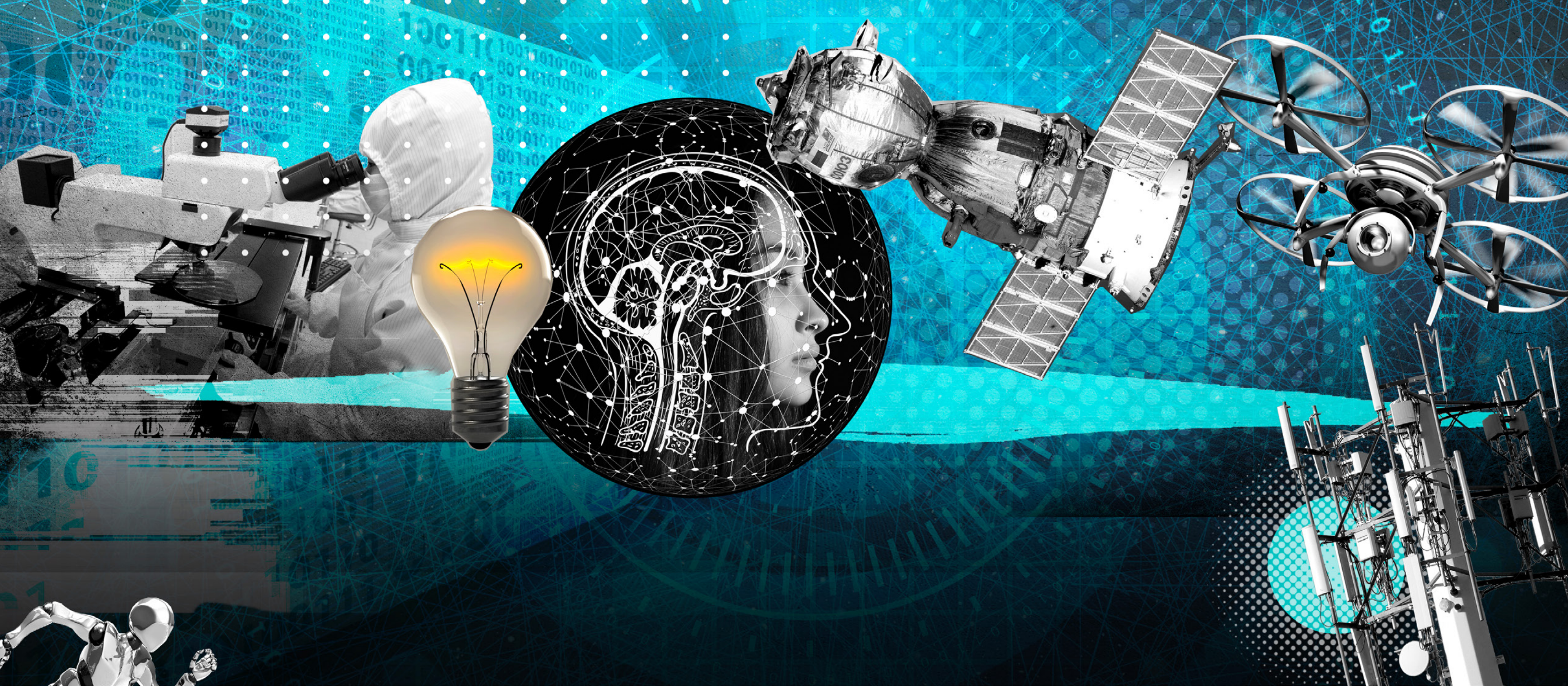

The Geopolitics of Semiconductors

PREPARED BY EURASIA GROUP
SEPTEMBER 2020

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Key findings

- Technology and market trends over the past decade have concentrated cutting-edge semiconductor manufacturing capabilities among a handful of companies located in global hotspots, including South Korea and, most importantly, Taiwan. This trend is now having geopolitical consequences.
- Semiconductors are a strategic vulnerability for China and its most important tech company, Huawei, which relies on cutting-edge manufacturing facilities in Taiwan to make the chips it needs to remain globally competitive.
- Despite massive government investment in semiconductors, it is unlikely that Chinese companies will enter the top tier of global semiconductor manufacturers over the next decade, leaving the country's technology sector dependent on access to foreign chips.
- US moves to restrict Huawei's access to cutting-edge chips threaten the viability of the company's global business and have been decisive in giving Washington the upper hand in its bid to convince key European allies and other major economies to ban or sharply restrict the Chinese supplier from their 5G rollouts.
- A separate US initiative to encourage semiconductor industry leaders including Taiwan Semiconductor Manufacturing Company (TSMC) to build advanced chip manufacturing facilities on US soil will further raise the stakes for China and Taiwan, with global chip suppliers increasingly under pressure to choose between "blue" (US) and "red" (China) supply chains.
- Taiwan and TSMC have taken on increased geopolitical importance in this environment; if the US broadens technology restrictions targeting semiconductors to other Chinese firms and succeeds in driving a wedge between China and Taiwan in the area of semiconductors, it would provoke a sharp response from Beijing, raising risks for global technology supply chains.
- Military action over Taiwan regarding this issue is unlikely; however, China has other options that it can use to try to gain leverage, including nationalization of TSMC facilities in China, IP theft, recruiting key industry talent, retaliatory actions against US and other Western technology firms operating in China, and greater investment in the domestic technology sector.
- As the US presses ahead with stricter and broader controls over semiconductors and related technologies, it will hasten decoupling of the two countries' tech sectors while further spurring China's attempts to establish a separate R&D and production system.
- This will be a messy and costly process that creates significant new risks across the $5 trillion global ICT sector and will continue during the next US administration, regardless of who wins November's election.

