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JUNE 2021

China's microchip ambitions:

Semiconductors advance the next phase of techno-nationalism

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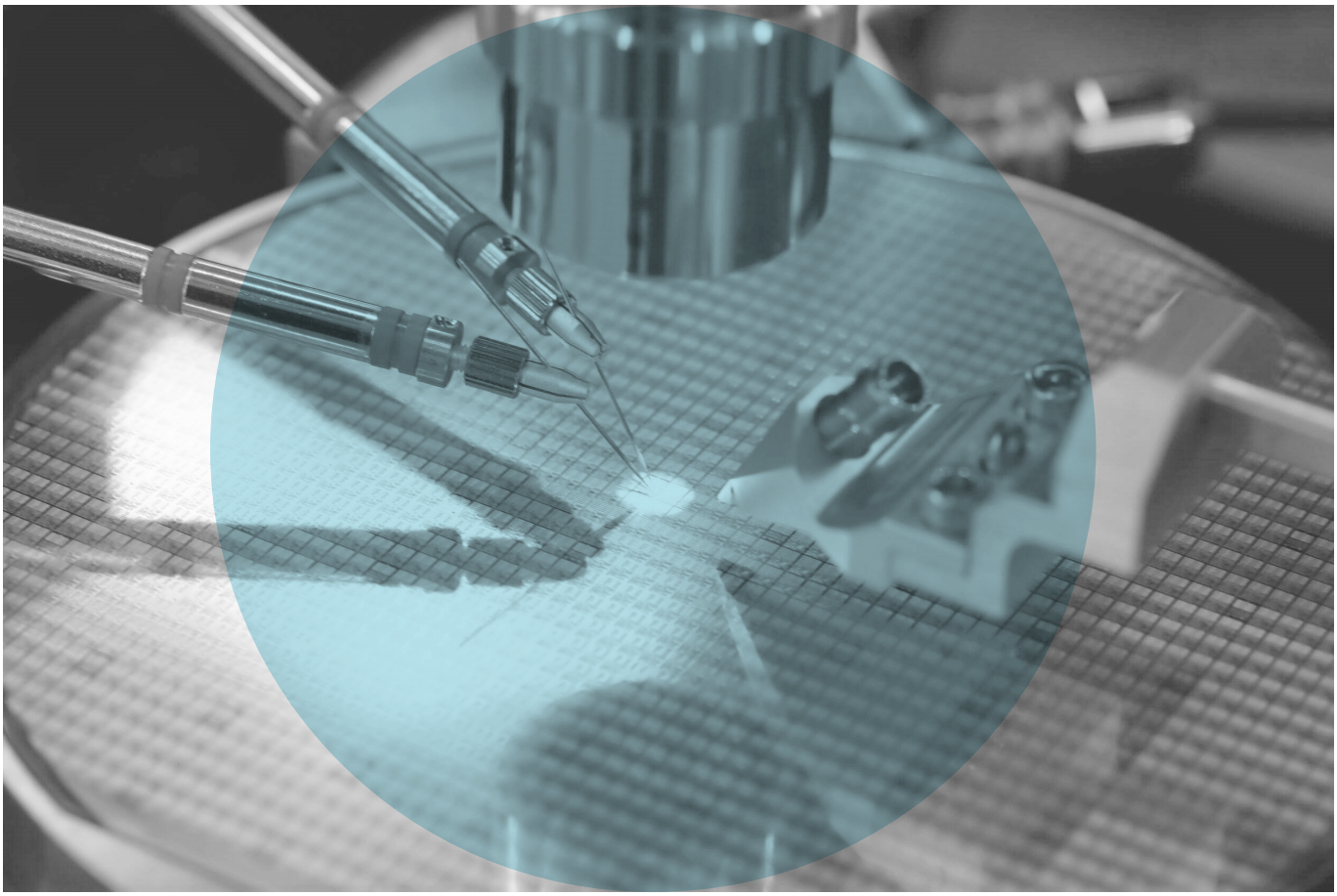


Contents

Introduction

A global chip shortage

Comprising the 'brains' for everything, from AI to machine learning and the internet of things (IoT), semiconductors represent the world's most essential and coveted technology. Almost every industry of the future – from fintech to cleantech and even quantum computing – depends on semiconductors.

Lockdowns and remote work in 2020 and 2021 have led to skyrocketing demand for microchips – the popular term for semiconductors.

Geopolitics also play a key role. Fear of new US export controls on American semiconductor technology drove Chinese tech companies to stockpile advanced chips. The chip shortage grew worse.[1]

An unbalanced landscape

The increased attention on semiconductors brought stark realities into the light. First, semiconductor manufacturing is disproportionately concentrated in Asia, especially in Taiwan. Single-source supply chains are fragile and highly vulnerable.

Second, China's tensions with the US and its allies is accelerating strategic decoupling, reshoring, and ringfencing throughout the semiconductor landscape. This runs against the grain of decades of relatively unrestrained flows of goods and services across borders. Semiconductor value chains have benefitted from geographic specialization and rationalized production networks.

Beyond geopolitical pressures, supply chains will face increased pressure to localize to meet goals of low-carbon environmental sustainability.

The emergence of techno-nationalism

This Part 3 of the series will focus on the actions China has taken to catch up to US tech firepower.

