and the United States.

As the result of the significant involvement of ODMs in production, chipset and module designers must play a larger role in systems design. This will be the case also for EMS providers, for which design has not been a traditional role. A larger percentage of the core intellectual property in second-tier handsets, for example, is owned by the semiconductor vendor responsible for the reference design, or the packaging vendor responsible for the system-in-package.

The OEM's role by contrast varies widely: Some are deeply engaged in quality control of select ODM suppliers, while others seek out lowest cost from multiple bidders. First-tier OEMs must balance high quality and reliability with a continuous flow of new products that have advanced features. They will face both price competition and an accelerated pace of newly introduced competitive products. The OEM's success requires solid integration of its supply chain and partnering that reflects an alignment of requirements, metrics, and execution.

The continued deverticalization of electronics production increases the responsiveness and efficiency of the industry and makes it more difficult for less efficient, vertically integrated companies to compete effectively. Electronics contract manufacturing revenues are forecast to double by 2008, according to IDC, and ODM

THE PROBLEM OF IP PROTECTION

For many years, Chinese culture has viewed knowledge as a free commodity to be used for the general good. This perspective tended to create a society in which concepts of intellectual property (IP) were abstract and lacking the clear definitions and moral constraints familiar to Western societies. An important point in China's accession to the World Trade Organization (WTO) was its agreement to enforce Western-style IP covenants and protections. The country has made progress in this area, but IP violations endure today to the point that few foreign companies view important IP as safe in China.

Patent Infringement

Patent and copyright infringement, for purposes of duplicating products locally and undercutting the original IP owner, is one of the principal forms of IP violation today. In April 2004, Analog Devices won a temporary injunction against High Tek Electronics, a distributor in India, after charging it and Chinese manufacturer Shanghai Belling of selling copies of Analog Devices' energy-metering chips. Other manufacturers in China that also copied these chips agreed to discontinue doing so. To date, ADI has not filed suit in China, and Shanghai Belling has issued no public comment on the lawsuit.

In 2002, Cisco accused Huawei, China's largest maker of telecommunications equipment, of stealing its IP (namely source code used in the company's IOS product line), violating its patents, and violating its copyrights in the development of Huawei's Quidway line of products. The two companies negotiated a settlement finalized in July 2004 in which Huawei agreed to modify its command line interfaces, manuals, help screens, and some source code.

Regarding the settlement, Huawei stated the following in an interview with *China Daily*: "Huawei has always respected and protected intellectual property rights, investing heavily in product research and development. Before the lawsuit, Huawei had already taken the initiative to amend its controversial products to avoid further disputes and enhance its competitiveness in order to explore overseas markets."

Typical cases of alleged IP theft, however, do not usually involve such large players. The more common scenario is described by Crowell & Moring, a U.S. law firm that specializes in IP protection:

"The U.S. company enters into a joint venture (JV) agreement with a Chinese company to produce widgets. The U.S. company licenses the widget patents and associated trade secrets to the JV under a very tightly written set of licenses, which prohibit the JV partner from disclosing the patented technologies to anyone. All proceeds as planned for about six months of production, following which the U.S. company begins to see 'knocked-off' widgets appearing in the marketplace. These ultimately are traced to a factory owned by the local JV partner, or a family relative, or possibly even a business that is an 'enemy' of the JV partner. Repeated efforts to enforce the licenses and IP rights, however, prove unsuccessful—the factory cannot be closed down, and while injunctions can be obtained from the courts, the U.S. company ultimately resigns itself to bargaining for an 'acceptable' level of IP violations."

Counterfeits

Counterfeit products represent a serious problem. In some cases, the allegations involve products based on IP of one company branded by another. In other cases, they are more traditional copy-and-replace activities using the labeling and trademarks of the original vendor. Charles Browne, president of DuPont China Holding, relates that DuPont has experienced "no theft of IP, but it has seen several instances of infringement in the form of counterfeits and fakes." This practice goes beyond the semiconductor industry. In January 2004, the U.S. Customs and Border Protection agency identified China as the top country of origin for seized counterfeit goods.

Laws and Legal Remedies

China passed a trademark law in 1982, a patent law in 1984, a copyright law in 1992, and an anti-unfair competition bill in 1993. In 2001, after acceding to the WTO, China issued new regulations to implement IP protection under the Agreement on Trade-Related Aspects of Intellectual Property (TRIPs), including one regulation that extended protection to the designs of integrated circuits (ICs).

Despite the advent of these legal mechanisms, there remain numerous Chinese laws that will appear curious, if not disturbing, to Western concepts of IP ownership. For example, the government can compel the licensing of patented technologies. And under import and export regulations, a licensee must be permitted to own improvements it develops under a licensing agreement. This right cannot be waived or modified by private contract.