US-China semiconductor competition will have global consequences

The process of designing, testing, manufacturing, and packaging the integrated circuits that power modern smartphones and computers is fiendishly complex and capital intensive. From its origins in Silicon Valley, the semiconductor industry has evolved over decades under intense competitive pressures into a highly specialized global industry. This evolution is now having geopolitical consequences.

Since the US-China trade and technology confrontation spilled into public view in 2017, most of the attention has centered on trade conflict and the US campaign against Huawei, China's 5G leader and its most important global technology company. However, recent US actions involving semiconductors—the integrated circuits that make modern digital technologies and applications possible—present a more fundamental problem for China.

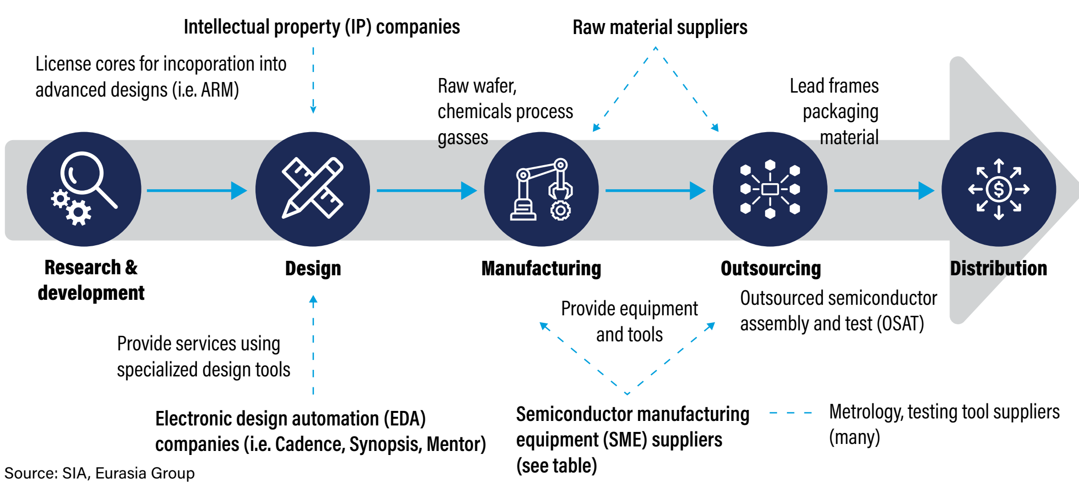
Specifically, recent US efforts to cut off the supply of cutting-edge semiconductors to Huawei and to encourage the construction of advanced chip factories on US soil have drawn the semiconductor industry into the US-China technology cold war, dramatically raising the stakes in the countries' trade and technology conflict.

This report by Eurasia Group's geo-technology practice analyses the geopolitical implications of recent political and market developments in the semiconductor industry—primarily in semiconductor manufacturing, carried out in sophisticated factories known as fabs. Understanding the political and technology dynamics of this critical sector will become even more important as mounting US pressure on China in the technology domain and China's domestic technology development and responses to US actions affect bilateral relations and create new risks for companies, market participants, and global technology supply chains.

Semiconductors are a strategic bottleneck, and China is vulnerable

Decades of progress in mass-producing chips containing ever-higher numbers of circuits has radically altered the economics of computing and fundamentally reshaped the global economy. The personal computer revolution of the 1980s, the internet revolution of the 1990s, and the smartphone and social media revolutions of the early 2000s were all built on silicon. The next generation of potentially game-changing consumer and industrial applications built on top of 5G networks will likewise depend on improvements in performance and computing power supplied by cutting-edge chips. Access to cutting-edge semiconductors is likewise critical to the balance of global military power, owing to their use in high-performance computing and artificial intelligence (AI) and Internet of Things applications, as well as their essential role in modern and next-generation weapons platforms.

Semiconductor production ecosystem spans many stages



Source: SIA, Eurasia Group

Given the huge cost of funding the research and manufacturing capacity needed to stay on the cutting edge of technology development, advanced semiconductor manufacturing capabilities have become increasingly concentrated among a few large industry players. These companies are located within a small number of countries, including geopolitical hotspots such South Korea and, most importantly, Taiwan.

According to the industry rule of thumb known as Moore's Law, semiconductors have roughly doubled in circuit density every two years since the 1970s, as companies at the forefront of technology development have raced to develop new ways to create denser and more powerful integrated circuits. This exponential performance improvement has not been driven by any kind of physical law or natural phenomenon. Rather, it is the product of research and innovation carried out by private firms in response to market forces. To justify making investments necessary to move up the technology curve, companies need to tackle complex engineering and manufacturing problems while generating a financial return that exceeds their cost of capital.