This study is Part 3 of a Hinrich Foundation series that began with the comprehensive primer *Semiconductors at the heart of a US-China tech-war* in January 2020. This Part 3 of the series will focus on the actions China has taken to catch up to US tech firepower.

As with Part 1 and Part 2, this report also revisits the concept of 'techno-nationalism' – the neo-mercantilist mindset that links a nation-state's technology prowess with its national security, economic prosperity, and socio-political stability.

Four key themes

The four themes of previous reports – **strategic decoupling**, **tech alliances**, **innovation mercantilism**, and the **In-China-For-China strategy question** – are also visited in this report. Export controls and restricted entity lists continue to be weaponized in semiconductor supply chains. Tech alliances continue to affect reshoring and diversification of global value chains.

The above developments have spurred massive spending campaigns to incentivize research & development (R&D) and production ecosystems, such as China's US$1.4 trillion digital infrastructure plan. Lastly, China's insatiable demand for semiconductors will continue to benefit American companies.

"Made in China 2025" is a 10-year national strategic plan announced by Chinese Premier Li Keqiang in May 2015. The plan aims to upgrade China's manufacutring capabilities with its semiconductor industry at the core.

Strategic decoupling, reshoring & ringfencing of semiconductors

Efforts by the US and China to decouple semiconductor supply chains, which began accelerating in January 2020, typifies behavior of early-stage techno-nationalism. In this stage, governments look to weaponize their supply chain strengths and attack their opponent's vulnerabilities. It is also a time to hedge against strategic vulnerabilities.

Expanding the Restricted Entity List

US efforts to decouple have been significant. As explained in Part 2 of the semiconductor series, a key action took place in August 2020. A revised rule determined that the use of any US software or technology in microchip production, anywhere in the world and by any producer, makes the finished item a direct product of the US. As such, any company on a restricted entity list would be effectively cut off.

The 'foreign direct produce rule' led to more chip shortages. Huawei has been on the receiving end of a US offensive for almost two years. What began as an initiative to prevent Huawei from expanding its 5G global footprint[2] morphed into a campaign to persuade other governments to remove Huawei technology entirely from their networks.[3]

Blocked from obtaining microchips from its prime chip subcontractor Taiwan Semiconductor Manufacturing Company (TSMC), Huawei turned to stockpiling. Between May 2020 and September 2020[4], Huawei's management pressed TSMC to ramp up production for an additional 2 million units of 7-nanometer chips, which were critical for Huawei's 5G network base stations.[5]

Many large Chinese technology companies have built their product offerings by relying on US semiconductors and related technologies.

The actions against Huawei revealed the criticality of US technology throughout semiconductor value chains – and across China's tech companies. Many large Chinese technology companies have built their product offerings by relying on US semiconductors and related technologies. The companies include iconic Chinese brands SMIC (China's leading chip manufacturer), HikVision (surveillance, facial recognition), SenseTime (AI), DJI (commercial drones), Dahua (surveillance, CCTV), and Alibaba (Cloud, e-commerce, fintech).

The fencing around semiconductors expanded. In 2020, the number of Chinese entities added to the Bureau of Industry and Security (BIS) restricted entity list doubled to 108, including the companies listed above.[6] Any item that is 'uniquely required' by a restricted entity to produce a chip of 10-nanometers or below would be subject to a 'presumption of denial'. Even for chips above 10-nanometers, sales to restricted entities are considered on a case-by-case basis.

In April 2021, six of China's preeminent supercomputing centers were added to the BIS restricted entity list. The most notable addition: the Shanghai High-Performance Integrated Circuit Design Center. [7]

The de-Americanization of China's supply chains

Given developments in the US, Beijing had little choice but to double down on efforts to de-Americanize its supply chains. The Chinese Communist Party announced its plan for 'dual-circulation', which calls for greater self-reliance on domestic innovation, production, and consumption in key sectors, while de-emphasizing China's long-running export-driven economic model as its primary engine for growth.[8] The plan is part of China's 14th 5-Year Plan, which runs from 2021 to 2025.[9]

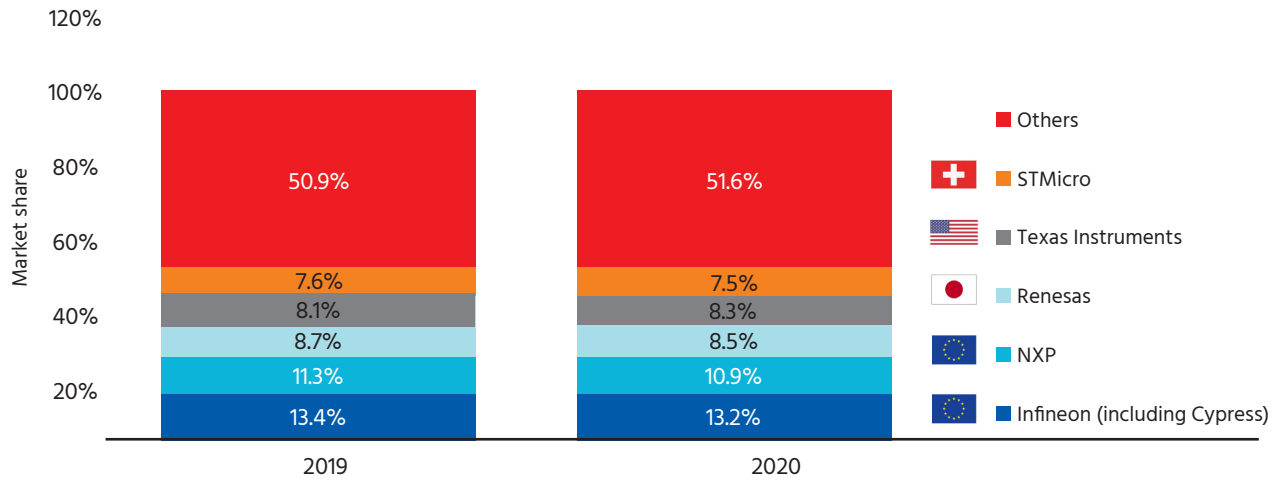
In the plan, funding for semiconductor self-reliance is a top priority. Whether China will successfully build a home-grown semiconductor ecosystem in the near term is unlikely. However, the country is making progress in some areas, such as manufacturing memory chips.