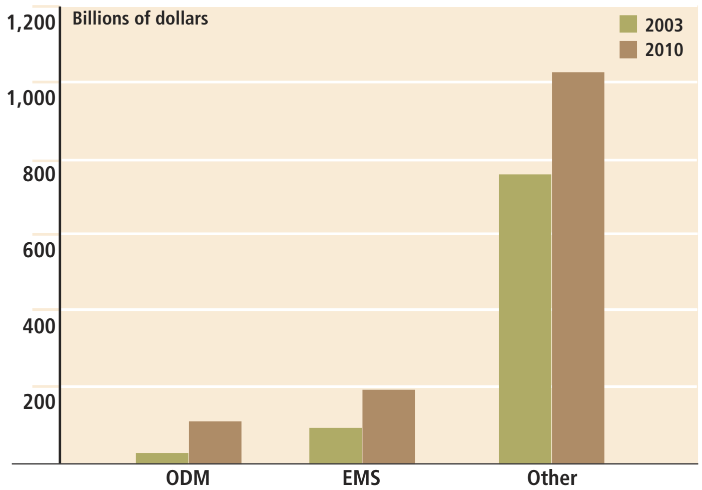
Seeking redress for IP violations can be a frustrating experience because of the comparative inexperience of Chinese courts in IP jurisprudence, which commonly causes inconsistent verdicts and uneven due process. This problem is magnified by the venue of the legal action: Regions like Shanghai, which are more familiar with IP issues, tend to make pursuit of violators easier, while regions in the interior are less responsive to complaints of IP violations. A second factor is the comparatively small dollar value of most fines and compensation orders.

As a result, companies that alleged IP problems have relied more on law enforcement when seeking domestic redress. The effectiveness of this tactic depends largely upon: the local governments' willingness to pursue IP violations, the nature of the violations, and the specific participants. Due to the weak remedies currently provided by China's judicial system, many corporations sue for IP violations in other venues. For example, Cisco's suit against Huawei was filed in the U.S.

Forecast

Although the government will be prodded into greater enforcement, the legal system and cultural mores needed to secure IP will evolve at a slow pace. As a result, IP of prime importance to its owners will not be designed or manufactured in China during the forecast period. This problem will remain, in the words of Rick Wills, Tektronix CEO, "the biggest issue for Western firms entering China." ■

FIGURE 16: ELECTRONICS PRODUCTION BY TYPE, 2003 VERSUS 2010



Source: IC Insights, PricewaterhouseCoopers, 2004

ODM and EMS electronics production revenues are small by comparison with that of OEMs through 2003. By 2010, however, contract manufacturing should make up nearly 30 percent of total electronics production worldwide.

production could grow at a compound annual rate of 22 percent through 2010, twice the rate of EMS production. (See Figure 16.) ODM production will be focused at the low end, in less-expensive mobile phones, for instance, but by the end of the forecast period should develop the potential to undertake some higher-value, higher-margin product categories as well.

Increases in Semiconductor Content

Semiconductor content continues to increase as a proportion of total electronics system production, which has allowed the semiconductor industry to grow more rapidly than the rest of the electronics industry. In March 2004, IC Insights reported that the percentage of value of semiconductors in electronics systems had risen from 4 percent in 1965 to 19 percent in 2003, and forecast semiconductor value to reach 25 percent of electronics systems production by 2008. One of the principal reasons cited for the forecast increase is the price pressure experienced by systems vendors resulting from the expansion of electronics production in China, which has caused an increase in demand for more functions per system dollar.

TABLE 8: WORLDWIDE SEMICONDUCTOR CONTENT IN ELECTRONICS PRODUCT CATEGORIES, 2003 ($ BILLIONS)

	Product revenue	Semiconductor consumption	Percentage of value
Consumer	189.3	29.4	16
Computer	351.4	73.6	21
Communications	175.4	42.3	24
Automotive	90.9	14.5	16
Industrial	169.3	13.7	8
Military/aerospace	78.4	3.8	5
Total	1,054.7	177.3	17