At present, only two companies—South Korea's Samsung and Taiwan's TSMC—are manufacturing semiconductors in volume at the most advanced process nodes. A process node is the industry term for a specific generation of manufacturing process and is named according to its smallest feature size. These industry leaders are currently producing in commercial quantities at the 7-nanometer (nm) node, while racing to transition to 5 nm, and then eventually to 3 nm by the mid-2020s. US integrated chip manufacturer Intel is also racing to produce in volume at 7 nm, but it has encountered challenges in meeting ambitious targets for the program, announcing in July that production of its next-generation chips would be delayed until 2022[1].

1 Technically, TSMC initially pushed its dense ultraviolet 193-nm lithography equipment down to 7-nm line features using complex techniques such as multiple (quadruple) patterning, which Intel has had difficult doing at commercial yields. Samsung decided to skip this step and go right to extreme ultraviolet.

And then there were three: Number of semiconductor manufacturing firms at key technology nodes, end 2019

Consolidation at the cutting-edge of semiconductor manufacturing has increased as process technology has become more expensive and complex. Only foundries and integrated device manufacturers with proven technical capabilities and large customers bases have been able to invest and remain competitive given the high capital cost and R&D expense of achieving commercial yields at ever-smaller features sizes. For advanced memory, DRAM feature sizes, for example, now require advanced lithography.

Process node (nm)	180	130	90	65	45/40	32/28	22/20	16/14	10/7	5	3
Number of semicondutor manufacturers working at each process node											
US	24	18	11	8	4	4	4	4	1	1	1
South Korea	4	4	3	2	2	2	2	2	2	1	1
Taiwan	9	9	6	6	6	6	5	3	1	1	1
Japan	18	10	7	6	5	1	1	1			
China	19	18	16	13	8	6	3	1	1		
Other	20	13	5	1	1	1	1				
Total	*94*	*72*	*48*	*36*	*26*	*20*	*16*	*11*	*5*	*3*	*3*

Note: Some companies in the above table have fabrication facilities located in countries outside of where they are headquarted but have been included in country totals. The table also does not distinguish between producers of different types of semiconductors, such as CPU/GPU, application-specific semiconductors, and memory, each of which is driven by different market requirements around feature size.

The cutting edge: TSMC, Samsung, and Intel each have plans to push toward 3 nm, but at present only TSMC and Samsung are producing in commercial volumes at 7 nm. SMIC is also attempting to move below 10 nm.

Major industry players — **Process node (nm)**

✓ Currently producing in commercial volumes (✓) Under development/planned

Country	Company	90	65	45/40	32/28	22/20	16/14	10/7	5	3
Taiwan	TSMC	✓	✓	✓	✓	✓	✓	✓	(✓)	(✓)
South Korea	Samsung	✓	✓	✓	✓	✓	✓	✓	(✓)	(✓)
US	Intel	✓	✓	✓	✓	✓	✓	✓*	(✓)	(✓)
UAE	GlobalFoundries	✓	✓	✓	✓	✓	✓	✓		
China	SMIC	✓	✓	✓	✓	✓	✓	(✓)		
South Korea	SK hynix	✓	✓	✓	✓	✓	✓	✓		
Japan	KIOXIA	✓	✓	✓	✓	✓	✓			
Taiwan	UMC	✓	✓	✓	✓	✓				
Switzerland	stm	✓	✓	✓	✓	✓				
Germany	Infineon	✓	✓	✓	✓					
US	IBM	✓	✓	✓	✓					
US	Texas Instruments	✓	✓	✓	✓					
Japan	Fujitsu	✓	✓	✓						

*Intel is in commercial production at 10 nm but has encountered challenges with high volume production at 7 nm.
Sources: SEMI, Eurasia Group

The concentration of advanced manufacturing capabilities among a handful of countries and companies is the result of decades of market pressure, as rivals that were unable to keep up with the large and increasing capital outlays required to compete at the global cutting edge have dropped out of the race toward ever smaller process nodes. These require more complex equipment that can take significant resources to master. This trend is likely to persist over the next decade.

At present, 7-nm chips—including Huawei's Kirin 990 system-on-chip, manufactured by TSMC in Taiwan—are the most advanced semiconductors in commercial use. Huawei's chip design arm HiSilicon had been working with TSMC on the latest in the Kirin series, at the 5-nm processing node.

Despite the growing prowess of Chinese technology firms in areas such as 5G, AI, mobile applications, and quantum computing, the country remains far behind the global cutting edge of semiconductor manufacturing. As a result, to meet Beijing's ambitious goals for China's technology and economic development and to remain globally competitive, domestic tech companies rely on overseas fabs to create their most advanced chips.