Chinese Vice-Premier Liu He has been appointed by President Xi Jinping to lead the country's push to acheive self-sufficiency in advanced semiconductors production. Liu has been the chief negotiator in the US-China trade talks.

Source: Bloomberg. 2021. "Xi Jinping picks top lieutenant to lead China's chip battle against US". https://www.bloomberg.com/news/articles/2021-06-17/xi-taps-top-lieutenant-to-lead-china-s-chip-battle-against-u-s

A future of electric vehicles

Figure 1 – Automotive semiconductor manufacturers market share worldwide in 2019 and 2020



Source: Statista 2021

China is currently the world's largest market for electric vehicles, with potential for massive growth. Beijing has strategically mandated EV sales to account for 40% of new vehicle sales by 2030.[10] Scaling of manufacturing operations in China will shift the advantage to Chinese automakers domestically and globally, if value chains remain concentrated in the country.

Increasing demand for EVs has enormous implications for the semiconductor industry. As EVs become increasingly connected to Internet of Things (IoT) and smart city environments, they require more advanced AI systems. That will prompt more partnerships between semiconductor firms and the automotive sector. In May 2021, Tesla announced a new collaboration with Samsung to supply the EV company with 5-nanometer chips.[11]

Huawei has also shifted emphasis on the production of chips for the EV sector in China, partly because the automotive sector requires less advanced chips on the market. Consequently, Huawei will not be constrained by export controls. In May 2021, Huawei announced a "smart-car" partnership with Chinese EV maker Changan.[12]

Meanwhile, Intel is in discussions with the European Union to supply microchips to European EV manufacturers. Similar to the US, the EU is keen to mitigate the risks of over-reliance on fragile supply chains. During the preparation of this report, Intel was conferring with EU representatives to secure US$10 billion in subsidies to build a 'Eurofab', primarily to supply the local automotive sector.[13]

As EVs become more technologically sophisticated, automotive value chains will be pulled into the semiconductor arena. Consequently, electric vehicles are set to feature prominently in the conversation on techno-nationalism.

Innovation mercantilism

The trends that defined the semiconductor landscape in 2020 are accelerating, leading to more pressure on China to address its semiconductor dilemma.

China imported close to US$380 billion in semiconductor related technology in 2020.

Semiconductors continue to be China's top import, exceeding oil imports. China imported close to US$380 billion in semiconductor related technology in 2020.[14] Some of the increased demand is attributable to the stockpiling prompted by fear of more US restrictions on microchips. In March 2021 alone, China imported 58.9 billion semiconductor units worth US$35.9 billion.[15]

Nascent Chinese firms aiming for the domestic market are seizing the opportunities. As of May 2021, a quarter of companies listed on Shanghai's STAR market – the equivalent to the Nasdaq – are semiconductor related.

