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Chinese Strategic Posture
The Case of Semiconductors

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Abstract

The study investigates the influence of politics over technology to then deepen the relevance of semiconductors as part of the defence realm in the case of China. To this end, the importance of technology in warfare and the entailed trade-offs are illustrated along with the efforts to regulate the export flow. The theoretical framework focuses on finding local validity rather than a universal one, bridging politics and technology via the time factor. Hence, semiconductors are included in the Chinese defence sector showing the relevance given them by Beijing's plans for military modernisation. An overview of the supply chain allows for a better understanding of the implications stemming from its global structure, underscoring the autarky-efficiency challenges any state needs to address. Consequently, China embodies a favourable case study because of its domestic power structure, modernisation ambitions, and imposed export controls directing its choices. A thorough analysis of policies and procurement means is employed to confirm the securitisation of the technology, gauging domestic prospects, international responses, and hindrances. Finally, two scenarios structure the main drivers into plausible outlooks, sketching development in the short term and suggesting further research avenues.

Keywords

China, Semiconductors, Defence Industry, Technology, Arms Procurement

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Declaration of Authorship

1. The author hereby declares that he compiled this thesis independently, using only the listed resources and literature.

2. The author hereby declares that all the sources and literature used have been properly cited.

3. The author hereby declares that the thesis has not been used to obtain a different or the same degree.

Prague **25/07/2021** **Lorenzo Scarazzato**

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LIST OF ABBREVIATIONS

AI	Artificial Intelligence
ATP	Assembly, Testing and Packaging
CCP	Chinese Communist Party
CFIUS	Committee on Foreign Investment in the United States
COCOM	Coordinating Committee for Multilateral Export Controls
DRAM	Dynamic Random-Access Memory
EFTA	European Free Trade Association
EMS	Equipment Manufacturer Service
EUV	Extreme Ultraviolet
FDI	Foreign Direct Investment
FIRRMA	Foreign Investment Risk Review Modernisation Act
GAO	General Accounting Office
IDM	Integrated Device Manufacturer
I(C)T	Information (and Communication) Technology
MIC2025	Made in China 2025
OFC	Offshore Financial Centre
OEM	Original Equipment Manufacturer
OODA	Observe, Orient, Decide, Act
PLA	People's Liberation Army
R&D	Research and Development
SEM	Semiconductor Manufacturing Equipment
SOE	State Owned Enterprise
TSMC	Taiwan Semiconductor Manufacturing Company
UMC	United Microelectronics Corporation
USDOC	US Department of Commerce
VC	Venture Capital
YoY	Year Over Year
ZDG	Zhongguancun Development Group

INTRODUCTION

"Worm's fate, though, had been decided several months earlier. A section of microchips had been replaced during maintenance. This was nothing unusual for a plane packed with thousands of chips that ran everything from avionics to the gun camera. [...] Much like the chips inside a smartphone, the processor in Worm's F-35 gun camera, for example, had blocks that did everything from store frames of video to convert files. When the microchip industry took off, it grew from just a handful of companies to more than two thousand, most of them in China, each creating five thousand new chip designs every year. These designs involved thousands of people at multiple locations, each team working on a different block. [...] [C]hips became so complex that no single engineer or team of engineers could understand how all their parts actually worked; the design process was so distributed that no one could vet all the people involved; and the chips were manufactured and bought in such great numbers that not even a tiny percentage could be tested, which almost no buyers, including the big American defense firms, even tried to do. Efficiency always beat security."[1]

Singer and Cole wrote a novel balancing fictional and nonfictional elements, exploring current trends, and projecting them onto a World War III scenario. While the authors ultimately decline the prediction power ascribed to their work,[2] given the research method employed, there is little doubt that it contains degrees of plausibility, as demonstrated by briefings held at the Pentagon.[3] In the book *-spoiler alert-* the F-35B pilot is shot down by a drone activating a homing signal produced by tiny antennas embedded in the replaced microchips. Once the security breach is discovered, the semiconductor supply chain shatters, and the US has to rely

[1] Peter W. Singer and August Cole, *Ghost Fleet: A Novel of the next World War* (Boston: Houghton Mifflin Harcourt, 2015), 70–71.
[2] Peter W. Singer and August Cole, 'How to Write About World War III', *The Atlantic*, 30 June 2015, https://www.theatlantic.com/international/archive/2015/06/ghost-fleet-world-war-III/397301/.
[3] Dion Nissenbaum, 'Author Warns U.S. Military to Focus on China', *Wall Street Journal*, 29 June 2015, sec. Politics, https://www.wsj.com/articles/author-warns-u-s-military-to-focus-on-china-1435539010.

on old equipment, retrieving non-compromised semiconductors from old consumer electronics in order to power its weapon systems.[4] While the described electronic warfare might sound part of the fictional portion of the novel, as recently as 2016, DARPA announced a chip able to withstand the jamming of drones and communications experienced by Ukrainian regular armed forces facing secessionists in Crimea.[5]

But what exactly are semiconductors? They are defined as "a class of crystalline solids intermediate in electrical conductivity between a conductor and an insulator. Semiconductors are employed in the manufacture of various kinds of electronic devices, including diodes, transistors, and integrated circuits. Such devices have found wide application because of their compactness, reliability, power efficiency, and low cost"[6]. Although there are different types of semiconductors, the term and its colloquial version "chip" are here employed to indicate the class of integrated circuits, semiconductors containing more than one transistor.[7] They constitute a fascinating case study, for they are essential to countless purposes, from home appliances to fighter jets, and have therefore been dubbed the "strategic industry of the XXI century, […] foundation of economic and military power"[8]. Furthermore, the semiconductor supply chain was one of the first that became global, implying crucial dependencies and trade-offs between autarky and efficiency. Xi Jinping's renewed political push for self-reliance and the underpinning attempts to securitise frontier technologies,[9] officially to become a manufacturing superpower, cannot disregard the inherent military implications. While it is a

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[4] Singer and Cole, 'How to Write About World War III', 117.

[5] Thomas Gibbons-Neff, 'This New DARPA Chip Could Give U.S. a Leg up in Electronic Warfare', *Washington Post*, 12 January 2016, sec. Military, https://www.washingtonpost.com/news/checkpoint/wp/2016/01/12/this-new-darpa-chip-could-give-u-s-a-leg-up-in-electronic-warfare/.

[6] Encyclopaedia Britannica Editors, 'Semiconductor', Encyclopedia Britannica, accessed 19 July 2021, https://www.britannica.com/science/semiconductor.

[7] John VerWey, 'Chinese Semiconductor Industrial Policy: Prospects for Future Success', *Journal of International Commerce & Economics*, 2019, 3.

[8] James A. Lewis, 'China: In Search of Tech Supremacy Through Chip Production?', ISPI, 7 June 2021, https://www.ispionline.it/en/pubblicazione/china-search-tech-supremacy-through-chip-production-30703.

[9] Alexander Brown, 'Huawei's Global Troubles Spur Beijing's Push for Self-Reliance', MERICS, 1 June 2021, https://merics.org/en/short-analysis/huaweis-global-troubles-spur-beijings-push-self-reliance.

self-fulfilling prophecy, integrated circuits embody a proxy in a larger dispute among great powers, and even though the focus is here on China, it is hard to avoid mentioning the US, either as a benchmark or as an agent of the international system.

Against this backdrop, the present work seeks to underscore the relevance of semiconductors in China's defence realm, highlighting the importance of state policies in granting both the technological edge over the enemy and the reliability of the underlaying components, paramount factors in the modern conception of warfare. Thus, the central hypothesis states that, in the Chinese case, semiconductors can be framed and better understood as part of the defence industry because integrated circuits are a cornerstone in the strategy Beijing is deploying to swing the global balance of power.

To this end, the first chapter delineates the technological evolution from the second industrial revolution through the progressive military legitimisation in the course of the XX century (with the definitive anointment by World War II) to the nesting at the core of the bipolar competition. The increasing relevance of technology has been rivalled only by the complexity of actually ensuring its integrity. Hence, semiconductors are introduced as a dual-use technology, a harbinger of export controls and inherent trade-offs.

The second chapter engages the delicate matter of the balance existing between technology and society, resorting to a version of soft determinism. Heavily influenced by the time factor, the theoretical framework accounts for the forecast relevance Beijing policies might finally assume as the pace of semiconductor development, prescribed by Moore's law, slows down. In the light of the laid premises, the reasoning briefly outlines Buzan's arms dynamics to then deepen the policies governing the Chinese defence industry and its relationship with technology. Notably, semiconductors emerge as one of the clear priorities in which the central government invests to modernise its armed forces, leapfrogging basic stages to reach global technological leadership.