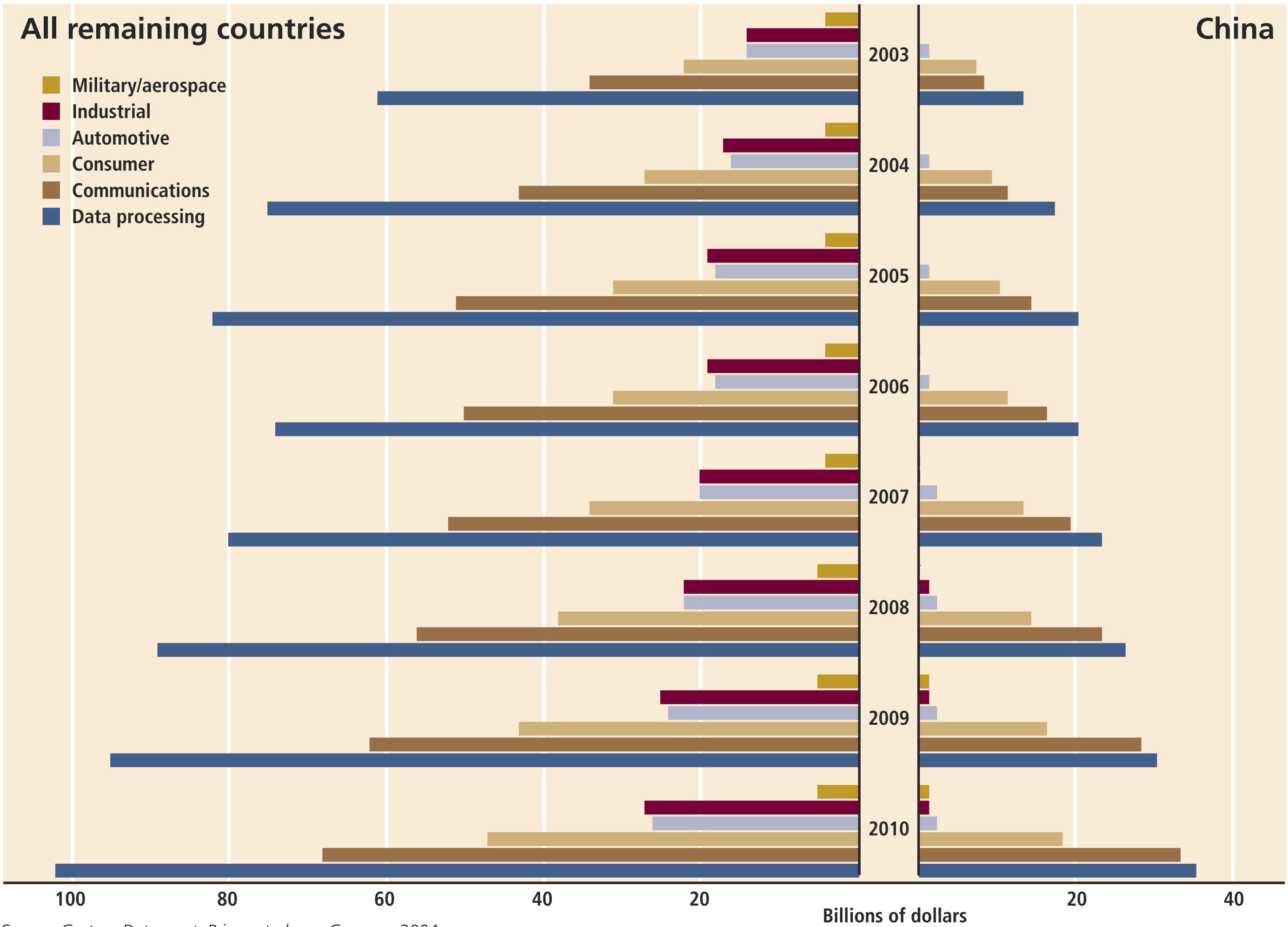
Source: DECISION Consulting, Gartner Dataquest, PricewaterhouseCoopers, 2004

Table 8 on page 51 compares semiconductor consumption by application category in 2003 to categories of electronics system production. According to this analysis, the product categories most often manufactured in China—communications, computer, and consumer—also have the highest level of semiconductor content. The trend toward the rising value of semiconductor content in systems relative to the other value in systems is likely to be encouraged by the growth of ODMs because they tend to favor chipsets and reference designs over the in-house equivalent—more of the intellectual property and thus the value is within the chipset.

Semiconductor Consumption Forecast

The migration of electronics production to China will be the most significant factor in semiconductor consumption growth there. Export percentages are not expected to change significantly, according to Gartner Dataquest. Although domestic consumption will rise, electronics production shifts to China will tend to mitigate changes in percentage of export.