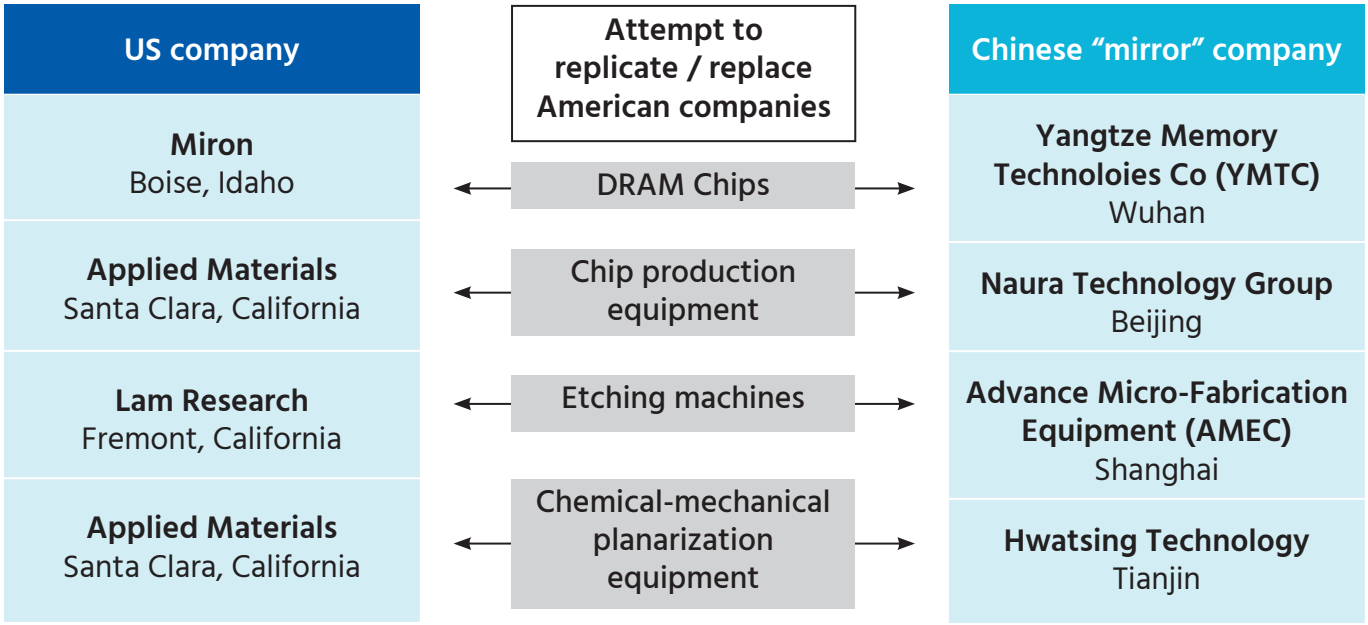
Yet, chip manufacturing capacity by Chinese firms remains disproportionately low compared to domestic demand. In 2020, China accounted for more than 50% of global demand. However, Chinese chip manufacturers accounted for only 6%

Figure 2 – Investments in memory chip fabrication in China (US$ bn)

Company	HQ	Segment	Node(nm) K	Wafers/ month	US$ bn	Production	Location	Investors
YMTC	China	3D NAND	30	200	24	2018	Wuhan	Wuhan govt, Unigroup, SMIC
Hujian Jin	China	DRAM	32	60	24	2018	Fujian	Fujian govt
Tsinghua	China	NAND/ DRAM	TBD	100	30	2018	Nanjing	Nanjing govt
Giga Devi	China	DRAM	TBD	TBD	TBD	2018	Hefei	Hefei govt
Intel	US	3D NAND	30	30	5.5	2016	Dalian	Dalian govt
SK Hynix	S. Korea	DRAM	20	130	5.5 + 800 m expan-sion	2005	Wuxi	N/A
Samsung	S. Korea	3D NAND	30	100	7.5 + 7.0 expansion	2014	Xian	N/A

Source: https://www.sciencedirect.com/science/article/pii/S0308596120300513?via%3Dihub#bib6

Figure 3 – Chinese state-backed "mirrors" of US companies



Source: https://asia.nikkei.com/Spotlight/The-Big-Story/US-China-tech-war-Beijing-s-secret-chipmaking-champions

of domestic sales in China. Foreign-based companies, many of them American, continue to dominate and account for 95% of sales.[16]

There has been very little measurable progress in China's efforts towards self-sufficiency. Beijing hopes to achieve 70% percent self-sufficiency in semiconductors by 2025, as stipulated in the Made in China 2025 plan. Realistically, however, that goal may be decades away.

State and non-state actors in the US maintain iron-clad control over critical 'choke points' along semiconductor value chains.

State and non-state actors in the US maintain iron-clad control over critical 'choke points' along semiconductor value chains – providing the US government with overwhelming geopolitical leverage. US firms such as Ansys, Cadence Design, Synopsis, Nvidia, and Qualcomm own and control vital design tools, IP, and software at the front-end of value chains. Applied Materials, LAM Research, and KLA-Tencor dominate the manufacturing equipment needed to mass produce leading-edge semiconductors.[17]

Beijing aims to reverse-engineer and replicate each niche within an end-to-end semiconductor value chain.

To be fair, China is not standing still. It has unleashed a torrent of new funding and doubled down on efforts to accelerate self-reliance initiatives. Beijing aims to reverse-engineer and replicate each niche within an end-to-end semiconductor value chain. Central planners have designated 'shadow' or 'mirror' Chinese companies for foreign companies currently operating in equivalent niches.[18]

State support is increasing too. China's 14th 5-Year Plan features an annual increase in R&D spending of 7% per year for specifically targeted strategic technologies, such as next-generation semiconductors, AI, and quantum computing.[19] That support followed President Xi Jinping's proposal in 2020 of US$1.4 trillion of Chinese investment on digital infrastructure and technology in coming years. Older initiatives to develop semiconductors are also expected

to receive new infusions of capital. These include the US$150 billion National Integrated Circuit Industry Investment Fund and the Tsinghua Holdings Tech Investment Fund.

CASE STUDY

TSMC: Nanjing Investment

Recent events demonstrate that TSMC is bending to the will of Washington more than it has been obliging Beijing.

Taiwan-based TSMC is perhaps the world's most important semiconductor fabrication company. Recent events demonstrate that TSMC is bending to the will of Washington more than it has been obliging Beijing.

Consider its recent decisions. When it committed US$2.87 billion to expand its fab in Nanjing[20], it chose to focus on chips of 28-nanometers, which is 2 or 3 generation-old technology.