The third chapter explicates the supply chain structure, clarifying its inherent complexities and dependencies, such as the massive reinvestments in research and development (R&D) needed to remain at the forefront of innovation. A brief profile of the main actors is also delineated in order to highlight both the global environment and the differences between the rise of semiconductor industries in East Asian countries and China.

The fourth chapter focuses on the Chinese policies to kickstart a domestic semiconductor industry, lingering over the latest round of attempts. Its analysis allows gauging in detail Beijing's strategy and commitment to the goal, defining both the means employed to foster procurement and the international responses to them. Finally, the main hindrances weakening the process are considered and balanced with its main drivers to sketch a short-term prospect related to the competition with the US.

Whenever possible, primary sources are employed, such as texts of policies, memorandums, and official documents. Nonetheless, given the language barrier, the work relies extensively on secondary sources. The existing literature is integrated with databases, newspapers articles, and think tank reports and translations.

CHAPTER 1. Relevance

Autarky-Efficiency Dilemma

As Moravcsik illustrates, the dilemma between efficiency and self-sufficiency in armaments production has been plaguing states since their formation. Early European arms races in the XVI century dramatically increased the cost of war, resulting in the progressive dependence on imported raw materials and the need to export in order to lower the production costs and pursue mercantilist policies. Despite states' intentions and efforts to regulate the market, for the most part, it eschewed the attempt to be curbed to the point that armies and navies of the major competing powers were mutually dependent on the adversaries' supplies. The first effort to subvert the trend was attempted in the late XVII century when France took the initiative to revisit mercantilism. The intention was to continue generating an economic surplus while striving for autarky, with the goal to bring arms production under governmental control via the creation of state arsenals. However, the results were underwhelming, and the manufactured weapons proved expensive and of poor quality.

The approach towards arms production and export started shifting again from the XVIII century when the importance of possessing the technological edge began to prove significant. Until then, states had proven unable to exert any substantial form of control on trade, resulting in innovations quickly spreading among all the competing actors. As a direct consequence, wars had been fought with widespread weapons and similar strategies, meaning that the sheer power of numbers had long been the primary variable to victory.[10] As Voltaire posited: "God is on the side of the big battalions"[11]. However, with the progressive professionalisation of the armies, governments started playing a more active role in the choice of the equipment, harnessing a powerful source of demand. Whereas mercenaries used to be free to pick their weapons wherever was cheaper, the creation of national armies allowed the enforcement of standardised armaments, de facto legitimising the formation of significant national weapons industries. Thus, states began to invest in research while actively supporting procurements in fields related to production.

With the change of approach, the quality of arms manufacture stopped being a tool merely functional to achieve economic autarky and assumed its own relevance in states' security policies. The higher degree of control over the market meant the possibility to enforce embargoes as a warfare strategy, and the effective blockades imposed during the Napoleonic Wars demanded countermeasures. The outcome consisted of a new wave of attempts to sever

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[10] Andrew Moravcsik, 'Arms and Autarky in Modern European History', *Daedalus*, Searching for Security in a Global Economy, 120, no. 4 (1991): 23–27.

[11] François-Marie (Voltaire) Arouet, 'Letter to François-Louis-Henri Leriche', 1770.

foreign dependencies. Calls for the implementation of new mercantilist policies focused on self-reliance both in terms of raw materials acquisition and weapons manufacture. Therefore, the production was concentrated in capital-intensive industrial centres and states increased their control over exports.[12]

Technology and Relative Gains

Measures to regulate the market barely held until the second industrial revolution, in the mid-XIX century, when the technological development was so steadfast that, for the first time in history, the weapon succession process was dictated not by breakages but obsolescence. As the national military expenditure started rising, the loop became self-feeding, and efficiency prevailed once more over autarky, causing state industries to depend on the cheaper and more dynamic private defence sector. In fact, the latter gained a primary relevance in the field and took the lead of the technological race, either replacing state arsenals or acting as their subcontractor. The results were soon oligarchic or monopolistic scenarios, where entire states were heavily reliant on privately owned industries, as depicted by the case of Prussia, whose artillery was entirely supplied by Krupp. This dependence provided the weapons producers sector with enormous leverage and, by the beginning of the XX century, their lobbying had resulted in the abolition of most trade barriers. The new commerce freedom allowed firms to export and sell to both sides of conflicts. Host states turned a blind eye in the name of the efficiency paradigm that permitted them to lower the expenditure of their own military supply. However, monopolies are notoriously counterproductive for the consumers. To balance this negative tendency, states often tried to pursue efficiency by purchasing abroad, causing stirs with the domestic industries, whose influencing and lobbying power had reached places so high that parliaments, chancellors, and Kaisers intervened to block the foreign acquisitions.[13]

[12] Moravcsik, ‘Arms and Autarky in Modern European History’, 25–28.
[13] Moravcsik, 29–31.

Since World War I, the European economic framework has been characterised by protectionism and enhanced measures to hinder armaments exports, although not always efficient as emphasised by events such as the Treaty of Rapallo. Contextually, the two global conflicts represented the ultimate consecration of the importance of detaining the technological edge over the adversaries, meaning that a smaller but better-armed force would have better chances of winning against a superior number of ill-armed enemies.[14] Thus, the period starting in the 1940s embodied a time of great technological fervour, especially in the US, where as much as 40 per cent of GDP was rerouted to inflate the defence spending.[15] Firms found themselves able to invest vast amounts of capital in R&D, certifying both the end of the era when state arsenals had been linchpins in the state defence manufacture and that of Europe as the main centre of technological innovation.

World War II had also shaped the parameters of the dominant conflict scenario that would have been hardly changed to this day. Therefore, as dictated by the armed forces, states were focused on enhancing weapons features because a "small edge in performance can mean survival".[16] This incremental innovation path to develop new armaments resulted in a progressive rise in fixed costs, given the considerable amount of research needed to produce and implement even minor improvements in technologies.[17] As a direct consequence of the technological paradigm, only countries with large markets, such as the US, were able to afford the military budget to sustain the outlays, de facto gaining the rank of world first-tier producers: states able to

[14] Renaud Bellais, 'Technology and the Defense Industry: Real Threats, Bad Habits, or New (Market) Opportunities?', *Journal of Innovation Economics Management* n°12, no. 2 (21 August 2013): 60.

[15] William J. Lynn III, 'The End of the Military-Industrial Complex', *Foreign Affairs*, 20 October 2014, https://www.foreignaffairs.com/articles/united-states/end-military-industrial-complex.

[16] John A. Alic et al., *Beyond Spinoff: Military and Commercial Technologies in a Changing World*, First Edition, First Printing (Boston, Mass: Harvard Business Review Press, 1992), 114.

[17] Mary Kaldor, 'The Weapons Succession Process', *World Politics* 38, no. 4 (July 1986): 585, https://doi.org/10.2307/2010167.

innovate and produce the entire range of weapons systems on their own.[18] The advent of the Cold War setting merely strengthened the outlined trend, with defence agencies willing to invest in a wide range of projects deemed able to provide technological edge even if in the long run. Notably, R&D largely focused on electronics and aerospace, considered crucial industries for innovative weapon systems.

In the depicted context, the transistor was invented in 1947 at Bell Labs. In 1958 Texas Instruments developed the first integrated circuit prototype and, as soon as 1961, semiconductors began to be sold on the market by Fairchild. The US government played a crucial role in recognising the importance of the industry and shaping it by providing technical assistance, R&D funds and, most importantly, guaranteed demand. In fact, military procurement granted generous profit to the sector, encouraging more private firms to enter the market, pushing it forward. The ensuing economies of scale made the price affordable to the civilian segment, triggering the manufacture of a broader range of products and subsequent cycles of innovation.[19]

Dual-Use Technology and Export Controls

As investments boomed in the course and aftermath of World War II, the relationship between military and civilian economies transformed. Pushing autarky over efficiency, the US developed military technology that only later reflected into the civilian sphere. Among the early relevant instances can be found the radar, jet engine, and atomic power. The consequence of spillovers from one sector to the other allowed for increased efficiency but also for an increased struggle in telling apart civilian and military technologies, as almost every item could be framed

[18] Keith Krause, *Arms and the State: Patterns of Military Production and Trade*, 1st ed. (Cambridge University Press, 1992), https://doi.org/10.1017/CBO9780511521744. Antonio Calcara, 'Cooperation and Non Cooperation in European Defence Procurement', *Journal of European Integration* 42, no. 6 (22 October 2019): 799–815, https://doi.org/10.1080/07036337.2019.1682567.