FIGURE 17: SEMICONDUCTOR CONSUMPTION BY APPLICATION, CHINA VERSUS ALL REMAINING COUNTRIES, 2003–2010

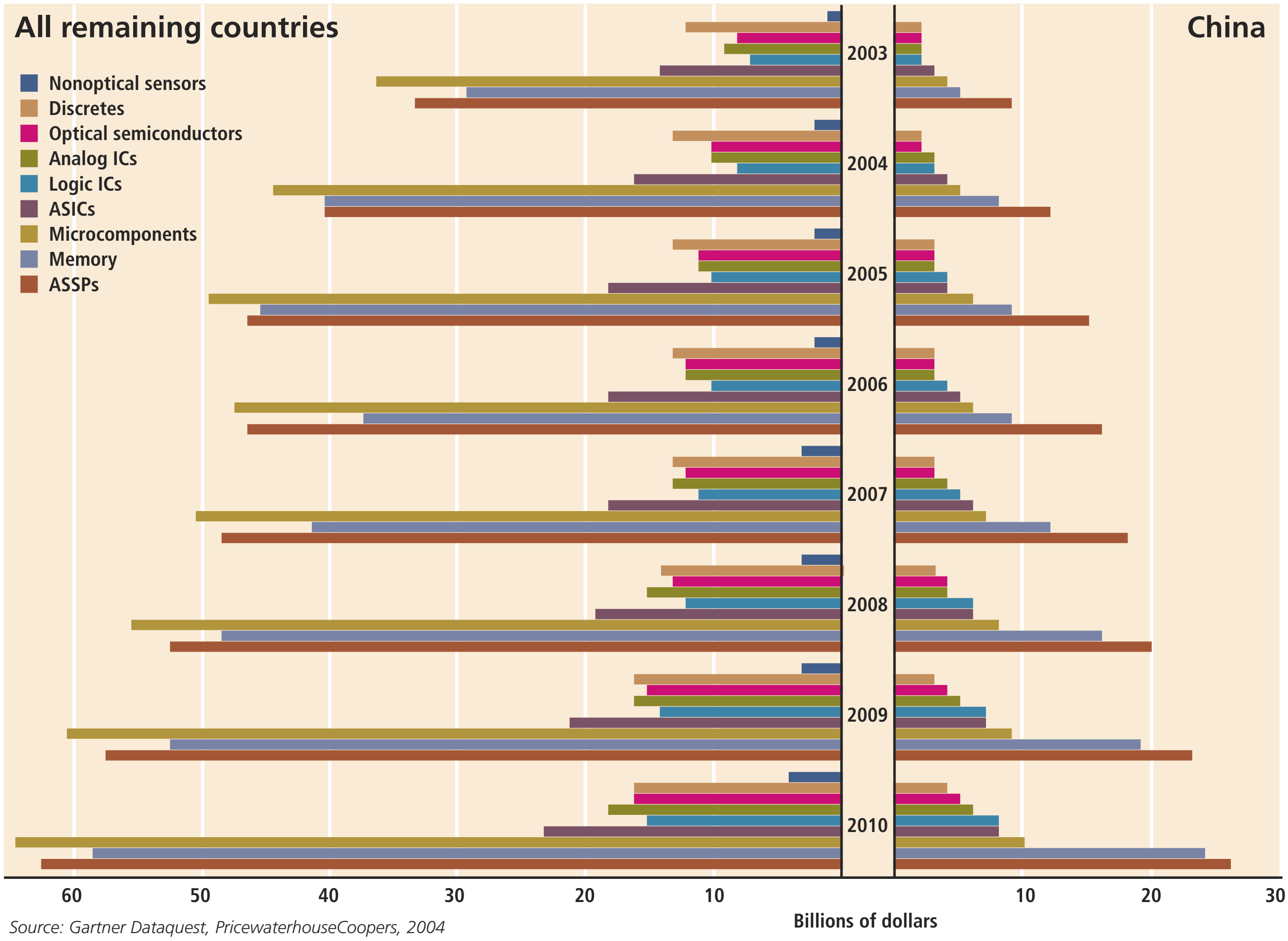


Source: Gartner Dataquest, PricewaterhouseCoopers, 2004

Figure 17 presents an aggregate demand forecast that compares China's predicted semiconductor consumption with that of all remaining countries. All application categories will see double-digit consumption growth in China between 2003 and 2010. Category CAGRs for China from 2003 to 2010 are forecast to range from 14 to 25 percent. Applications categories for the rest of the world, by contrast, will experience rates of 5 to 11 percent.

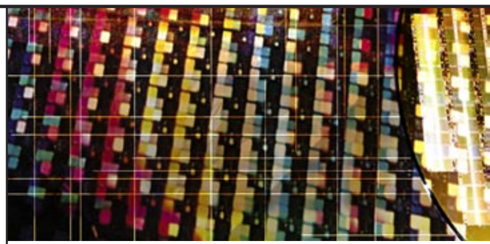
Communications (22 percent CAGR) and industrial applications (25 percent CAGR) will experience the highest growth, but the latter will constitute only 1 percent of total Chinese consumption primarily involving manufacturing systems, security systems, medical, and test and measurement equipment. Within communications, mobile phone semiconductor consumption will see the highest volumes, and 3G phones built in China will alone account for nearly $20 billion in semiconductor demand by 2010. Overall, China's consumption will grow at 17 percent, compared with 9 percent for the rest of the world.

FIGURE 18: SEMICONDUCTOR CONSUMPTION BY DEVICE TYPE, CHINA VERSUS ALL REMAINING COUNTRIES, 2003–2010



Source: Gartner Dataquest, PricewaterhouseCoopers, 2004

Segmenting the market by device type reveals a related trend. Application-specific categories of device types consumed will be emphasized over general-purpose microcomponents, according to Gartner Dataquest. (See Figure 18 on page 53.) Although notebook PC production volume in China could approach 50 percent of worldwide by 2010, and desktop PC production will exceed 50 percent by then, mobile phones, digital still cameras, digital TV, and DVD and video game players added together will generate even higher semiconductor demand in revenue terms in China. The electronics product mix in the rest of the world, by contrast, will include fewer handhelds and consumer electronics products.



This chapter provides an assessment of conservative, moderate, and aggressive IC production growth scenarios. It then compares these scenarios to Chinese government predictions on IC consumption (both export and domestic) in the country.

The Chinese semiconductor market has two distinct parts: the domestic market and the much larger export market. Roughly two-thirds of the semiconductors consumed in China today are exported as components of products assembled in China for sales abroad. Table 9 shows a breakdown by segment.

TABLE 9: SEMICONDUCTOR EXPORT PERCENTAGES BY SEGMENT

Market segment	2003 Sales ($ billions)	Percentage exported
Data-processing electronics	12.7	60.2
Communications electronics	8.3	64.0
Consumer electronics	7.2	78.9
Automotive electronics	0.8	75.1

Source: Gartner Dataquest, PricewaterhouseCoopers, 2004

These four segments account for 98 percent of the total semiconductor market in China. On a dollar-weighted basis, they constitute an average export ratio of 66.3 percent.

The Chinese domestic market will need to grow faster than the export market if it is to increase the share of semiconductors it consumes. This growth might be stimulated by the Chinese government's use of standards to command the design of specialty semiconductors for the domestic market. Production of these semiconductors likely will be a special province of Chinese fabs.

The effects of the growth of the Chinese semiconductor market—whether it increases or not—and the growth of the Chinese semiconductor industry are treated in the scenarios that follow.