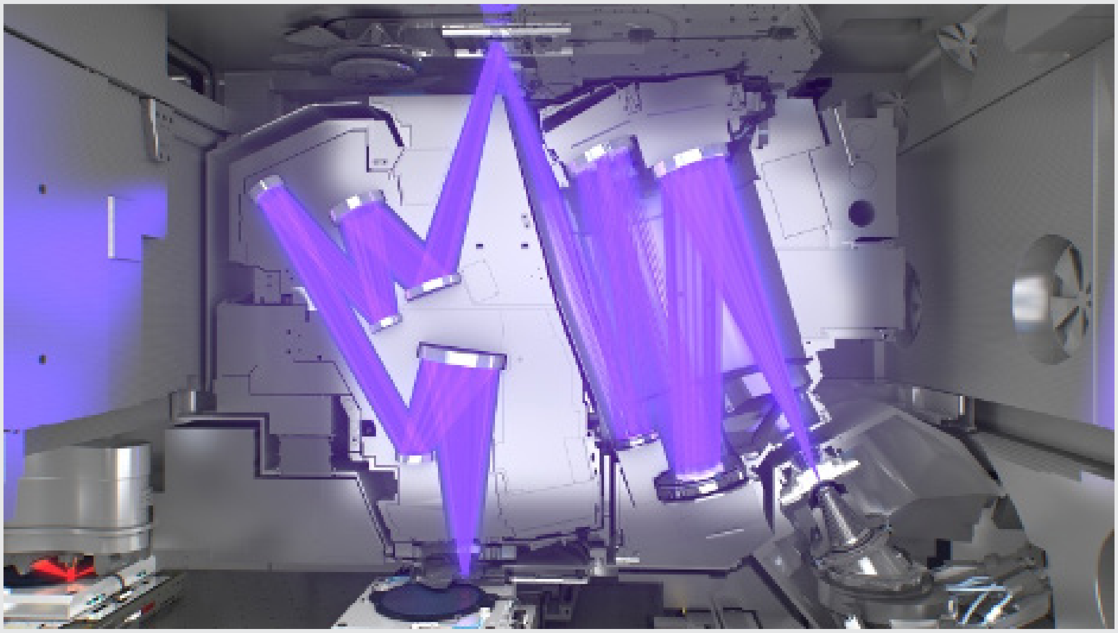
China has been stepping up its push to master advanced semiconductor manufacturing. Through its massive National IC Investment Fund, established in 2014 and recapitalized in 2019, and other regional and local funds, China has earmarked funding in excess of $200 billion—more than the inflation-adjusted cost of the US Cold War-era Apollo moon shot—to move China up the manufacturing curve. Yet it has so far achieved limited results. China's leading fabrication company, Semiconductor Manufacturing International Corporation (SMIC), remains three to five years behind industry leaders Intel, Samsung, and TSMC. In August, SMIC claimed it would be able to push its existing lithography equipment to 7 nm, but this would constitute a major breakthrough for the firm, and would still leave it behind industry leaders.

Although China will continue to pour money into the sector, its manufacturers are unlikely to break into the very top tier of global manufacturers in the critical application-specific integrated circuit (ASIC) market—the workhorse chips that power smartphones and computers—at nodes below 7-10 nm for the foreseeable future. This is due primarily to the high and growing cost of R&D and the challenges of installing and operating large-scale semiconductor manufacturing equipment necessary to manufacture in commercial volumes at process nodes below 10 nm.

Intel, Samsung, and TSMC have already been forced to look for new ways to collaborate and share costs to maintain the current pace of cutting-edge innovation. Combined R&D spending and capital expenditures by US semiconductor firms rose to $72 billion in 2019, from $40 billion in 2007, reflecting the rising cost of keeping up with Moore's Law. In 2018, another big player, GlobalFoundries—owned by UAE sovereign wealth fund Mubadala—effectively dropped out of the race for global leadership, announcing it would abandon development efforts at the 7-nm node, primarily because of prohibitive tooling costs.

One specific bottleneck for SMIC and other Chinese producers is extreme ultraviolet (EUV) lithography technology, a next-generation manufacturing technology that is required to move to nodes below 7 nm. EUV, which uses shorter wavelengths of ultraviolet light to achieve finer and denser patterns of circuits than is possible with earlier manufacturing techniques (please see box), is in use by TSMC and Samsung at the 7-nm process node. Intel is working to integrate EUV into its commercial production lines but has encountered problems. TSMC, Samsung, and Intel will all rely on EUV for their 5-nm fabrication.

Extreme ultraviolet lithography



Source: ASML

EUV is the next-generation semiconductor manufacturing technology that is being deployed by global industry leaders to achieve feature sizes below 7 nm. The previous state-of-the-art 10-nm process node used light generated by argon fluoride excimer lasers at wavelengths as short as 193 nm to etch circuits onto silicon wafers. Although scientists were able to push the limits of 193-nm lithography through innovations such as water immersion and other techniques such as multiple pattering, to enhance the resolution of the manufacturing process, these workarounds hit their effective limit at 7nm. They can be used for some layers, but getting sufficient commercial yields using these techniques is challenging. Cutting-edge production at 7 nm and below by TSMC and Samsung uses a mix of EUV and more traditional lithography techniques to achieve smaller feature sizes than are possible with earlier methods.

EUV technology uses light at wavelengths as short as 13.5 nm to etch finer features, allowing denser integrated circuits that deliver more computing power with lower power requirements. However, the process of generating a light beam at such short wavelengths and harnessing it to create integrated circuits at commercially viable yields is enormously complex. EUV lithography involves creating microscopic droplets of tin, which are dropped into a vacuum, bombarded with powerful lasers, and vaporized into plasma, which then emits EUV light at the target wavelength. The EUV light is focused and bounced off a succession of mirrors and specially designed photomasks before etching the reflected pattern onto the silicon wafer.