Conversely, its mega-project in Arizona in the US plans multiple fabs and will, over the long-term, produce 3-nanometer or even 2-nanometer chips – the absolute leading edge in chip innovation.

Similarly, when the Trump administration modified the foreign direct product rule in 2020, TSMC immediately pulled the plug on further orders from Huawei's HiSilicon and stopped shipping restricted microchips a few months later.

Such responses continue under the Biden administration. TSMC has suspended orders for Tianjin Phytium Information Technology and six other Chinese supercomputer entities that are now blacklisted.[21] This underscores the extent to which the world's semiconductor companies still rely upon US technology – even TSMC, with its best-in-class production capabilities. More broadly, Washington's historical geopolitical relationship with Taipei gives the US considerable sway.

Concerns about Beijing's increasingly hard line have stoked fears about IP theft. Although older 28-nanometer technology was not subject to export controls, for example, TSMC's investment in Nanjing sparked debate in Taipei. Political sentiment continues to gravitate toward ratcheting up restrictions under Taiwan's Commercial Secrets Act, a law that aims to protect national security by preventing the loss of strategic intellectual property and technology.[22]

Hence TSMC ringfences its most advanced IP and processes in Taiwan. This solution looks to be risky over the long term. With other players with significant R&D and production know-how exiting China, TSMC will face more pressure to diversify production locations.

Issuing new government decrees or spending initiatives, however, does not guarantee success for Beijing's semiconductor plans. Although their ranks are growing, Chinese semiconductor firms trail considerably behind leading foreign firms in producing beyond the 12-nanometer chip manufacturing threshold.

Unequal challenges

Both the US and China share the same objective: They want to localize semiconductor manufacturing. But each country faces entirely different challenges with very different degrees of difficulty. Beijing must continue to play a lop-sided game of catch-up. Washington's task is arguably easier. Nearly all its intended corporate partners are American or from countries with strong historic ties to the US.

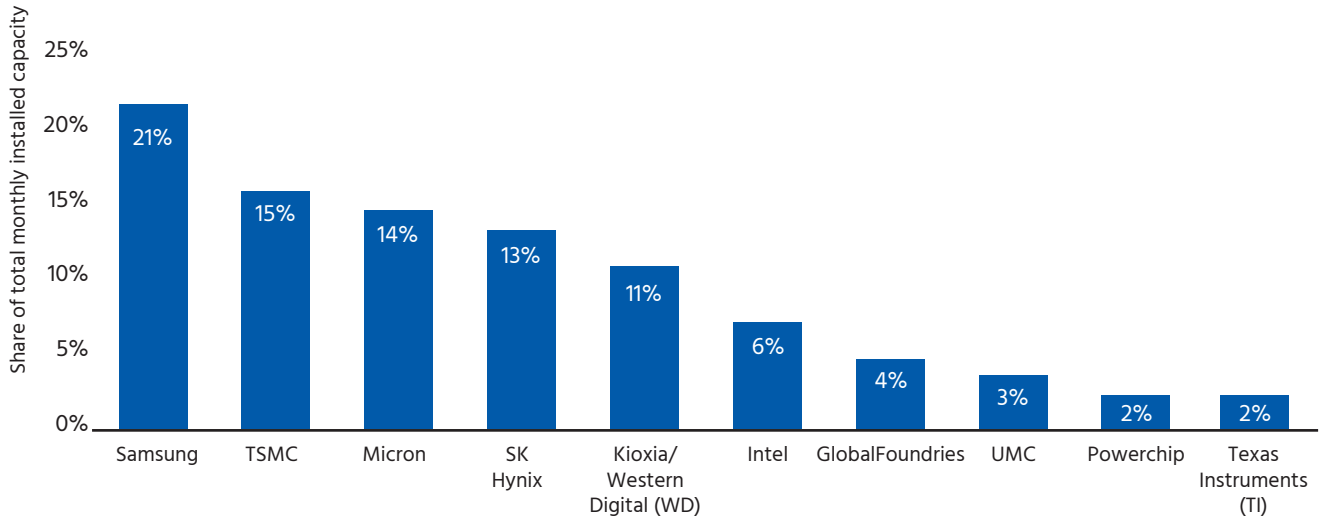
Beijing faces barriers to entry that go beyond financial investments or gaps in expertise. They involve the near-impossible task of leveraging decades of thought, trial and error, and incremental advances in hyper-niche technologies.

Beijing faces barriers to entry that go beyond financial investments or gaps in expertise. They involve the near-impossible task of leveraging decades of thought, trial and error, and incremental advances in hyper-niche technologies by market leaders such as Samsung, Intel, and TSMC.