Conservative Growth Scenario

This scenario assumes that China does nothing more than build the wafer fabs that are in place or under construction as of mid-2004. It assumes that these fabs will be run at an average 85 percent capacity, which is typical for the industry. In addition, it assumes that China's wafer fab output is valued at $1,200 per 8-inch equivalent—a figure used by many analysts. This scenario also assumes that wafer costs average 50 percent of semiconductor revenue and that SPA&T costs average 16 percent of revenue. These assumptions incorporate discrete devices and IC production. Using these assumptions, if only current fabs or those under construction are put into production, China's semiconductor production revenue will be $16.1 billion by the year 2010. This projection represents a CAGR of 21 percent. If the Chinese semiconductor market grows at 10 percent CAGR until 2010, China's production under this scenario will constitute 28 percent of the Chinese demand.

In keeping with a conservative scenario, attainment of this projection appears highly probable. The results of the moderate scenario, presented next, show a more aggressive growth pattern that is more likely to reflect reality during the forecast period.

In formulating this scenario, we use the same assumptions articulated previously regarding the value of wafers, fab utilization, and related factors.

Moderate Growth Scenario

This scenario is based upon China achieving the specific objectives articulated by the CSIA (a part of the Chinese Ministry of Information Industries, or MII): "Our objective is: by 2005 the output of nationwide ICs should reach 20 billion pieces, the sales should reach 60–80 billion yuan, which will account for 3 percent to 4 percent of the world market and will meet 30 percent of the demand of the domestic market, […] embedded CPU, DSP, RF, and IC card chips for computer, communication, digital audio-visual and information engineering can be designed and produced by ourselves; the 8-inch (200mm), 0.25µm technology should become the mainstream production technology of the industry; […] By 2010, the output of nationwide ICs should reach 50 billion pieces, the sales should reach 200 billion yuan, which will account for 5 percent to 6 percent of the worldwide market and will meet 50 percent of the demand of the domestic market. The technology of chips mass production should approach or reach the international mainstream level of that time."

PLANT LOCATION ALTERNATIVES TO CHINA

The current general enthusiasm for China has not entirely overshadowed the attractiveness of other countries that also offer competitive labor costs and other benefits. A number of major companies are investing in facilities in other locations in Asia outside China. Renesas, for example, announced plans in August 2004 to invest $4 million in a large-scale integration (LSI) design center in Ho Chi Minh City. The center will open in October with an initial staff of 20 to 30, and will produce designs for system chips that will operate with the company's SH mobile processors. Long-term plans for the center include expansion to 200 designers by 2006 and as many as 1,000 by 2010.

Also in August 2004, ASM International announced plans to establish a wafer processing equipment plant in Singapore that could employ 50 people by the end of 2004 and ship 100 systems annually by 2006. The plant, which will require an investment of $50 million over the next several years, will be able to take advantage of Singapore's intellectual capital and is intended to serve the local Asian market.

National security concerns could prompt parts of the industry to ensure the location of a portion of semiconductor plant capacity in lower-risk locations than China or Vietnam. In July 2004, the Mexican government announced its Silicon Border initiative, a plan for a 10,000-acre semiconductor industry office park along the border with the United States. The proximity of this location to the United States could make it a safer place to produce parts for military applications. Additionally, some supply chain synergies could result from the establishment of such a park in Mexico because of the existence of many contract electronics manufacturing plants there. However, labor costs in Mexico are higher than those in a number of places in Asia, and the country lacks a large educated workforce.

Companies should keep in mind that the rapid growth of the Chinese economy and Chinese education will give workers there more options to avoid low-paying jobs. Companies should also consider that governments will continue to compete aggressively in their efforts to attract manufacturing industry. China's continued attractiveness as a manufacturing location will depend on the nature and magnitude of such dynamics. ■

Under this moderate-growth scenario, China's IC production revenue will be $24.1 billion by the year 2010. This represents a CAGR of 28 percent. To attain this level of production, China will need to fabricate wafers at the rate of 1.3 million 8-inch-equivalent wafer starts per month (WSpM). If all fabs under construction and those announced that have a World Fab Watch probability of 0.55 or greater were built and placed into service at standard 85 percent capacity, China would still be 211,000 WSpM units short of its goal. Consequently, this scenario would require the construction of five additional fabs of 45 WSpM capacity at a total cost of $12.5 billion. This much capacity would be available if all plants that today have a World Fab Watch probability of 0.45 or greater were built. Because such a scenario relies on the construction of fabs that are only rumored at present, this projection should be seen as slightly optimistic. Such a perspective is seconded by the improbable goal stated in the CSIA plan for the year 2005, namely to have sales of Chinese semiconductors equal 30 percent of Chinese consumption—as just discussed.

The assumptions of the CSIA indicate a worldwide CAGR of 16 percent to 19.2 percent for the semiconductor market for ICs. If the worldwide market averages a more conservative 10 percent CAGR, the value of Chinese production would represent 8.8 percent of the worldwide market by 2010; if the worldwide market averages 13 percent worldwide, the Chinese portion would be 7.3 percent by 2010—both robust numbers for Chinese market share, in light of China's current 3 percent market share.