EUV's substantial power requirements, the need to overhaul important parts of the manufacturing process to work with shorter wavelengths of UV light, and other engineering and performance hurdles created substantial challenges getting EUV to run with sufficient uptime, throughput, and yield to be commercially viable.

Dutch semiconductor manufacturing equipment company ASML is the world's only commercial producer of EUV lithography equipment. EUV lithography machines can cost upward of $140 million. ASML's EUV equipment also uses significant amounts of US technology, giving the US government an excuse to try to control shipments of EUV equipment to China under US export control regulations.

Media reports in early 2020 indicated that the US had been pressuring the Netherlands to block the delivery of advanced EUV lithography equipment to SMIC by ASML. Without access to this equipment and the teams of doctorate-level engineers who spend months working to install and fine tune it, SMIC—and by extension China—may have no viable path to reach process nodes below 7-10 nm in the foreseeable future. This will leave Huawei and other Chinese technology companies dependent on foreign chip suppliers. Meanwhile, the US foreign direct product rule targeting Huawei's chip arm HiSilicon has effectively severed the connection between the Chinese tech leader and its top supplier of chips fabbed using EUV equipment in Taiwan.

Fallout for Taiwan as US attempts to drive wedge between "red" and "blue" supply chains

In recent months, the US has ramped up pressure on China in the area of semiconductors in two ways, both of which have pulled Taiwan deeper into the US-China technology conflict.

First, elements of the US government concerned about the long-term security of supply chains for advanced semiconductors used in military and sensitive civilian applications have stepped up efforts to ensure that the US retains access to trusted manufacturers. The 15 May announcement that TSMC will invest up to $12 billion to build a 5-nm manufacturing facility in Arizona was an important step forward in this effort. Although TSMC's announcement did not explicitly state that the investment was intended to pave the way for TSMC to become part of the Pentagon's "trusted" supply chain—possibly owing to sensitivities about how this would be perceived in Beijing—it is likely that this is one of the project's goals.

Second, other hawkish factions in the Trump administration and certain US government agencies have zeroed in on Taiwan's importance as a supplier of cutting-edge semiconductors to Chinese companies as part of their campaign to cripple Huawei. On the same day that TSMC announced its new Arizona facility, the US issued a long-awaited foreign direct product rule designed to stop shipments of advanced semiconductors to Huawei's HiSilicon chip subsidiary from TSMC.

The US actions underscore how Taiwan has become the focal point and driver of new US concerns about the semiconductor industry's trajectory. Since 2017, as China's homegrown semiconductor design capabilities have grown, and US-China technology tensions have worsened, Chinese company interaction with leading Taiwan firms, including Huawei/HiSilicon's relationship with TSMC, has increased significantly. In the process, Beijing has begun incentivizing TSMC to move more manufacturing operations and advanced technology to the mainland. TSMC's Nanjing fab, currently producing at 16 nm, is its most advanced in China, though the company has resisted attempts to get it to expand and provide cutting-edge manufacturing at its China-based facilities. Instead, advanced manufacturing for customers such as HiSilicon has grown at TSMC facilities in Taiwan. HiSilicon accounted for 14% of TSMC revenue in the first quarter.

US officials have also become uncomfortable with the growing presence of Chinese engineers at TSMC, which they view as increasing potential risks of IP theft or introduction of malicious hardware or software into US-bound supply chains. Rising US doubts about Taiwan as a safe haven for US IP—specifically, the potential for Chinese intelligence services to inject malicious code or hardware into advanced semiconductor designs—are another likely driver behind the push to convince TSMC to build advanced manufacturing operations in the US. Leading US technology companies, including many that are likewise supplying the US government and military, already rely on TSMC to manufacture their cutting-edge semiconductors. US companies account for about 60% of TSMC revenue.

US seizes on China's semiconductor vulnerability in its campaign against Huawei

Until recently, US policies to address these risks had been primarily defensive, including the US entity list action and subsequent moves against Huawei. The new US foreign direct product rule targeting shipments of semiconductors to HiSilicon from third-country suppliers including TSMC also falls under this umbrella. The rule is meant to require companies such as TSMC to apply for a license, with the presumption of denial, before shipping products made with US technology to HiSilicon.

Although the rule's vague wording initially led to doubts about whether TSMC would be forced to apply for such a license, TSMC in June clarified that it would abide by the spirit rather than the letter of the regulation. TSMC stopped taking orders from HiSilicon in mid-May. In July, it announced it had found replacements for its lost HiSilicon business, and that it would wind down its relationship with the firm in mid-September.

The US action targeting Huawei's access to TSMC was a major escalation in the US-China tech cold war—arguably more notable than the original May 2019 entity list action restricting Huawei's access to a broad array of US technologies. While Huawei's suppliers have found numerous ways around the entity list, the new restrictions on semiconductors that incorporate US technology have the potential to cripple the Chinese company, which may not be able to compete in the global marketplace over the long term without access to cutting-edge chips.