The challenges are discouraging. A recent report authored by the Boston Consulting Group and SIA detailed more than 50 types of highly sophisticated and specialized equipment involved in the semiconductor wafer production process. This involves oxidation and coating, lithography, etching, doping and metal disposition. The process also includes the use of more than 150 specialized materials.[23]

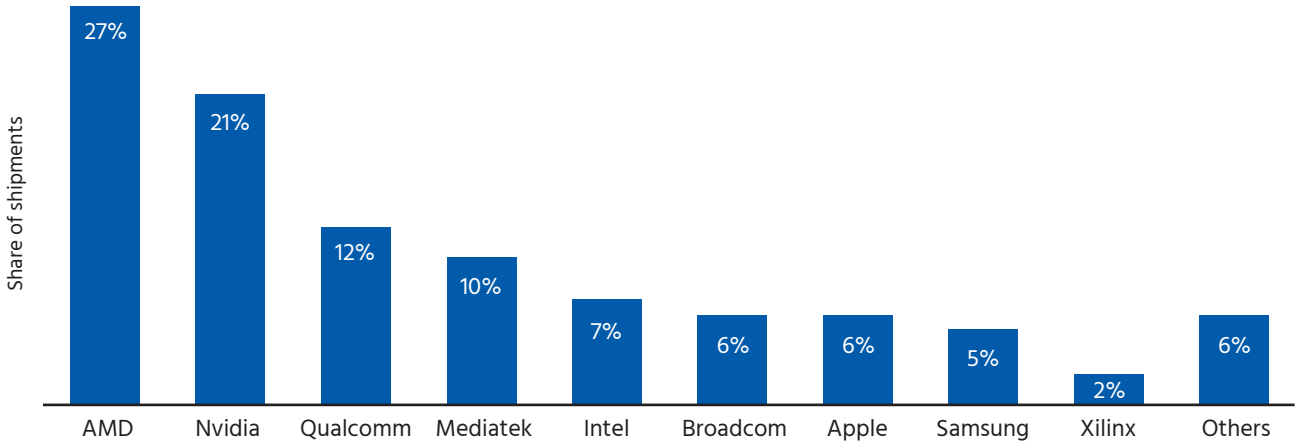
Indeed, producing a 5-nanometer chip is a miracle of science. The degree of technical prowess it takes to produce a 5-nanometer chip in commercial quantities, at scale, with virtually no margin for error, represents a zenith in human achievement.

Figure 4 – Leading semiconductor foundries' share of 300mm wafer capacity worldwide as of December 2020



Source: Statista 2021

Figure 5 – Distribution of 7-nanometer wafer shipments worldwide in 2021, by IP owners



Source: Statista 2021

Consider the nanometer. One nanometer equals one billionth of a meter. A state-of-the-art 5-nanometer chip node has silicon densities of between 130 million to 230 million transistors per square millimeter. A 3-nanometer or even 2-nanometer chip increases the technological achievement by orders of magnitude and exponential improvements in capability.

The likes of TSMC, Intel, Samsung, ASML, and Applied Materials are racing with each other to produce new innovations. Meanwhile, Chinese firms are still struggling to become self-reliant in the production of older generation technologies.

China's fabs have made progress is one important area: the mass production of state-of-the-art flash-memory chips.

China's fabs have made progress is one important area: the mass production of state-of-the-art flash-memory chips.[24] The first semiconductor report highlighted Yangtze Memory Technology Company (YMTC) and the market impact of a state-backed firm once it produces high quality chips. YMTC continues to ramp up production capacity and can now significantly underprice its competitors.

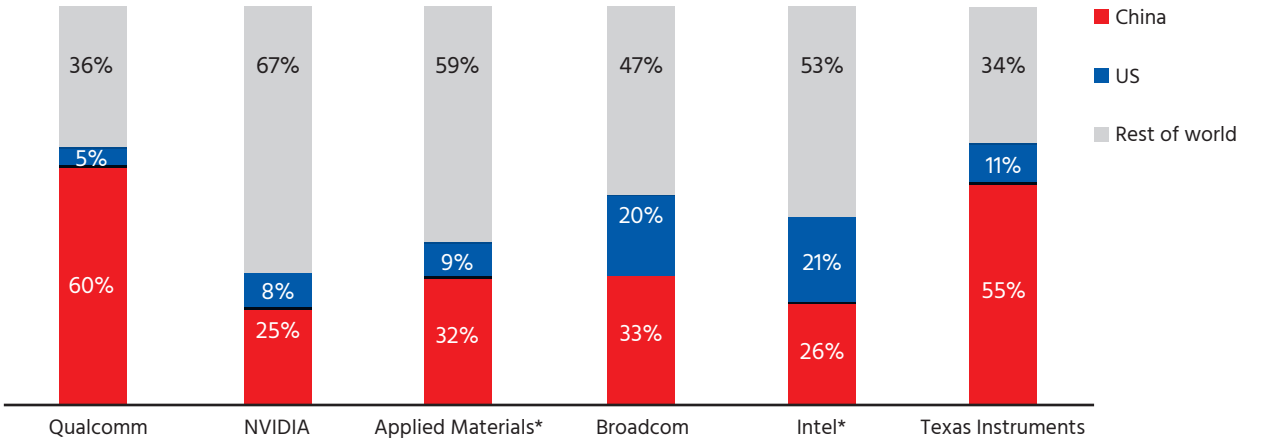
In October 2020, Intel, the world's largest maker of NAND Flash memory chips, sold its Dalian fab to SK Hynix of South Korea, presumably with the knowledge that foreign companies will soon be facing a glut of memory chips in the China market.[25]

China will continue leveraging US and foreign companies with large market share in China.