> *"Overall, Chinese companies, big companies, are looking at export as part of their growth strategy, rather than depending on domestic consumption."*
> *—H.K. Foo, Millennium Microtech*

Aggressive Growth Scenario

The aggressive scenario represents the upper bound of possible developments. It is based on the assumption that the Chinese semiconductor market will grow at twice the worldwide rate and that China achieves its stated goal that Chinese semiconductor industry sales equal half the value of the Chinese market (as explained in the previous scenario). This projection uses the previously employed baseline of worldwide growth of 10 percent CAGR, and it ascribes a 20 percent CAGR to China.

Under this aggressive-growth projection, China's IC consumption is predicted to be $89.5 billion, while revenue from the IC industry will be $44.8 billion by the year 2010. At the beginning of 2004, the Chinese IC industry stood at $4.3 billion. Consequently, this scenario calls for a 10-fold increase in seven years. This increase represents a 42 percent CAGR during this period, which seems distinctly unlikely. For purposes of comparison, it is instructive to recognize that the three countries to previously enjoy breakout growth in their own semiconductor industries—Japan, Korea, and Taiwan—did not sustain a CAGR of 30 percent for more than two consecutive years.

In view of history's lack of precedent, how can China generate this level of production and what would such production require? Two models are possible depending on which type of semiconductor manufacturing comes to predominate—the wafer foundry and SATS model (common in China today) or the IDM and fabless model (which accounts for approximately only 17 percent of sales revenue for ICs in China in mid-2004). The salient difference between these two models for the purpose of this analysis is how they recognize revenue from sales. The cost of a semiconductor is roughly 50 percent for wafer fab and 16 percent for SATS. As a result, in the wafer foundry and SATS model, for every $1,000 semiconductors sold, the Chinese industry would recognize only 66 percent of its contribution. However, in the model of a Chinese IDM, the full $1,000 is recognized as semiconductor sales revenue.

INTERPRETING CHINESE SEMICONDUCTOR STATISTICS

Despite increasing international interest and press coverage, market reports and statistics of the Chinese semiconductor industry are difficult to obtain and often subject to misunderstanding and skepticism. Because Chinese government agencies rely upon these reports and statistics to establish industry policy, companies should be aware of how these statistics differ from conventional semiconductor statistics.

The two principal indigenous sources for most Chinese semiconductor industry and market reports, data, and statistics are China Center for Information Industry Development (CCID) Consulting and the Chinese Semiconductor Industry Association (CSIA), both of which are associated with the Ministry of Information Industries (MII) and share common data sources and industry analysts. Because both sources compile their data and write their reports in Chinese and then translate them into English, their English language reports contain a number of translation anomalies, especially related to units of measure.

Both sources compile and analyze their data based upon an industry structure that is somewhat different from that employed by Western analysts. This industry structure is not clearly defined in their English language reports, but may be best described by the following statement contained in the CSIA seminal "An Investigation Report of China's Semiconductor Industry 2002":

"The term 'the semiconductor industry' in this Report covers IC design, IC manufacture, packaging and test, semiconductor discrete device and semiconductor supporting sector, etc. In view that the investigation on supporting sector is not comprehensive, the term 'China semiconductor industry' in 'General Introduction' and in its relevant statistic data excludes this sector."

Therefore we have come to understand that according to MII, CCID, and CSIA usage, their reports on the Chinese semiconductor industry are based upon an industry structure organized into the following sectors.

IC Design

This sector includes integrated circuit (IC) design companies, institutes, and laboratories as well as all fabless IC semiconductor companies in China regardless of ownership structure. Most of the revenue and all of the unit production reported for this sector come from product sales of the fabless semiconductor companies.

IC Manufacture

Sometimes identified as wafer manufacturing, this category includes wafer foundries, wafer fabrication plants of foreign IC semiconductor companies, and Chinese IC integrated device manufacturers (IDM). As a result, the revenue and unit production reported for this sector is a nonhomogeneous mix of wafer and finished-product unit sales.

Packaging and Testing

This sector includes the IC semiconductor packaging, assembly and test (SPA&T) plants of foreign semiconductor companies as well as all IC semiconductor assembly and test services (SATS) plants and companies in China. This sector does not include the discrete SPA&T plants of foreign semiconductor companies or the IC SPA&T activities of Chinese IDMs. Because some SPA&T plants of foreign semiconductor companies utilize a wafer/die sale/buy back business model and others a consigned wafer/die business model, the revenue production reported for this sector is not homogeneous and is potentially misleading. However, the unit production reported is relatively homogeneous.

Discrete Device

This sector includes all Chinese discrete IDMs as well as all discrete wafer fabrication and SPA&T plants of foreign semiconductor companies in China. Because many of the SPA&T plants of foreign semiconductor companies utilize a consigned wafer/die business model rather than the fully costed IDM business model, the revenue production reported for this sector in not homogeneous and is potentially misleading. However, the unit production reported is relatively homogeneous.

Both CCID and CSIA compile their data from reports filed by the various entities in each industry sector. These entities typically report their activities as separate standalone companies, and CCID and CSIA consolidate the reports from each company in an industry sector without any eliminations or offsets. The results are often industry sector totals that are aggregates of nonhomogeneous inputs (for example, foundry wafer revenues and wafer shipments combined with IDM finished unit product sales revenues and unit shipments) and therefore misleading.