There is potential for Huawei to work around some strictures on its ability to use TSMC to manufacture chips for its future product lines. The firm has recently announced stepped-up cooperation with Taiwan smartphone chip supplier MediaTek and with UNISOC, a leading domestic chip maker for mobile applications backed by Tsinghua Unigroup and the National IC Investment Fund. Both are designing chips at below the 10-nm level, but both rely on TSMC for fabrication. Huawei's ability to use these firms' chips for advanced consumer devices will hinge on how the foreign direct product rule is applied. The clarification of the rule for Huawei, issued in August by the Commerce Department, appeared to close off this avenue. It also greatly expanded the scope of the rule, which now includes basically any electronics components manufactured using US technology where Huawei or affiliates are in any way involved as intermediate or end beneficiaries.

As of late August, Huawei suppliers were scrambling to ship components before the 14 September deadline—some were even willing to ship semi-finished products, while the US semiconductor industry trade group was pressing the Commerce Department to extend the deadline for compliance. For other key semiconductors, such as baseband chips for 5G base stations, there were no clear alternatives for Huawei even before the new rule update, if the TSMC channel remains closed.

The resulting uncertainty about Huawei's supply chain is already affecting the global telecom sector. The recent US actions appear to have handed Washington the advantage in its campaign to convince key European allies and other like-minded countries to ban the company from their 5G rollouts, for example. The UK government cited concerns about the US foreign direct product rule's impact on Huawei in its recent decision to require UK mobile operators to remove Huawei equipment from their networks. Although the decision came amid a groundswell of hawkish sentiment among Conservative Party lawmakers in the wake of the pandemic, the more important motivation for the UK plan was apprehension among the national security establishment that the new US restrictions targeting Huawei might force the Chinese supplier to fall back on alternative suppliers whose components have not been thoroughly vetted for security risks. The government moved ahead with the ban despite forecasts that it would delay the arrival of 5G in the UK by at least two years and cost operators up to £2 billion.

Even in the absence of official or de-facto bans, mobile operators that have historically relied on Huawei equipment will have assess the risks to the company's long-term viability as a global supplier if the US maintains its stranglehold on Huawei's access to cutting-edge chips.

Industry revenue at risk as further US action targeting broader array of Chinese tech companies increasingly likely

Trump administration officials are playing a complex game with semiconductor global supply chains. On the one hand, the drive to undercut Huawei has set in motion a process that will result in the "designing out" of US semiconductors by Chinese firms. Other global firms in HiSilicon's supply chain—including foundries, packaging and testing firms, and electronic contract manufacturers that assemble all or portions of final products—may also try to replace US technology where possible to reduce the risk from US extraterritorial export controls. This would be similar to the way the original entity list action against Huawei forced some US companies to consider ways to reduce their potential exposure to the US export control system by locating more facilities, for R&D and production, outside the US. This will be a lengthy process, however.

Ultimately, these actions, coupled with other moves to exclude Chinese companies from other layers of the global technology "stack," could hasten the bifurcation of the technology industry into separate "red" and "blue" supply chains making products destined for China and the US, respectively.

On the other hand, US actions against Chinese semiconductor firms are likely to increase as officials in Washington respond to industry complaints that the massive state subsidies available to Chinese semiconductor manufacturers from the nearly $200 billion national IC fund and its regional and local affiliates will eventually distort global supply chains in the highly market-driven semiconductor sector. This will create new barriers for the flow of US or other third-country technology into China that uses US IP. Last year, the Commerce Department slapped the entity list designation on Fujian Jinhua for this reason.

Future US actions targeting China in semiconductors could include adding domestic foundry leader SMIC and memory producers Changxin and Yangtze Memory Technologies to the entity list, under an expanded US definition of "military end use." This would further undercut the revenue of US semiconductor manufacturing equipment (SME) companies that supply Chinese manufacturers, sapping the funds available to be reinvested into the R&D necessary to develop subsequent generations of semiconductors and related manufacturing equipment (please see box) while throwing up significant new barriers to China's semiconductor development. Although ramped up purchases by the US military could offset some of the pressure on US semiconductor companies that sell to these Chinese companies, military customers do not typically acquire semiconductors at the same rate and volume as commercial players. China would likely view any US move to cut off the supply of advanced technology to its semiconductor champions as a material escalation in the US-China technology conflict.

New US semiconductor industrial policy coming into focus: Build it and others will come

Amid this increasingly complex technology and geopolitical backdrop, TSMC's decision to build an advanced manufacturing facility in the US is of major importance, both for the US administration and for the industry. While TSMC so far has only outlined plans to begin production at 5 nm by 2024, at which point the 5-nm process node will no longer be the global cutting edge, the company intends to transition to more advanced manufacturing at the Arizona facility over time.

The US government's attempts to entice TSMC into building a US fab are part of a broader US strategy around economic security, one pillar of which seeks to create a package of financial incentives to encourage reshoring of advanced manufacturing by both US and foreign firms. TSMC will be the first beneficiary of this approach, with other US and global technology leaders likely to follow.

Although questions remain about the ultimate level and timing of federal funding for the initiative, Intel's recent difficulties surmounting challenges at 7 nm have heightened the urgency around this issue. Mounting US-China tensions and an interest among lawmakers in spurring reshoring of advanced technology manufacturing back to the US have driven a sea change in Washington regarding the federal government's willingness to engage in industrial policy—not just in semiconductors but also in 5G and potentially other technologies that have emerged at the center of US-China strategic competition.