For Beijing's semiconductor agenda to move forward, companies like YMTC must avoid the fate of Huawei, which was effectively crippled after being placed on the restricted entity list. China will continue leveraging US and foreign companies with large market share in China and hope that, out of self-interest, they will lobby their respective governments to refrain from more restrictions.

Turning to professional lobbyists, lawyers and public relations firms may be Beijing's best option to buy time in the short term to mid-term. However, this strategy could create more reputational and legal challenges for US and foreign companies navigating the In-China-For-China situation.

Figure 6 – Percentage revenue (2020) of selected US semiconductor companies, by region



Source: Statista, Texas Instruments Annual Report 2020

*Net revenues

The In-China-For-China conundrum and the road ahead

The basic conundrum facing foreign semiconductor companies in China is a Faustian bargain.

China's ambitions pose further challenges. Any sector that depends on semiconductors will have to adopt an 'In-China-For-China' supply chain and operations strategy which must reflect Beijing's goals of self-reliance and the challenges posed by local competitors.

The basic conundrum facing foreign semiconductor companies in China is a Faustian bargain. As China aims to achieve self-reliance, it is actively working to supplant foreign players with home-grown national champions. As such, foreign companies operate with the knowledge that, in exchange for access to the world's largest semiconductor market, they could eventually cede way to a local player.

If these companies can maintain a commanding innovation lead in their field and ringfence their most precious IP and processes outside of China, they can survive the Faustian bargain. This outcome requires defending market share in China by staying ahead of the local Chinese competition and introducing the next generation of products when local competitors begin to catch up.

This strategy continues to retain its efficacy. The decision by TSMC's Nanjing fab to produce more 28-nanometer chips for China's expanding electronic vehicle sector is a case in point. US firms such as Qualcomm, Intel, and Nvdia are also following this same logic as they partner with local Chinese entities to manufacture older generation 28, 14, and 10 nanometer chips.

American chip manufacturers currently enjoy brisk sales to Chinese firms in these trailing-edge nodes and are living in fear of new US government restrictions.

But as state-backed companies like YMTC close the gap in various niches, the US semiconductor sector finds itself agitating for increased support from Washington. This brings the discussion to the second part of the China conundrum: the proverbial horse race.

Should the US semiconductor sector ask Washington to help it run faster or should it also ask the government to try to slow down its opponents?

Recent developments show a clear preference to help the industry run much faster.

Recent developments show a clear preference to help the industry run much faster. Support for the CHIPS for America Act confirms the US industry needs more funding for R&D, education, and building manufacturing capacity. But tripping up an opponent through export controls inflicts collateral damage on US firms by cutting off market share and handing opportunities to nascent Chinese companies.

In this regard, US industry has remained consistent in its message. After acknowledging governments' role in shaping semiconductor value chains, CEO of the Semiconductor Industry Association John Neuffer said: "In the short term,

government should refrain from intervening as industry works to correct the current supply-demand imbalance causing the (chip) shortage."

In practice, however, Washington's strategy will focus on both slowing down China while making its own horse run faster. While this adds to increasing tensions between markets and states, it is inevitable.

As the US-China tech cold war moves into the next phases, the urge to diversify, decouple, and reshore strategic supply chains intensifies.

Taiwan and the silicon shield myth

Taiwan's emergence as the world's semiconductor hotbed has highlighted the vulnerability of global value chains and the need for diversification.

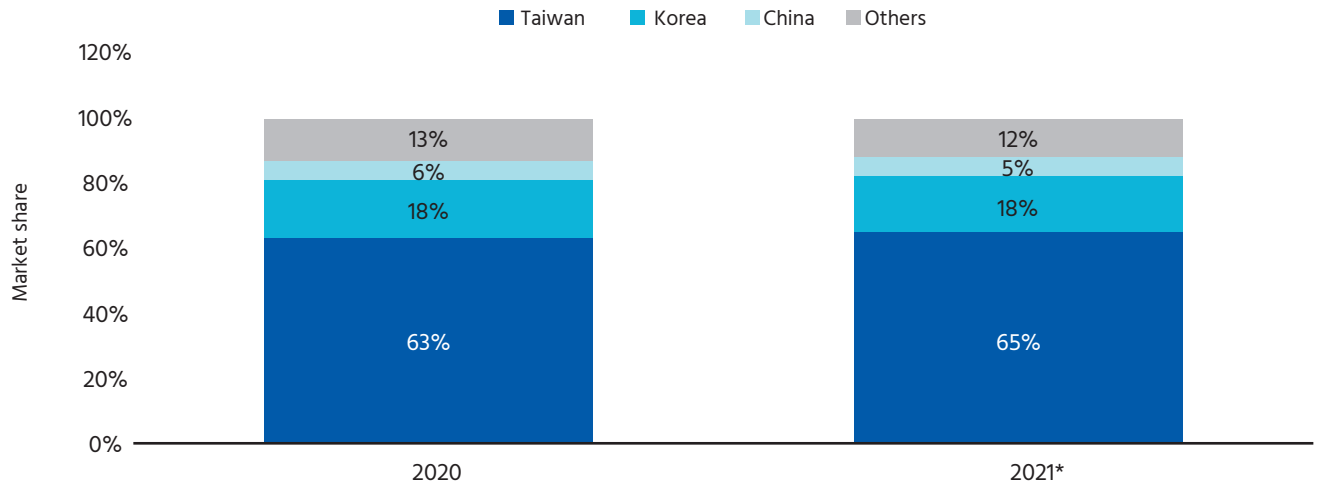
Taiwanese subcontractors account for more than 60% of global chip manufacturing.[26] Taiwan's emergence as the world's semiconductor hotbed has highlighted the vulnerability of global value chains and the need for diversification.