[19] Peter R. Morris, *A History of the World Semiconductor Industry* (IET, 1990), 73.

as dual-use. The issue was particularly relevant at the level of components, for not too different semiconductors could power missiles as well as heart pacemakers.[20]

During the Cold War, the Western block took precautions to prevent exports of arms, nuclear-related items, and dual-use technology to the Eastern one and China, enforcing in 1953 the Coordinating Committee for Multilateral Export Controls (COCOM). Given the polarised setting of the international system, COCOM proved quite effective until its 1994 dissolution. While autarky had been at the core of the geopolitical competition, efficiency hardly bothered the US. Thanks to its defence-related spending and the superior level of support to the semiconductor industry, it had managed to maintain the lead in the field on both competitors and allies for decades. [21] However, as expanded in the third chapter, under its aegis, different mixtures of government support, specialisation, innovation, and favourable timing had allowed for the development of allies' viable semiconductor industries, growingly able to rival the US one in particular niches. Furthermore, the 1990s marked a turning point in the relationship between the two fields of the economy, for civilian R&D replaced military R&D at the forefront of technological innovation.[22] Hence, after COCOM had expired, the US Congress decided to loosen the rules governing the case-by-case concession of export licences, hoping to boost its domestic economy (efficiency) and national security (autarky) accordingly. As part of this effort, in 1998, the US Bureau of Industry and Security arranged end-use visits with China to determine the entity of risks posed by the trade of dual-use technologies to the country. Being reliant on the willingness of the Chinese authorities, the US delegation was permitted to conduct only a tiny fraction of the planned inspections, making the Bureau of Industry and Security ultimately unable to determine the actual purpose of the exported items. The episode

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[20]John A. Alic, 'The Dual Use of Technology: Concepts and Policies', *Technology in Society* 16, no. 2 (January 1994): 157–58, https://doi.org/10.1016/0160-791X(94)90027-2.

[21] Christopher F. Corr, 'The Wall Still Stands! Complying with Export Controls on Technology Transfers in the Post- Cold War, Post-9/11 Era', *Houston Journal of International Law* 25, no. 3 (2003): 450–54.

[22] Alic et al., *Beyond Spinoff*.

spurred Congress to backpedal on its decision, stiffening controls and establishing a Pentagon position to monitor dual-use technology transfers to China.[23]

On the international level, COCOM was replaced by the 1996 *Wassenaar Arrangement on Export Controls for Conventional Arms and Dual-Use Goods and Technologies*, "established in order to contribute to regional and international security and stability, by promoting transparency and greater responsibility in transfers of conventional arms and dual-use goods and technologies"[24]. Although all parties had committed to COCOM, the US had proven to be the most dedicated enforcer, privileging security over the economy. As mentioned beforehand, the posture was often to the detriment of domestic companies, which accepted the imposition of a smaller market out of the considerable margin they retained over other countries. Yet, the US situation worsened with the transition to the Wassenaar Arrangement. In fact, the members merely pledged to "enhance co-operation to prevent the acquisition of armaments and sensitive dual-use items for military end-uses, if the situation in a region or the behaviour of a state is, or becomes, a cause for serious concern"[25]. Unlike the previous multilateral export control system, the Arrangement, which is still in place, lacks legally binding powers and a clear target. Countries are free to base their export policy on domestic interests without breaching any international law and, being absent an explicit threat such as the one posed by the USSR, the US General Accounting Office (GAO) formulated that "[t]he United States is the only member that considers the relationship between semiconductor manufacturing equipment and military end uses sufficiently critical and considers China's acquisition of this technology a potential threat to regional or international stability. We found that European, Japanese, and U.S. export

[23] Michael D. Klaus, 'Dual-Use Free Trade Agreements: The Contemporary Alternative to High-Tech Export Controls', *Denver Journal of International Law & Policy* 32 (2003): 113–14.

[24] Wassenaar Arrangement Secretariat, 'The Wassenaar Arrangement on Export Controls for Conventional Arms and Dual-Use Goods and Technologies', § I, art.1 (1996), https://www.wassenaar.org/app/uploads/2019/12/WA-DOC-19-Public-Docs-Vol-I-Founding-Documents.pdf.

[25] 'The Wassenaar Arrangement on Export Controls for Conventional Arms and Dual-Use Goods and Technologies', § I, art.3.

control authorities license sales of semiconductor manufacturing equipment to China that is at least two generations more advanced than the threshold stipulated in the Wassenaar"[26]. Moreover, the mechanism underpinning the Arrangement dictates how states denying licences are required to notify the other members within sixty days. Nothing prevents the latter from granting a licence for the very same product. The sole obligation is to report, within sixty days, licences issued for exports denied by others in the previous three years. Fundamentally, denials serve as business opportunity advertisements to member states willing to sell, voiding the original purpose of establishing multilateral export control.[27]

As the GAO underlined, the US is more inclined towards national security than other parties, and efficiency has often been sacrificed on the altar of autarky, forcing domestic firms to withstand strict export policies and letting foreign companies undercut them. As a consequence, the latter are able to undermine the competitiveness of the former, in turn weakening US national security already strained by the rivals' acquisitions of the technologies Washington was trying to retain. This is the case of semiconductor manufacturing equipment (SEM) because "Japan and European countries have made it clear that they do not consider chips or SEM exports to China to represent a security threat. Consequently, their licensing policies are far more liberal than are U.S. licensing policies. While the United States still has a large semiconductor production equipment base, China can obtain all major types of semiconductor production equipment from non-U.S. sources in Japan and Europe"[28]. Since the quoted statement by the Semiconductor Industry Association then-president before the Congress, US actions have been undertaken to limit Chinese access to non-US equipment, their

[26] General Accounting Office, 'Rapid Advances in China's Semiconductor Industry Underscore Need for Fundamental U.S. Policy Review', Report to the Ranking Minority Member, Committee on Governmental Affairs, U.S. Senate, Export Controls (Washington, D.C.: General Accounting Office, April 2002), 17, https://www.gao.gov/assets/gao-02-620.pdf.

[27] Klaus, 'Dual-Use Free Trade Agreements: The Contemporary Alternative to High-Tech Export Controls', 115–16.

[28] George Scalise, 'Hearing on the Impact Of Military And Dual-Use Technology Exports To China', § U.S.-China Commission Export Controls and China, U.S. Congress (2002), 1032, https://www.uscc.gov/hearings/hearing-impact-military-and-dual-use-technology-exports-china.

limited effect underscoring the little benefits stemming from unilateral export controls (despite the US accounting for 48 per cent of market share in terms of revenue as of 2020)[29].

All in all, export control rests on national interests and foreign policy and, although it has hitherto been the leitmotif, the contraposition autarky-efficiency might seem an oversimplification in the modern world, as the two are more intertwined than ever for new supply chain layers have made a once-obvious trade-off increasingly more complex to unravel. Yet, the underlying drivers remain the same.

Before globalisation, protectionism was intuitive: sharp lines could be drawn between domestic and foreign firms, making it easy to forage the former and hinder the latter. Blurring said lines caused policies meant to shelter national industries to have repercussions on other segments of the domestic economy, making advantages not so clear-cut. [30] Such as the 1986 *US-Japan Semiconductor Agreement* illustrates: seeking to shelter its semiconductor firms, Washington pressured Tokyo into raising the price of the Japanese dynamic random-access memory (DRAM) chips to avoid driving US DRAM makers out of the market. As a result, the treaty caused harm to the US computer producer and consumers, forced to pay a DRAM chip 30 to 40 per cent more than their European counterparts.[31] The very same dynamic could be observed in the aftermath of the tariffs imposed on steel and aluminium imports by the Trump administration.[32]

While it is true that similar patterns were found before globalisation, their scale carried little weight with policymakers. The matter of downstream effects became preponderant once

[29] Helen You, 'Semiconductors and the U.S.-China Innovation Race', *Foreign Policy*, 16 February 2021, https://foreignpolicy.com/2021/02/16/semiconductors-us-china-taiwan-technology-innovation-competition/.
[30] Alic, 'The Dual Use of Technology', 163.
[31] Bryan Johnson, 'The U.S.-Japan Semiconductor Agreement: Keeping Up the Managed Trade Agenda', Backgrounder, The Center for International Economic Growth (Washington, D.C.: The Heritage Foundation, 24 January 1991), https://www.heritage.org/asia/report/the-us-japan-semiconductor-agreement-keeping-the-managedtrade-agenda.
[32] Geoffrey Gertz, 'Did Trump's Tariffs Benefit American Workers and National Security?', *Brookings* (blog), 10 September 2020, https://www.brookings.edu/policy2020/votervital/did-trumps-tariffs-benefit-american-workers-and-national-security/.

strategic industries went global. Materials, components, and capital from abroad implied the necessity to have precise information on ripple effects to understand how foreign dependence and shrinking production capacity affect mobilisation. Projections of future needs are required to determine both the basal requirement and the one in case of war to prevent supply chain disruptions by taking precautions such as stockpiling and bankrolling domestic production capacity.[33] Unsurprisingly, the last two measures are the perfect description of the reactions sparked by the COVID-19 black swan. In this regard, the pandemic has served as a Sputnik moment for governments, showcasing the crucial relevance of semiconductors and the spectre of a prolonged shortage.[34] While today the automotive and consumer IT sectors are the most hit by the integrated circuits dearth,[35] it is not hard to envisage further future weaponisation of the supply chain to impair enemy defence sectors.