One of the most confusing terms used in their reports is "Pieces" or "pcs" (sometimes mistranslated "wafers"). As used in their reports, the definition of this term varies with the type of company, so that

WAFER FOUNDRY AND SATS BUSINESS MODEL

Using the 50:16 ratio for foundry-to-SATS revenue typical for the industry, China will need to derive $33.9 billion from foundries to meet its target production by 2010. At $1,200 per wafer, this requirement translates into 28.3 million wafers, or at 85 percent utilization, 2.77 million WSpM. To reach this level of wafer starts, China would need to put into production every fab that has been announced, planned, or currently under construction. Even then, it would need 28 additional fabs of capacity of 45,000 WSpM (or 20,000 starts of 300mm wafers). A reasonable estimate is that these new fabs would require an additional investment of $70 billion.

it includes finished devices from a fabless semiconductor company, wafers from a wafer foundry, finished devices from an IDM, and assembled and possibly tested units from a SPA&T plant or SATS company. It is very difficult to relate one to the other and therefore almost impossible to determine average selling prices (ASP) from their industry sector data.

Because at least one of the largest SPA&T plants of a foreign semiconductor company uses a wafer/die sale/buy back business model, its reported revenues are approximately four times as large as they would be if reported using the conventional consigned wafer/die (cost less die) basis. This reporting difference is very significant and could account for a potential overstatement of 25 percent in the 2003 revenues for the packaging and testing sector, 17 percent in the 2003 revenues of the Chinese IC industry and 8 percent in the 2003 revenues of the Chinese semiconductor industry.

Because CCID and CSIA consolidate the reports from each plant or company in an industry sector without any eliminations or offsets, double counting between sectors is very probable. For example, here is a hypothetical manufacturing flow for a Chinese fabless semiconductor company that uses a Chinese wafer foundry and SATS company to manufacture its products:

- Datang is a fabless semiconductor company in the IC design sector.
- ASMC is a wafer foundry in the IC manufacturing sector.
- GAPT is a SATS company in the packaging and testing sector.
- Solectron is an electronics manufacturing services (EMS) customer.
- Datang Microelectronics buys 1,000 wafers (200mm) from ASMC for $1,200 per wafer for a total of $1,200,000.
- Datang consigns the 1,000 wafers to GAPT for assembly and testing in plastic ball grid array (PBGA) packages with 600 net die per wafer and a die free package cost of $1 per package, for a total of $600,000.
- Datang sells the 600,000 finished units to Solectron for an ASP of $4 per device for a total of $2,400,000.

Using CCID and CSIA reporting practices, these transactions would be classified and recorded as follows:

	Pieces	Revenue
IC manufacturing sector	1,000	$1,200,000
Packaging and testing sector	600,000	$600,000
IC design sector	600,000	$2,400,000
Total	1,201,000	$4,200,000

As a result of CCID and CSIA reporting practices, the total Chinese semiconductor industry revenue in the hypothetical example just described is overstated by 75 percent and unit shipments by 100 percent when compared to conventional Western reporting standards.

Compared to the more conventional practices and standards of the World Semiconductor Trade Statistics (WSTS) and related industry associations and analysts, these differences in CCID and CSIA reporting practices and standards could lead to noticeable variability in reported Chinese semiconductor industry results, depending upon the mix of business models employed. Furthermore, these differences could have a significant impact on China's apparent ability to meet the CSIA's objective of increasing the output of nationwide IC to meet 50 percent of the domestic market by 2010.

An example of an identical IC device that is wafer fabricated, packaged, assembled and tested in China can illustrate that impact. Based upon the current CCID/CSIA reporting practices, an average reported semiconductor industry revenue could be 100 yuan if the device were manufactured and sold by a Chinese IDM, but only 66 yuan if the device were manufactured by a wafer foundry and SATS supplier for a foreign fabless semiconductor company, or a more significant 166 yuan if the device were manufactured by a wafer foundry and SATS supplier for a Chinese fabless semiconductor company.

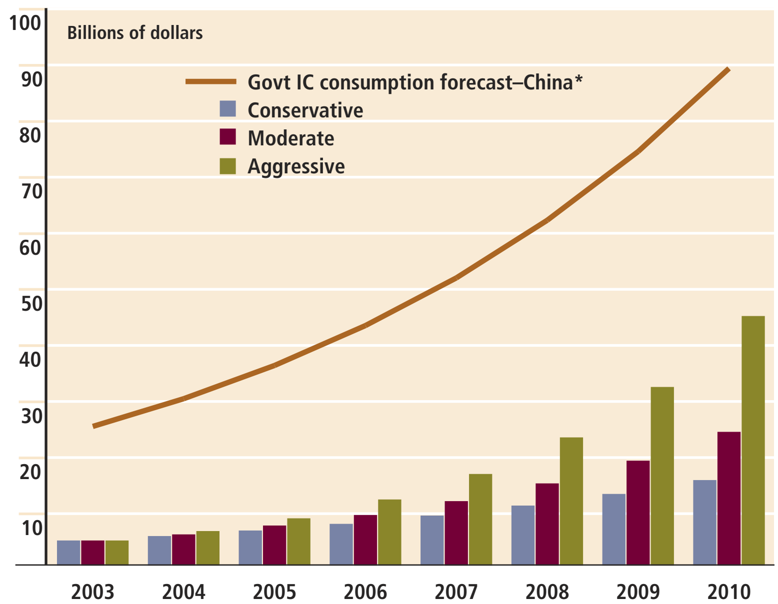
Increasing international interest and visibility during the next few years may encourage CCID and CSIA to discontinue their current Chinese semiconductor industry reporting practices and standards. If China elects to change to more conventional semiconductor industry reporting practices and standards, the country may find it desirable to revise the CSIA objectives accordingly. ■

IDM AND FABLESS BUSINESS MODEL

The IDM and fabless business model would require wafer production of $22.4 billion by 2010, or 1.83 million WSpM. Reaching this output volume by 2010 would require all fabs announced, planned, and under construction to be brought online, plus the construction of seven additional fabs with a capacity of 45,000 WSpM. These additional plants would require an investment of $18 billion.