As US-China tensions drive more Taiwanese and foreign companies to move operations out of China and into Taiwan, an interruption to this supply chain would be catastrophic. It could match the scale of disruption caused by the 2011 Fukushima earthquake that shut down critical semiconductor and automotive supply chains for months.

Three factors in particular draw attention to the present dilemma: geopolitics, pandemics and, most recently, climate change.

Since early 2020, cross-straits tensions between Beijing and Taipei have seen the most significant escalation in decades. Observers speculate that Taiwan is protected by a so-called 'silicon shield'. Because the US, China, and the world rely upon the island as an indispensable resource, they will refrain from taking

Figure 7 – Semiconductor foundries revenue share worldwide in 2020 and 2021



Source: Statista 2021

action to disrupt or upend the status quo – for fear that it would backfire. While intriguing, the idea amounts to a false assumption. Geopolitical forces could easily have unintended consequences and upend Taiwan's semiconductor superpower status.

As President Xi Jinping enters his third term, speculation mounts about his ambitions. Is he looking to cement his legacy by pushing for reunification with Taiwan, as the nation prepares for the next Chinese Communist Party Congress in 2022 and the centenary of the People's Liberation Army in 2027?[27] Even if this does not occur, other factors require diversification of the world's semiconductor manufacturing capacity.

The pandemic has exposed other supply chain risks. In May 2021, rising infections led to stay-home orders and subsequent heavy demand on local power grids, which caused blackouts. A higher surge in infections could lead to labor shortages.

Concentrating so much of the world's manufacturing on a small island vulnerable to climate change is irresponsible.

Meanwhile, a prolonged drought has reduced Taiwan's water supply. Semiconductor production consumes large amounts of water. Concentrating so much of the world's manufacturing on a small island vulnerable to climate change is irresponsible. There will be more pressure in the future to concentrate production within local markets to meet sustainability goals.

Conclusion

This third report in the Hinrich Foundation semiconductor series has served to provide updates and analysis of recent techno-nationalism in the semiconductor sector, with a focus on China's ambitions. Key findings and observations include:

- Both Beijing and Washington are investing historical amounts of funding into their respective semiconductor sectors, with the aim of achieving self-sufficiency. New funding is oriented toward accelerating innovation and manufacturing capabilities.

- Despite making advances in trailing-edge memory chip production, China remains highly dependent on US semiconductor technology. Beijing's plans to create manufacturing capacity in leading-edge chips are lagging farther behind, particularly as China becomes more geopolitically isolated from the US and its historic allies – all of them key semiconductor players.

- In contrast to the US, investment in China by foreign firms in semiconductor fabrication has been relegated to second or third generation technology.

- China's growing capability to manufacture memory chips has seen the rise of companies like YMTC, which has benefited from China's massive state-funding efforts. This will likely result in an oversupply of NAND and similar memory chips in the future.

- China continues to represent the largest source of sales revenue for many American and foreign semiconductor companies. Continued access to this market has further complicated the "In-China-for-China" conundrum. As

Beijing doubles down on the promotion of its own national champions, American semiconductor companies must obtain increased funding to maintain their lead in the race.

- The shifting of more and more high-end chip manufacturing into Taiwan is convenient but dangerous in the long-term, given the geopolitical and sustainability issues confronting sole-sourced supply chain scenarios from Taiwan. This will accelerate diversification and reshoring of semiconductor supply chains.

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Other reports written by Hinrich Foundation Research Fellow Alex Capri include:

- *Semiconductors at the heart of the US-China tech war*
- *Strategic US-China decoupling in the tech sector*
- *Techno-nationalism and the US-China tech innovation race*
- *Techno-nationalism and diplomacy*
- *Techno-nationalism and corporate governance*
- *India: A 21st century technology hub?*
- *Techno-nationalism via semiconductors: Can chip manufacturing return to America?*

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Alex Capri is a research fellow at the Hinrich Foundation and a senior fellow and lecturer in the Business School at the National University of Singapore.

He is the author of *Techno-Nationalism: How it's reshaping trade, geopolitics, and society* (Wiley), due out in 2021.

From 2007-2012, Alex was the Partner and Regional Leader of KPMG's International Trade & Customs Practice in Asia Pacific, based in Hong Kong. Alex has over 20 years of experience in global value chains, business and international trade – both as an academic and a professional consultant.

He advises governments and businesses on matters involving trade and global value chains. Areas of focus include: IT solutions for traceable supply chains, sanctions, export controls, FTAs and trade optimization.

Alex has been a panelist and workshop leader for the World Economic Forum. He writes a column for Forbes Asia, Nikkei Asia and other publications and is a frequent guest on global television and radio networks.

He holds a MSc from the London School of Economics in International Political Economy and a BSc in International Relations from the University of Southern California.

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Endnotes

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