Semiconductors are the crude oil of the XXI century[36] and, even though integrated circuits are not going to cause a revolution in military affairs, they are going to power the next one.

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[33] Alic, 'The Dual Use of Technology', 165–66.

[34] Across the spectrum of semiconductor producers, many foresee the shortage not to ease before 2023. *See* Simona Jankowski and Robert Sherbin, 'NVIDIA Announces First Quarter Fiscal 2022 Revenue Tracking Above Outlook', Press Release, NVIDIA, accessed 12 June 2021, http://nvidianews.nvidia.com/news/nvidia-announces-first-quarter-fiscal-2022-revenue-tracking-above-outlook; Jeanne Whalen, 'Chip Shortage Will Last beyond 2022 as Demand Far Outstrips Supply, Intel Chief Says', *The Washington Post*, 13 April 2021, sec. Tech Policy, https://www.washingtonpost.com/technology/2021/04/13/intel-ceo-semiconductor-chip-shortage/; Debby Wu, 'TSMC Lifts Targets After Warning Chip Crunch May Hit 2022', *Bloomberg*, 15 April 2021, sec. Technology, https://www.bloomberg.com/news/articles/2021-04-15/tsmc-profit-beats-as-chip-shortage-shows-no-sign-of-abating.

[35] In the second quarter of 2020, the automotive industry reduced its chip procurements to accommodate the lowered sales caused by the pandemic. Contextually, lockdowns triggered a spike in remote devices to prop up fields such as healthcare and private IT infrastructure to enable work-from-home, distance learning, and entertainment. However, with the loosing of social distancing measures, the market for cars rallied sooner than anticipated, so that the year-over-year monthly sales became positive in the last quarter of the year. As a consequence, semiconductor demand surged to the point the offer was not able to satisfy it. As many automotive companies were forced to halt some production lines, there was a global scramble to stockpile chips, worsening the situation. *See* Falan Yinug, 'Semiconductor Shortage Highlights Need to Strengthen U.S. Chip Manufacturing, Research', Semiconductor Industry Association, 4 February 2021, https://www.semiconductors.org/semiconductor-shortage-highlights-need-to-strengthen-u-s-chip-manufacturing-research/; Ondrej Burkacky, Stephanie Lingemann, and Klaus Pototzky, 'Coping with the Auto-Semiconductor Shortage: Strategies for Success', Automotive & Assembly (McKinsey & Company, 27 May 2021), https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/coping-with-the-auto-semiconductor-shortage-strategies-for-success.

[36] Klaus, 'Dual-Use Free Trade Agreements: The Contemporary Alternative to High-Tech Export Controls', 109.

CHAPTER 2. Theoretical Framework

Technology and Society

So far, technology has been characterised as a mere component underlying the trade-off between economy and security. Yet, to better frame semiconductors as part of the defence sector, it should be considered a variable with its own stature. Whether dependent or independent, it has been long debated in the literature. Under the nuclear threat of the Cold War, the dispute gained a new impulse, framing technology as an independent force shaping history and society with no constraint, a new Frankenstein's creature where humanity played the role of helpless creator.[37] During the late 1980s, the opposite view became prominent, deploring technological determinism, for it was labelled too simplistic, unaccenting contingencies, and leaving no room for human agency. Thus, the new wave of social constructivism aimed at reaffirming the primacy of politics over technology. However, both opposites include a variety of nuances, de facto establishing a continuum between hard technological determinism and radical social constructivism, making the matter one of degree, scope, and context rather than a dichotomous kind.[38] This broader gamut includes the approach hitherto implicitly maintained and now detailed as soft determinism (or weak constructivism), implying interaction and mutual conditioning between the two poles.

In the previous chapter, technology has been analysed mostly as dependant on (social) strategic goals, efficiency being the main counterweight to the employment of dual-use exports as an ordinary tool to foreign policy. The simplification was allowed by the long predominance of the US industry and the controlled Cold War setting, consenting to strict state control on technologies such as semiconductors. Yet, traces preluding the establishment of a mutual

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[37] Langdon Winner, *Autonomous Technology: Technics-out-of-Control as a Theme in Political Thought* (Cambridge, Massachusetts: MIT Press, 1977), 306–17.

[38] Allan Dafoe, 'On Technological Determinism: A Typology, Scope Conditions, and a Mechanism', *Science, Technology, & Human Values* 40, no. 6 (November 2015): 1050, https://doi.org/10.1177/0162243915579283.

influence can be found in the pressure exerted on the US by the creation of foreign industries, the lobbying of the domestic ones[39], and the swing in favour of commercial R&D. As it shines through the text, both social and deterministic elements have conditioned the course of the integrated circuit history, just assuming different weights in different moments. Therefore, to complete the framing of the continuum, the last variable left to codify is the time factor.

Thomas P. Hughes embedded the latter as the nexus linking technological determinism and social constructivism, coining the technological momentum.[40] The original concept stems from physics and is employed to determine an object's quantity of motion, formulated as the product of its mass and speed in a given direction. In its transposition to social science, the mass is represented by the financial, technical, and political structure supporting the advance of technology, while the metaphorical speed indicates the pace of development. The more momentum, the more difficult it is to slow down or deviate the course of an object. Hence, "younger developing systems tend to be more open to sociocultural influences while older, more mature systems prove to be more independent of outside influences and therefore more deterministic in nature"[41]. Consequently, momentum can be gained and lost, so "[a] technological system can be both a cause and an effect; it can shape or be shaped by society"[42].

In 1965, the co-founder of Fairchild (and later of Intel) Gordon E. Moore empirically quantified the growth of semiconductors, postulating that the density of transistors per integrated circuit

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[39] While the Cold War policies imposed by the US government had been accepted by the semiconductor industry because of the margin held over the competition. Interests started to diverge with the reduction of the advantage and the emergence of the Japanese industry. The divide widened after the end of COCOM, when the strict US policies kept depriving the domestic semiconductor industry of market shares, and the latter "have repeatedly questioned the contribution of semiconductor manufacturing equipment to military capabilities and proliferation and ask whether there is still any strategic rationale for controlling these items". *See* U.S. Congress, 1022. More recently, Lam Research CFO that China's demand "has to be satisfied by somebody". *See* Roslyn Layton, 'Applied Materials, Lam Research And KLA Continue Selling To China Despite Security Concerns', *Forbes*, 17 November 2020, https://www.forbes.com/sites/roslynlayton/2020/11/17/applied-materials-lam-research-and-kla-continue-selling-to-china-despite-security-concerns/.

[40] Thomas P. Hughes, 'Technological Momentum in History: Hydrogenation In Germany 1898–1933', *Past and Present* 44, no. 1 (1969): 106–32, https://doi.org/10.1093/past/44.1.106.

[41] Thomas P. Hughes, *Does Technology Drive History? The Dilemma of Technological Determinism*, ed. Merritt Roe Smith and Leo Marx (Cambridge, Massachusetts: MIT Press, 1994), 101.

[42] Hughes, 112.

would have doubled every two years.[43] Although dubbed a self-fulfilling prophecy, the renamed Moore's law proved a reliable estimate, providing an objective and timeframe to the industry, setting the speed of the semiconductor momentum.

Given Hughes' theory, it is hard to eschew hard deterministic views while accounting for an extended period of time, and Ceruzzi saw in the pace of Moore's law "raw technological determinism […] at work" for "[c]omputing power must increase because it can".[44] Therefore, it is necessary to focus on finding *local* instead of *universal* validity to be able to capture the political influence exerted over the cadence of technological evolution.[45]

Having attested the fluid balance and mutual influence of the technological and societal factors, the present work seeks to deepen the Chinese efforts to build a leading-edge semiconductor industry on par with the US. This becomes particularly relevant given the increasing costs and technical production challenges slowing down the pace marked by Moore's law. In the present conjuncture of lowered speed in development, Beijing hopes to capitalise on the global industry losing momentum. Building the necessary mass to support its domestic industry might finally prove successful in kickstarting its own. The hitherto expressed theoretical elements provide the framework to understand why Chinese politics can play a role in shaping the course of technology, with determinism heavily conditioning both causes and effects.

The causes could be synthesised by the implication of technology "merely open[ing] a door; […] not compel[ling] one to enter"[46]. The statement entails that states privileging efficiency could either renounce the chase of the technological advantage or buy cheaper off-the-shelf products from foreign industries able to sustain the required R&D expenses. Whereas the

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[43] Gordon E. Moore, 'Cramming More Components onto Integrated Circuits', *Electronics* 38, no. 8 (19 April 1965): 6.