There is some precedent for a US proactive industrial policy aimed at advanced semiconductors. In the late 1980s, the government, working with 14 US-based semiconductor manufacturers, formed Sematech, a nonprofit consortium focused on advanced chip design and manufacturing R&D. The initiative was a response to concerns that Japan was surpassing the US in advanced semiconductors and played a role in helping the US industry solve certain manufacturing problems. Government funding for Sematech lapsed in the mid-1990s following a recovery in the US semiconductor industry, though the consortium continues to contribute to global semiconductor R&D.

Still, the competitive landscape and financial demands of advanced semiconductor manufacturing have changed considerably since the 1980s, and the economics of advanced semiconductor manufacturing in the single-digit-nanometer era will require the collaboration of a critical mass of industry leaders. Top US firms are in discussions about a new framework, which will include the US government working with an industry consortium. This would be an entirely new approach and could involve a joint venture featuring several sector technology leaders.

A successful effort to establish cutting-edge fabs on US soil would ensure that—as semiconductors become ever more critical to the operation of advanced systems such as 5G telecommunications, AI, and quantum computing—the US becomes a preferred location for multiple 5-nm and below advanced foundries and the relevant supporting ecosystems. **Along with TSMC, Samsung probably has sufficient cash reserves to build fabrication facilities in the US, even without US government subsidies. The main problem is that the commercial rationale for siting these facilities on US soil has been lacking. TSMC's decision to build the Arizona fab suggests that US officials were able to make a strategic case for new investments in US capacity.**

As of summer 2020, financial and policy backing for the broader industry effort, including tax breaks, investment, expedited approvals, and other preferential treatment, was attracting bipartisan support in Congress. Lawmakers are eager to see a more active US industrial policy to counter China and secure supply chains for the US government, including the Department of Defense. While there are still some obstacles, including skepticism from Democrats of corporate subsidies and from Republicans of interference in the free market, there is broad support for bringing federal incentives for developing US cutting-edge manufacturing capability up to the level enjoyed by semiconductor firms in other countries such as Israel and Europe. The main question is not whether the US will roll out new industrial policy support for domestic semiconductor manufacturing, but rather around the overall level and timing of federal funding for the effort. As of early August, a scaled-down version of the Chips For America Act—with a grant package likely totaling as much as $10 billion—was included in the pandemic stimulus package under the HEALS Act, which could be passed by the end of September. Similar provisions were included in amendments to the 2021 National Defense Authorization Act.

The benefits of a new US technology-industrial policy for semiconductors will include not only the construction of cutting-edge fabs, but a more robust semiconductor manufacturing ecosystem as a whole. TSMC, for example, has agreed to bring along critical supply chain companies, conduct R&D in the US, and train hundreds of US engineers in Taiwan to be able to run the new plant. This will result in knowledge transfer and cluster effects that benefit US industry over time.

China's response will heighten risks for Taiwan

Taken in combination, these US moves to restrict China's access to the most advanced process nodes and force TSMC and other global companies to choose between a US ("blue") or a Chinese ("red") supply chain have the potential to be viewed in Beijing as a major strategic threat. **Even partial restrictions on access to TSMC's most advanced manufacturing capabilities could undermine China's domestic economic and technology development strategy**, which is centered on building up capabilities in advanced manufacturing and other digital technologies under policies such as Made in China 2025. It would also dent Beijing's and Chinese tech companies' ambitions to compete in the global marketplace, including through initiatives such as the Digital Silk Road component of the Belt and Road Initiative. Beijing's eventual response will likely include some limited forms of retaliation against US or other Western tech firms operating in China, as well as increased commitment to domestic innovation.

Any forced decoupling of Huawei or other Chinese companies from TSMC also carries the long-term risk of higher geopolitical tensions across the Taiwan Strait. The status quo that governs the strait is partially dependent on economic ties, including the strategically important role that TSMC plays in supplying Huawei and other leading Chinese technology firms with cutting-edge semiconductors. Removing that ballast would push the relationship toward a more unstable place; some Taiwan-based companies have already responded to President Tsai Ing-wen's drive to reshore from the mainland to the island by moving some operations out of China.

Military action over Taiwan regarding the semiconductor issue remains unlikely. Beijing and Washington will both attempt to avoid initiating a course of action that could lead to uncontrolled escalation between the world's two leading military powers. That said, China has other options short of military action that it can use to try to gain leverage, including increased saber rattling, nationalization of TSMC facilities in China, recruitment of key TSMC or Samsung personnel, IP theft, retaliatory actions against US and other Western technology firms operating in China, and greater investment in its domestic technology sector, including leveraging capital markets via the Hong Kong Stock Exchange or the new high-tech STAR market in Shanghai.

US pressure will push China to embrace alternatives to ARM and x86 ASIC architectures, but huge challenges loom

As the technology decoupling process gains momentum, Chinese companies, backed by Beijing, will increasingly pursue alternatives to Western development frameworks that rely to some degree on a US technology nexus. This includes semiconductor design, where a debate has been raging within China over dependence on the Arm architecture and specific key pieces of IP such as cores.