Regardless of the growth scenario through 2010, IC consumption in China could outpace the level of production there.

FIGURE 19: CHINESE IC PRODUCTION SCENARIOS VERSUS CONSUMPTION



**Assumes 20% CAGR for 2003–2010*

Source: CSIA, World Fab Watch, PricewaterhouseCoopers, 2004

The implications of the aggressive growth scenario are analyzed in the next section. To compare what the three growth scenarios represent economically, Figure 19 shows the requirements of the three scenarios in a completely smoothed curve. These numbers are presented for comparison purposes and are not year-by-year projections.

Toward the end of the forecast period, the results predicted by the aggressive scenario diverge significantly from those projected in the other two. Results of this kind undoubtedly will require a significant increase in capital investment and a new vision of China's role in the semiconductor market.

Implications of the Growth Scenarios

The overall market growth presented in the aggressive scenario is certainly possible; however, the ability of China to ramp up to the fab levels required is improbable even under the IDM and fabless business model. Consequently, China will have a productivity gap, rather than an opportunity gap. That is, the ability to increase semiconductor manufacture at the level it aspires to will be the gating factor to growth.

This semiconductor productivity gap represents a larger problem than China not meeting its government-formulated goals. In response, the Chinese government could overreact and, through incentives and other inducements, cause investments in new fabs that are not otherwise economically justified. Such a development could lead to overcapacity and underutilization, which will exacerbate the amplitude of the infamous economic cycles in the semiconductor industry—especially those occurring after the 2005–2006 time frame.

Additional factors might supervene. If China were to become the dominant semiconductor manufacturer, other countries might feel political pressure to diminish investment in China or, possibly, draft legislation that would make further investment less desirable or, in an extreme case, impossible.

China's place in worldwide semiconductor wafer production varies under the three scenarios.

CONSERVATIVE SCENARIO

If all of China's current plants were equipped and ramped for capacity at mature yields, China's share of worldwide semiconductor wafer fabrication would rise to 6 percent (from roughly 2 percent in 2003). However, if China also completes construction and brings to full production the 15 additional plants envisioned in this scenario, its share of semiconductor wafer fabrication will rise to 9 percent by 2008, making it an important producer in a comparatively short period of time.

MODERATE SCENARIO

If all the 22 additional plants envisioned under this scenario were financed, constructed, and ramped to full capacity at mature yields, China's share of worldwide semiconductor wafer fabrication would be 11.5 percent.

For more details on the calculations behind these numbers, see "Aggressive Growth Scenario," on page 57.

AGGRESSIVE SCENARIO

If all the plants envisioned in the earlier scenarios were brought online at full capacity, and between 7 and 28 new fabs were also built and brought online by 2010, China's share of worldwide semiconductor wafer capacity would be between 14 percent (using a 100 percent IDM business model) and 21 percent (using the wafer foundry and SATS model). If the ratio stays at the current rate of 17 percent for the IDM model, China's worldwide share will be nearly 20 percent.

The world reaction to such a rapid rise to prominence will be difficult to guess. At this level, it is unlikely that governments will take retaliatory actions, but it is equally unlikely they will simply accept China's new role as part of the "inevitable" manufacturing shifts due to globalization. This latter perspective is based on the view that semiconductors are strategically critical and that Western nations have a strong interest in the availability of semiconductors from dependable—that is, like-minded—partner nations.

Forecast

Under all these scenarios, the industry would be wise to expect that an important Chinese IDM will eventually arise—that is, an IDM that will rank among the world's top 25 on the basis of semiconductor sales by 2010 or shortly thereafter. A distinct

For a discussion on the importance of such standards, see page 46.

possibility is a company that would start by focusing on the second-source mid-market and commodity products consumed in large numbers by the Chinese semiconductor market. This growth could come, in part, from designing products that meet China-specific standards. Sales of these products would be mostly to domestic consumers. In addition, the IDM would derive substantial business from mid-tier components that are not affected by standards issues and are aimed primarily at the export segment of the market. Based upon the preceding discussions, we believe that the Chinese market is indeed strong enough to support the growth of a major IDM on its internal volume alone.

There is no doubt that China will continue to see rapid growth in its semiconductor industry. All projections point to growth that exceeds the conservative scenario presented earlier. Likewise, due to China's production gap, it is safe to say that the aggressive scenario is simply too ambitious given the current state of China's semiconductor industry. As a result, we conclude that the moderate scenario is a reasonable, perhaps slightly aggressive projection of China's semiconductor manufacturing industry through the year 2010.

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