[44] Paul E. Ceruzzi, 'Moore's Law and Technological Determinism: Reflections on the History of Technology', *Technology and Culture* 46, no. 3 (2005): 590–93.

[45] Matthew Evangelista, *Innovation and the Arms Race: How the United States and the Soviet Union Develop New Military Technologies* (Cornell University Press, 1989), https://doi.org/10.7591/9781501734304.

[46] Lynn White, 'The Act of Invention: Causes, Contexts, Continuities and Consequences', *Technology and Culture* 3, no. 4 (1962): 28, https://doi.org/10.2307/3100999.

effects caused by the former option might be mitigated with alliances and accords, countries would substantially declare partial factual disarmament, given that second-rate technologies would make second-rate weapons systems and provide bloody defeats once faced with the paradigm regulating warfare. Although on a different scale, similar results would stem from the latter option because states would renounce any attempt to remain self-reliant in order to afford the technology offered by third parties. "[G]reat power status is, at the end of the day, measured by the independent ability to wage war"[47]. To obviate this issue, states could opt for autarky, as China is trying to, but it implies cumbersome investments into the creation of a viable domestic industry able to sustain R&D to provide cutting-edge technology.

The deterministic effects are represented by the perpetuation of the dilemma, as maintaining the edge entails unremitting commitment, stemming from the need to sustain the industry and the security dilemma pushing other countries to innovate more. Politics always have the chance to opt for efficiency, but it would need to face the consequences highlighted beforehand.

Arms Dynamics

As expressed in the first chapter, the technological edge started to play a crucial role in warfare since the second industrial revolution and was ultimately corroborated by the experience of World War II. Notably, the relationship between the two sides of the economy started to be blurred by spillovers from the military to the civilian sector, dual-use technologies being the epitome of the process. In the early stages of the Cold War, the US semiconductor industry was dependent on the funds provided by defence agencies, granting the military fundamental control over the structure of the sector. As chips began being employed in the civilian segment, the industry gained momentum and started growing increasingly independent of military demand and its declining subsidies. While US efficiency proved a decisive strategic advantage

[47] Barry Buzan, *An Introduction to Strategic Studies* (London: Palgrave Macmillan UK, 1987), 40, https://doi.org/10.1007/978-1-349-18796-6.

over the USSR, it also constituted a blow to states' ability to influence its course. The direction was kept somehow in check by the geopolitical setting and COCOM restrictions despite the global expansion hindering the efficiency of export controls, but the 1990s constituted a watershed. Innovation being dictated by civilian R&D and the loose rules of the Wassenaar Arrangement meant that cutting-edge technology, including the one necessary to build first-class military capabilities, could be bought off-the-shelves.[48] Remarkably this was the case of semiconductors, in spite of them being understood as the foundation of defence capabilities such as weapon systems, navigation, communication, battle management, space, cyber and electronic warfare. Furthermore, their role of force multipliers has been deemed crucial in asymmetric confrontations, allowing states to punch above their weight.[49] The factual handover to the civilian sector R&D meant a swing towards efficiency, implying that states could exert only partial control over the pace of technology, being "riders, and not the horse itself"[50].

Buzan identified three complementary models to describe a range of arms dynamics spanning from the maintenance of the status quo to arms race.

The first one is labelled Action-Reaction and is based on the proposition that "states strengthen their armaments because of the threats they perceive from other states"[51]. External factors generating a self-reinforcing security dilemma mirror the view of offensive realism transposing it from international relations to the strategic studies subfield. The presence of revisionist states, such as China, seeking to improve their position in the international system is likely to tip the scale towards arms races. Since World War I, weapons systems have diversified, making it harder to produce a proper comparison, and the uncertainty only feeds the Thucydides trap.

[48] Aaron L. Friedberg, *Reviewing the Cold War: Approaches, Interpretations, and Theory*, ed. Odd Arne Westad, Cold War History (London: Frank Cass Publishers, 2000), 214–16.
[49] Ming-chin Monique Chu, *The East Asian Computer Chip War*, 1st ed. (Routledge, 2013), 39, https://doi.org/10.4324/9781315866727.
[50] Buzan, *An Introduction to Strategic Studies*, 107.
[51] Buzan, 76.

However, in the case of semiconductors, the magnitude is still assessable, and their dimension in nanometres provides valid metrics to gauge development and deriving military strength.

As the Chinese then-Minister of Industry and Information Technology Miao Wei formulated, "the scale and level of a country's IC development has become an important measurement of a country's national competitiveness and overall strength"[52]. Two more variables that underlie Action-Reaction are awareness and motives. The former indicates the consciousness states have of the process in which they are engaged, while the latter accounts for the often-indiscernible drivers guiding the state behaviour, influencing the whole model. The last component is represented by timing. As suggested by the name of the theory, a move should be followed by a countermove in a sequenced pattern. Yet, there are often mutual and simultaneous reactions to what could be the adversary's possible move, leading to a spiral model. Particularly relevant in the course of the Cold War, said constant positive plunging led to an internalisation of the process, institutionalising it.[53]

The latter variable allows for the establishment of the Domestic Structure model. Stemming from the first one and being complementary to it, it provides an explanation to a wider range of cases. While external factors still provide the needed justification, the model holds that ad hoc reactions are supplanted by dynamics generated within the state[54] responding not only to technological advances but also to a wider range of internal interests. Particularly relevant in the US case, the phenomenon has allowed for the establishment of powerful non-governmental organisations, able to push innovation in directions not always ascribable to Action-Reaction dynamics.[55]

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[52] Esther Majerowicz and Carlos Aguiar de Medeiros, 'Chinese Industrial Policy in the Geopolitics of the Information Age: The Case of Semiconductors', *Revista de Economia Contemporânea* 22, no. 1 (11 June 2018): 8, https://doi.org/10.1590/198055272216.

[53] Buzan, *An Introduction to Strategic Studies*, 77–93.

[54] Buzan, 111–12.

[55] Mark C. Suchman and Dana P. Eyre, 'Military Procurement as Rational Myth: Notes on the Social Construction of Weapons Proliferation', *Sociological Forum* 7, no. 1, (1992): 137–61.

However, the effort to tackle increasingly complex and expensive technologies has made them even more so, fuelling the imperative mentioned in the opening chapter, bedrock to technological determinism and constituting the third model described by Buzan. The Technological Imperative constitutes the scholar's definitive paradigm, considered the one in which the previous two converge. Embedded into the independent global process of technological advancement, the Action-Reaction model sees uncertainty grow due to constant military power fluctuations. Therefore, to avoid being taken aback in case of adversaries' positive plunging, states need to institutionalise R&D (Domestic Structure), feeding others' security dilemmas and fuelling the cycle. The faster the innovation pace, the more frenzy the attempts to keep up, reinforcing the deterministic treadmill.[56]

Illustrated as it is, Buzan's tripartite model seems to leave little room for the softer technological determinism that pledged to typify this theoretical framework. Yet, the time factor proves once more the keystone in finding local validity to the process of arms dynamics. Therefore, the Cold-War US is seen as characterised by a focus on radical technological advancements initially pursued by civilian scientists. Its innovation course continued with the recruitment of allies in the armed forces before seeking consensus among the executive power. Only at this stage, external threats were considered in order to justify investments to turn R&D into prototypes.[57] The weak constructivist view allows shunning deterministic single-factor models while still accounting for Domestic Structure and Action-Reaction elements. The described course is applicable to numerous cases, including semiconductors. Still, it only accounts for the initial stage of technologies, neglecting the longer incremental perspective that leads technologies towards a more deterministic path, as described by Hughes. It remains worthy of

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[56] Buzan, *An Introduction to Strategic Studies*, 108–9.

[57] Donald MacKenzie, review of *Innovation and the Arms Race: How the United States and the Soviet Union Develop New Military Technologies*, by Matthew Evangelista, *International Security*, Technology and the Arms Race, 14, no. 1 (Summer 1989): 166, https://doi.org/10.2307/2538768.

consideration whenever the loss of momentum allows politics to steer the course of innovation, fulcrum of this work.

While in the US case the military-industrial complex is identified as a crucial step of the process, the case is harder to make for the USSR. The Soviet Union lacked the pluralist forces typical of the West, and it did not witness the formation of an independent domestic structure. Yet, to an extent, given the alignment of its military and political interests, the whole country could be considered as such.[58] Consequently, the indigenous impulse towards innovation resulted stifled by systematic constraints, and radical advancements were frequently pursued as a mere reaction to foreign technological advancements or threats (Action-Reaction). Moreover, the direction of the process was reversed compared to the US. In the top-down, centralised setting, the upper echelons were in charge of determining the priorities in the innovation agenda.[59] The fact implied a conservative preference for quantity over quality improvements and the complacency towards the development of technologies unable to provide clear prospects. Hence, the Soviet Union tended to follow the path set by the US, rarely taking an independent course, managing to balance the stifled innovation through the capability to mobilise substantial resources swiftly.[60] Despite the collapse of the USSR and the end of the Cold War, the Soviet organisational structure remains relevant as its legacy has heavily influenced the Chinese defence sector and subsequent strategies.