Founded in 1990 as Advanced RISC Machines, Arm creates and licenses designs for semiconductor cores that power modern CPUs, GPUs, mobile systems on a chip (SOCs), telecommunications baseband chips, semiconductors used in high-performance computing, and other modern electronic devices and digital applications. Arm, which originated in the UK as a joint venture among Apple, Acorn Computer, and VLSI Technology, is also 49% owner of a Chinese joint venture, Arm China, that as of 2018 claimed to license chip designs used in 95% of Chinese-designed SOCs. Arm was acquired by Softbank in 2016 for $32 billion, and by this summer had become the subject of fevered takeover speculation, with both US GPU leader NVIDIA and Samsung reported as potential suitors.

In 2019, Arm and its China joint venture, which is 51% owned by a consortium of state-controlled Chinese investors, became caught up in the US campaign against Huawei. Shortly after the US entity list action targeted the telecom gear maker in May 2019, the UK-based parent company of Arm instructed its employees to halt cooperation with Huawei, citing US-origin technology contained in its chip designs. Nearly all Chinese-designed semiconductors, including chips that power Huawei's base stations, servers, and smartphones, use Arm designs. The company subsequently resumed cooperation with Huawei (and HiSilicon) after concluding that it could supply the Chinese company designs for its Armv8-A instruction set architecture and subsequent generations of the technology used in Huawei's Kirin line of mobile SOCs and other products using UK, but not US, IP.

More recently, the Arm Chinese joint venture has become the subject of a power struggle between its investors and its Chinese CEO, in which 200 employees took the extraordinary step of calling on Beijing to intervene to "protect" what they dubbed a "strategic asset" and a "Chinese-controlled joint venture that should abide by the Chinese laws and fulfill the social responsibility in China." US officials suspect the goal of Chinese—likely government-backed—investors buying into the China ARM unit is to eventually make it an independent operating unit that remains untouchable by US export control laws and help fuel China's independent semiconductor industry development.

Uncertainty about the venture's future and its access to technologies that include substantial amounts of US IP, meanwhile, has spurred China's interest in alternatives to Arm's proprietary chip architecture, including the open-source RISC-V community.

Illustrating how US pressure on China over semiconductors is increasingly disrupting the industry, the Delaware-incorporated RISC-V Foundation, which includes more than 325 members and drives the development and adoption of an open-source instruction set architecture for microprocessors, opted to relocate to Switzerland last year to minimize future uncertainty and the potential for disruption to the group's open collaboration approach from the US export control system.

Although the move sparked concern among some US lawmakers, RISC-V is an open source architecture that has been available to Chinese players for some time. It remains unclear whether US officials could exert control over the foundation, even though some of the initial funding for development of the architecture came from the Defense Advanced Research Projects Agency.

Looking ahead

Although serious market challenges remain, the new US industrial policy on semiconductors taking shape will be in place well beyond November's election. Democratic challenger Joe Biden will almost certainly support the effort to attract more cutting-edge fabs to the US if he wins the presidency, while also maintaining a tough approach on Huawei. At the same time, he would continue to promote broader US technology policy initiatives, likely to include 5G, AI, and quantum computing.

Beijing's eventual reaction to US pressure may complicate US efforts to build trusted semiconductor supply chains in multiple ways. A strong reaction from Beijing that seeks to punish Taiwan or TSMC would roil markets, provide added impetus to US attempts to bring advanced semiconductor manufacturing to US shores, and throw industry supply chains into turmoil, accelerating the bifurcation of the US and Chinese tech ecosystems.

Although this could occur swiftly in many aspects of US-China economic integration—such as the internet, electric vehicles, and 5G decoupling in the technology underpinning all of these—vast changes to the semiconductor sector would be more difficult and painful. Constraints on capital, personnel, and technology will limit the potential emergence of two wholly separate systems. But the process is likely to be messy and costly, creating new risks for the $5 trillion ICT industry and market participants throughout 2020 and beyond.

For leading technology firms in China such as Huawei, which are used to easy access to advanced manufacturing in Taiwan or elsewhere, the search is on for an alternative semiconductor manufacturing ecosystem. Beijing will be there to help, with the National IC Investment Fund, preferential policies for the industry including new ones released in August, and an expedited listing process for semiconductor firms on the new high-tech STAR market in Shanghai.

Yet major challenges will persist for some time given constraints such as a shortage of domestic talent, lack of experience with cutting-edge manufacturing technologies, and the steady advance of the global cutting edge. A slowdown of Moore's Law and a stretched-out industry roadmap below 3 nm, coupled with the sky-high costs of building and operating a cutting-edge fab, will mean that the pace of growth in the gap between Chinese domestic players and global industry leaders will likely slow in the coming years, improving prospects for Chinese companies to move faster up the curve. Huawei's deep pockets, industry experience, management system, and entrepreneurial attitude will also enable progress in some areas. Other efforts will be aimed at devising system-level solutions with less advanced semiconductors that are "good enough" for some applications.

China's advantages in this competition, including its STEM education system, dedicated industrial ministries, funding mechanisms, and market size will eventually produce breakthroughs, but the US will continue to hold key advantages and harbor a willingness to use punitive measures. If the US decides to further restrict semiconductor manufacturing equipment exports to China in addition to other measures such as the foreign direct product rule, China's timeline for achieving greater self-sufficiency will be pushed further out.

In any case, the global semiconductor industry will be in for a prolonged period of adjustment as the US-China-Taiwan triangle moves toward a new and hopefully more stable equilibrium.