Chinese Defence Industry

Since the foundation of the People's Republic of China in 1949, and until the 1978 Sino-Soviet split, the USSR proved to be the main supporter of an indigenous defence industry, primarily to expand its sphere of influence and create a buffer zone with the West (especially in light of

[58] Buzan, *An Introduction to Strategic Studies*, 103.
[59] MacKenzie, 'Innovation and the Arms Race: How the United States and the Soviet Union Develop New Military Technologies', 167–68.
[60] Kaldor, 'The Weapons Succession Process', 583–88; Buzan, *An Introduction to Strategic Studies*, 97.

the Korean War). Blueprints, teaching materials, entire production lines, and more than eight thousand advisors per year flowed from Moscow to Beijing in order to kickstart Chinese domestic manufacturing. The Soviet Union sought to keep China dependent on its weapon systems exports to prevent Western interferences by providing technology and schematics only for small arms and artillery. However, it soon had to resort to coproduction to maintain its influence over developing China.[61] The skillset and tacit knowledge gained during the collaboration proved crucial after the Sino-Soviet split, allowing China to reverse-engineering imported systems and develop indigenous innovation in strategic fields. Yet, despite Deng Xiaoping's reforms, the defence sector remained backwards and at a loss until the mid-1990s.[62] With the fall of the Berlin Wall, military budgets around the world began to shrink in the light of the reduced global tensions and need for armaments.[63] Originating from the Pentagon, weapons industries mergers and acquisitions began to consolidate the sector, and China made no exception.

Besides the global restructuring push, the 1990s handover from military to civilian R&D was artificially promoted in China, and, in 1997, the People's Liberation Army (PLA) was ordered to divest from its commercial activities and to focus on fighting "limited local wars under high-technology conditions"[64]. PLA white papers following the First Gulf War, studying the NATO intervention in Kosovo and the war in Iraq, highlighted the relevance of technology on the battlefield and the need to avoid falling behind. They marked the beginning of an ongoing process towards the modernisation of the whole defence sector, accenting indigenous innovation. Hence, the approach dictated by "high-technology condition" was later declined

[61] Xiaobing Li, *A History of the Modern Chinese Army* (University Press of Kentucky, 2007), 123–25.
[62] Tai Ming Cheung, *Fortifying China: The Struggle to Build a Modern Defense Economy* (Ithaca: Cornell University Press, 2009), 102–19.
[63] Stockholm International Peace Research Institute, *SIPRI Yearbook 1998*, Armaments, Disarmament and International Security (Oxford: Oxford University Press, 1998), https://www.sipri.org/yearbook/1998.
[64] Richard Bitzinger, *Arming Asia: Technonationalism and Its Impact on Local Defense Industries*, Routledge Security in Asia Series 11 (London; New York: Routledge, Taylor & Francis Group, 2017), 49–57.

into *informatisation* and *intelligentisation*, with the goal of leapfrogging the capabilities of superior military forces. Although not defined publicly, the first term can be traced back to the development of net-centric capabilities to deploy "real-time, data-networked command and control […] and precision strike"[65], exploiting space, cyber and electromagnetic warfare to incapacitate enemy systems. The second term is more recent, and it indicates the employment of AI, big data, and advanced automation to enhance (chaoplexic)[66] warfare and shorten the OODA (observe, orient, decide, act) loop.[67]

The Western arms embargo on China, issued in 1989 and never lifted, combined with the US interpretation of the Wassenaar Arrangement (and consequent pressure on its allies), has shaped Beijing's approach towards armament. Faced with hindrances to its modernisation strategy, the Chinese Communist Party (CCP) was forced to rely on imports of critical weapon systems and advanced components from post-Soviet countries and Israel[68]. The coping tactics deployed to circumvent the imposed bottlenecks, deepened in the chapter regarding Chinese policies, include technological transfers through investments or joint ventures, R&D collaborations, reverse engineering, (cyber)espionage, and import substitution.[69]

Despite remarkable steps forward, China is weighted down by the structural weaknesses inherited from the USSR. Top-down reforms combined with the absence of proper internal competition have produced numerous inefficiencies and overlapping structures, while

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[65] U.S. Department of Defense, 'Military and Security Developments Involving the People's Republic of China 2019', Annual Report to Congress (U.S. Department of Defense, 2 May 2019), iii, https://www.defense.gov/Newsroom/Publications/.

[66] Antoine Bousquet, 'Chaoplexic Warfare or the Future of Military Organization', *International Affairs* 84, no. 5 (September 2008): 915–29, https://doi.org/10.1111/j.1468-2346.2008.00746.x.

[67] International Institute for Strategic Studies, *The Military Balance 2020: The Annual Assessment of Global Military Capabilities and Defence Economics* (London: Routledge, 2020), 9–10.

[68] Until 2005, when US pressures forced Tel Aviv to halt defence technology exports to China. *See* Shira Efron et al., *The Evolving Israel-China Relationship* (RAND Corporation, 2019), 15–20, https://doi.org/10.7249/RR2641; Conal Urquhart, 'US Acts over Israeli Arms Sales to China', *The Guardian*, 12 June 2005, sec. Middle East, http://www.theguardian.com/world/2005/jun/13/usa.israel.

[69] Sarah Kirchberger and Johannes Mohr, *The Economics of the Global Defence Industry*, ed. Keith Hartley and Jean Belin, 1st ed., vol. 16, Routledge Studies in Defence and Peace Economics (Milton Park, Abingdon, Oxon; New York: Routledge, 2019), 48, https://doi.org/10.4324/9780429466793.

excessive secrecy and bureaucracy, corruption, and local compartmentalisation and protectionism have resulted in an environment of stifled innovation bordering on the Soviet one.[70] Nevertheless, China is not the USSR, and it has learnt from the demise of the latter. Beijing is occupied building a first-rate military by enforcing policies pursuing advancements to achieve global technological leadership by 2049, year of the 100th anniversary of the People's Republic of China. Thus, at least since its 10th Five-Year Plan (2001-2005), the CCP has been pushing civil-military integration in order to bring qualitative dynamism and efficiency to the overwhelmingly state-owned defence sector.[71] The crucial linchpins of this effort are dual-use technologies, as they allow the establishment of synergies between the two sides of the economy. The 863 Programme, created in 1986 to oversee the development of strategic weapons, was remodelled in 2001 to direct joint R&D. Among the 1500 projects, the most relevant include breakthroughs in the fields of space, super-large-scale integrated circuits, and new materials.[72] Furthermore, dual-use technologies are easily imported given the faulty mechanism underlying the Wassenaar Arrangement, implying Beijing can avoid falling too far behind by buying what it cannot autonomously develop.

While the 12th Five-Year Plan (2011-2016) encompassed investments for $600 billion in strategic sectors, given the cloak of secrecy surrounding the actual employment of the subsidies, it is hard to determine the actual degrees of productivity and profitability of the Chinese defence sector.[73] It has been estimated that as much as 20 per cent of the 2015 $50 billion budget earmarked for defence procurement was destined to R&D, making China the second or third-highest defence-R&D spender in the world.[74] Capital is then a crucial factor, as it somehow counterbalances structural deficiencies and allows Beijing to focus on "strategic,

70 Cheung, *Fortifying China*, 5–9.
71 James A. Lewis, 'Semiconductors and Modern Defense Spending', Center for Strategic & International Studies, 8 September 2020, https://www.csis.org/analysis/semiconductors-and-modern-defense-spending.
72 Cheung, *Fortifying China*, 190–95.
73 Kirchberger and Mohr, *The Economics of the Global Defence Industry*, 16:53.
74 Bitzinger, *Arming Asia*, 67.

cutting-edge or revolutionary capabilities"[75] in order to foster indigenous innovation, autarky and civil-military integration. To these ends, the capital flow is directed by state-owned banks and closely monitored by the State Council. Even more so since 2017, when the PLA's Central Military Commission was reformed, and the CCP Committees assumed most of its functions, further tightening the grip of the Party over the armed forces.[76]

Playing a central role in the building of Xi Jinping's "Chinese Dream"[77], the defence sector has experienced unprecedented levels of support. Despite state incentives and being listed among SIPRI's top five weapons exporters, China has been dubbed a "niche innovator"[78] for it has been struggling to develop highly engineered systems. Therefore, Beijing is still actively pushing the harnessing of cutting-edge dual-use technologies in fields able to leapfrog its capacity. Notably, the list encompasses emerging and disruptive technologies such as AI, robotics, autonomous systems, and the components powering them like semiconductors.[79]

Before analysing procurement policies and methods the CCP employs to build domestic mass, an overview of the semiconductor supply chain is given so that implications and inherent trade-offs become clear.

CHAPTER 3. Global Supply Chain

The semiconductor industry is remarkably globalised, and the average production of a chip typically spans over four countries and 40000 kilometres. The causes are to be found in the structure of the model created to contain outlays and leverage specialist knowledge. Hence, since the mid-1990s, vertically integrated device manufacturers (IDMs) have become the

[75] International Institute for Strategic Studies, *The Military Balance 2018: The Annual Assessment of Global Military Capabilities and Defence Economics* (London: Routledge, 2018), 233.
[76] International Institute for Strategic Studies, *The Military Balance 2020*, 11–12.
[77] Robert Lawrence Kuhn, 'Xi Jinping's Chinese Dream', *The New York Times*, 4 June 2013, sec. Opinion, https://www.nytimes.com/2013/06/05/opinion/global/xi-jinpings-chinese-dream.html.
[78] Bitzinger, *Arming Asia*, 68.
[79] Kirchberger and Mohr, *The Economics of the Global Defence Industry*, 16:59.

exception in favour of segmented fabless-foundry[80] archetypes. Dividing the production process, former IDMs outsourced the fabrication stage to dedicated (pure-play) foundries, allowing specialisation and targeted investments. Some of the main specialisation instances are Intel[81] focusing on desktop and PC CPUs, Qualcomm on smartphone system-on-a-chip, TSMC on 10 nm semiconductors and below, ASML on lithography equipment, Samsung on memory, Nvidia on GPUs, South Korea on wafers, Japan on wafers and manufacturing chemicals.[82] While capital-intensive steps requiring high-specialisation and cutting-edge equipment are primarily concentrated in Europe and North America, the labour-intensive portions are usually located in countries with lower wages and taxes, notably Southeast Asia. The high degree of segmentation favours efficiency but generates long supply chains, dependence and disruptions undermining autarky and fuelling conflict.

Research and Development

The overarching imperative of the industry concerns R&D. It embodies the exasperated self-feeding cycle powering the semiconductor market along all the supply chain. Companies compete to offer better equipment, performances, or services for winners seize most of their niche revenue in the characteristic oligopolistic market structure. Larger revenues mean larger margins and reinvestments nurturing further innovation and specialisation to maintain the lead. Therefore, integrated circuits are the segment accounting for almost a quarter of the global R&D spending. The most recent data illustrate the 2019 R&D average expenditures as a percentage of sales, showing the US as the country reinvesting the most profits (16.4 per cent),

[80] "Fab" or "foundry" are the names commonly used to indicate semiconductor manufacturing facilities.
[81] Intel remains one of the few IDMs.
[82] Harald Bauer et al., 'Semiconductor Design and Manufacturing: Achieving Leading-Edge Capabilities', Advanced Electronics (McKinsey & Company, 20 August 2020), 4, https://www.mckinsey.com/industries/advanced-electronics/our-insights/semiconductor-design-and-manufacturing-achieving-leading-edge-capabilities.

followed by Europe (15.3), Taiwan (10.3), Japan (8.4), China (8.3), Korea (7.7), and other countries (5.6).[83]

The 2017 dataset shows the top R&D spenders and the value of their investments. While US firms accounted for half of the top ten positions, the placement changed as the remaining ones were split among South Korean, Japanese, and Taiwanese companies. The US claimed the first three places ordered by investment value with Intel, Qualcomm, and Broadcom. Even though all their R&D investments as a percentage of sales were around 20 per cent, Intel's $13.1 billion expenditure corresponded to the amount invested by the companies in the following four positions, embodiment of the winner-takes-most market structure mentioned beforehand.[84]

Raw Materials

The supply chain starts from raw materials. Depending on the characteristics needed, silicon or gallium compounds are the main choices. The latter is gaining more and more attention in the light of the foreseen expiry of Moore's law. Given the increasing costs and technical production challenges, the pace of development has recently slowed down, and the miniaturisation of chips is expected to reach the barrier of atom size in a couple of generations. Consequently, part of the research focus has shifted on improvements that continue to provide enhanced performances, such as the employment of gallium compounds instead of silicon. In both cases, China is the global player with the lion's share of said elements' production and reserves (Appendix 1).[85] The supply chain is just at its beginning, and this is only the first example of a long history of global mutual dependence.

[83] Héctor Hernández et al., *The 2019 EU Industrial R&D Investment Scoreboard.* (Luxembourg: Publications Office of the European Union: Joint Research Centre, 2019), 29, https://op.europa.eu/publication/manifestation_identifier/PUB_KJBD19001ENN.
[84] You, 'Semiconductors and the U.S.-China Innovation Race'.
[85] Emily K. Schnebele, 'Silicon', Mineral Commodity Summaries (U.S. Geological Survey, January 2021), 148–49, https://pubs.er.usgs.gov/publication/mcs2021.

Production

The second stage is the production phase, consisting of designing, manufacturing, and assembly, testing and packaging (ATP). The pandemic and the request for technology have bolstered the fabless approach to production, pushing for further process segmentation and, although IDMs are defined by the in-house production, even they are increasingly outsourcing the last phase to ATP services. The reason is that ATP is labour-intense and accounts only for 10 per cent of the chip value, whereas the main revenue comes from the first two production stages.

Fabless design companies ordered by their 2019 revenue highlight again a US preponderance, followed by Taiwan, Russia, and the UK: the first three firms in the top ten (Qualcomm, Broadcom and Nvidia) are based in the US and account for 60 per cent of the list's income. The margin constitutes insurance of continuity, as pursuing innovation will prove more and more expensive. In fact, as chips get smaller, design becomes more complex, having to take into account quantum effects and minor structural variations. Consequently, expenses will surge. Designing one 5 nm semiconductor totals $540 million, almost twice the amount needed for a 7 nm one and over three times the cost of a 10 nm chip.[86]

Manufacturing mainly depends on Germany, Japan, Netherlands, and the US for equipment and on China, South Korea, Taiwan, and the US for foundries.[87] Although with substantial difference in magnitude, the duo TSMC-UMC grants Taiwan a remarkable 47 per cent of the global capacity for chips of 10 nm and below. Steady leader in the foundry niche, TSMC has never relinquished the top position in 33 years, as illustrated by the fraction of revenues left to

[86] Bauer et al., 'Semiconductor Design and Manufacturing: Achieving Leading-Edge Capabilities', 5.
[87] TrendForce, 'Top 10 Foundry Revenues Expected to Increase by 18% YoY in 4Q20', *EE Times Asia* (blog), 8 December 2020, https://www.eetasia.com/top-10-foundry-revenues-expected-to-increase-by-18-yoy-in-4q20/.

the Korean runner-up, Samsung.[88] The manufacturing process roughly consists of creating silicon ingots, cutting them into blank wafers later filled with microelectronics and, in turn, sorted and cut into dies. Notably, Japan is a recognised leader in the wafer cutting industry, including supplies of chemicals materials, fabrication, and packaging. Specialised in a complementary field, the Dutch firm ASML is the only producer of extreme ultraviolet (EUV) lithography machines essential to create 5 nm chips.[89]

In 2026, the manufacturing market is expected to reach $119 billion, doubling its 2018 value, driven by the increasing sophistication and rising fixed costs. The standard lithography equipment alone costs around $100 million per unit, while the EUV necessary for 7 nm semiconductors can amount to 70 per cent more. Therefore, building and equipping a state-of-the-art 5 nm facility costs between $5 billion and $20 billion, three to twelve times the outlay for a 10 nm one. The operating expenses vary between $0.6 billion and $2 billion, making the total cost of ownership over ten years $11 billion to $40 billion.[90] To contextualise, the cost of the latest US Navy Ford-class aircraft carrier is about $13 billion per ship.[91] Besides, there is the issue of capacity. Considering that building the shell of a fab can take up to 24 months and 12 to 18 more months are necessary to ramp up production, running a facility at maximum capacity means that, in the best-case scenario, the investment breaks even in at least five years.[92] Any lower volume would mean longer timeframes before registering a positive cash inflow.

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[88] Christopher A. Thomas, ‘Lagging but Motivated: The State of China’s Semiconductor Industry’, *Brookings - Tech Stream* (blog), 7 January 2021, https://www.brookings.edu/techstream/lagging-but-motivated-the-state-of-chinas-semiconductor-industry/.
[89] You, ‘Semiconductors and the U.S.-China Innovation Race’.
[90] Antonio Varas et al., ‘Government Incentives and US Competitiveness in Semiconductor Manufacturing’ (Boston Consulting Group and Semiconductor Industry Association, 16 September 2020), 17, https://www.bcg.com/publications/2020/incentives-and-competitiveness-in-semiconductor-manufacturing.
[91] Brad Howard, ‘Expensive, Massive and Lethal: The Future of the Aircraft Carrier’, *CNBC*, 23 February 2021, sec. Digital Original, https://www.cnbc.com/2021/02/23/-expensive-massive-and-lethal-the-future-of-the-aircraft-carrier.html.
[92] Bauer et al., ‘Semiconductor Design and Manufacturing: Achieving Leading-Edge Capabilities’, 6.

ATP gets chips ready for shipment. Being a labour-intense stage, it is performed mainly in countries with low wages, such as China, Japan, Korea, Malaysia, Philippines, Portugal, and Vietnam. However, despite the location of the facilities, the firms' headquarters are mostly based in Taiwan (market share by revenue: 54 per cent), the US (17), China (12), Singapore (12), and Japan (5).[93]

Distribution

In the final stage of the semiconductor production process, chips are shipped to equipment manufacturers, either directly to the original ones (OEMs) or to intermediate services (EMS) that provide test, assembly, and return/repair assistance to OEMs. Taiwan possesses 75 per cent of the EMS market, primarily thanks to Foxconn holding half of the global revenue.

In terms of sales to consumers and other companies, Appendix 2 depicts the predominance of actors and the countries in which they are based, notably the Netherlands, South Korea, Taiwan, and the US.[94]

Actors

AI applications are projected to grow by 150 per cent in 2022,[95] and, given the broader role semiconductors play in powering current systems and emerging and disruptive technologies, such as quantum computing, 5G, Internet of Things, and autonomous systems, they are a strategic asset for states. COVID-19 has merely added motives to their prioritisation. As outlined in the previous sections, several countries and companies are involved in the production process, implying mutual dependence and vulnerability to the disruptions of a

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93 You, 'Semiconductors and the U.S.-China Innovation Race'.
94 Natalia Drozdiak and Aoife White, 'EU Kicks Off Race to Produce Advanced Semiconductors by 2030', *Bloomberg*, 9 March 2021, https://www.bloomberg.com/news/articles/2021-03-09/eu-sets-2030-goals-to-secure-tech-sovereignty-from-u-s-asia.
95 PwC, 'Opportunities for the Global Semiconductor Market: Growing Market Share by Embracing AI', PricewaterhouseCoopers, 2019, https://www.pwc.com/gx/en/industries/tmt/publications/global-tmt-semiconductor-report-2019.html.

convoluted supply chain. What is showcased by the pandemic might be replicated by natural disasters or geopolitical disputes. Consequently, states are striving for self-reliance or, at least, reduced dependence to protect sovereignty. The present section analyses the posture and motives of the main actors, lingering over the clash between the US and China, whose stakes concern the whole international system. Furthermore, attention is dedicated to the rise of East Asian countries, a useful benchmark to showcase the difficulties China faces.

United States

For the last three decades, the US has led the integrated circuit industry, reporting roughly half of the global revenues. Its firms are relevant in many steps of the supply chain and remarkably in R&D, making the expenditure on semiconductors the second-highest in the country after the pharmaceutical sector. Furthermore, advanced chips are the US fifth most important export, generating the revenue necessary to produce economic growth and feed the cycle pursuing innovation to maintain the headship. However, the focus on the fabless model has entailed complacency concerning manufacturing. In the 1990s, the US share of said production segment was 37 per cent, while it now amounts to a mere 12 per cent, far below the threshold maintained in other strategic industries.[96] The decline was not caused by shutdowns or offshoring. On the contrary, the industry has been expanding. Yet, the pace has been slower than that of its Asian competitors. The supply chain is intrinsically global, and the US does not perceive the pursuit of semiconductor self-reliance (other than the one necessary to power strategic sectors) as a priority. Still, a stronger semiconductor manufacturing segment means higher resilience and fewer disruptions, increased exports and surplus, and more reinvestments granting continuity. Estimates foresee a 5 per cent increase in semiconductor demand over the next decade, meaning a 56 per cent growth of the manufacturing capacity (or 10 million wafers per month).

[96] Aerospace (49 per cent), medical equipment (25), pharmaceuticals (23), petrochemicals (19). *See* Varas et al., 'Government Incentives and US Competitiveness in Semiconductor Manufacturing', 6.

Consequently, countries announced campaigns to seize the opportunity and a more significant share in the market. At the end of the second quarter of 2020, half of the prospected production had been addressed, comprising the US plan to develop its industry to address 3 per cent of the total (Appendix 3).[97] However, said percentage would not be enough, resulting in a further reduction of its global share by two points before 2030. To reverse the trend, the US needs to claim a percentage of the remaining new capacity ("white space") and attract a higher number of manufacturers. Recognising the closing window of opportunity, Washington promotes policies, spearheaded by the $50 billion incentive proposed *CHIPS for America Act*,[98] to provide viable solutions. Subsidising the construction of 10 fabs on US soil would address 24 per cent of the white space estimated for 2030 and, added to the 80 already operating and the status quo 9, the new facilities would result in a total US capacity of 14 per cent, four points more than the status quo projections. Becoming a competitive location, the US would be able to invert the trend avoiding the vicious circle shrinking its footprint. Contextually, it would also cover the demand stemming from the strategic defence and aerospace industries.[99]

As for the defence sector, government support is critical in de-risking investments. The demand is volatile, and the oligopoly market structure implies reliance on a small number of actors, able to cause downstream supply chain disruption following a single missed deadline. To understand why the stimulus could prove decisive, recalling the cost and timing of building and operating a fab is essential. With an upfront outlay of several billion, elevated operating costs, and years before breaking even the investment, state incentives are the most critical component influencing firms' decisions in picking fab locations. Other factors include synergies with existing footprints, access to talent, intellectual propriety and asset protection, and cost of labour. While the US scores high in the first three elements, in the latter and in

[97] Varas et al., 22.

[98] Tom Cotton Sen. [R-AR], 'American Foundries Act of 2020', S.4130 § (2020), https://www.congress.gov/bill/116th-congress/senate-bill/4130.

[99] Varas et al., 'Government Incentives and US Competitiveness in Semiconductor Manufacturing', 23–24.

government incentives, it is overshadowed by East Asian countries. Notably, a fab in the US entails running costs 30 per cent higher than in Taiwan and Singapore and up to 50 per cent more than in China (Appendix 4), considering its additional incentives for multinational companies sharing technology. The differences are explained through disparities in construction costs (up to 40 per cent of the gap), labour and utility costs (up to 40 per cent of the gap), but primarily by government incentives (up to 70 per cent of the gap).[100]

As mentioned in the first chapter, the Cold War witnessed the emergence of semiconductor industries among US allies. Benefitting from latecomer advantages, said countries were able to skip basic research and the construction of supply chains. Among the factors driving the sector's growth, political support had always proved crucial, especially in kickstarting or supporting the industry when it was losing momentum.

Japan

Japan managed to develop its semiconductor ecosystem starting as early as the 1960s. Its protectionist conditions allowed Tokyo to obtain licences from US firms while restricting their access to the Japanese market. Government support also sponsored collaborative research and knowledge spillovers, fostering high degrees of specialisation regarding enhanced manufacturing techniques rather than the product innovation characterising the US. The tightly-knitted ecosystem provided rapid feedback from end-users, shaping successful conjunctures between offer and demand. Furthermore, favourable policies and close links with banks assured investments during periods of market contraction. The Japanese model was so successful that it reduced the US market share by 50 per cent, leading Washington to intervene and force Tokyo into signing the 1986 *US-Japan Semiconductor Agreement*.[101] The

[100] Varas et al., 19–20.
[101] VerWey, 'Chinese Semiconductor Industrial Policy: Prospects for Future Success', 5; Johnson, 'The U.S.-Japan Semiconductor Agreement'.

competition suffered by US companies had led them to start offshoring labour-intensive segments of production to countries with lower wages, such as Taiwan or South Korea, de facto initiating the delocalisation process igniting the transition from the IDM to the fabless paradigm, laying the foundations for the dominant supply chain structure.

Taiwan

Following the establishment of a US ATP facility in the 1970s, Taipei sponsored the establishment of research institutes and science parks to acquire semiconductor technology. In the following decade, the policies allowed for the creation of domestic firms, including UMC, and spurred the return of almost 20000 US-trained technicians. Among them, Morris Chang, who later founded the first pure-play foundry and current sector leader, TSMC. By the turn of the millennium, Taiwan possessed a complete ecosystem, able to meet 91 per cent of the domestic manufacturing demand and 99 per cent of ATP requests.[102]

Currently possessing almost half of the global capacity for leading-edge chips, Taipei plays a vital role in semiconductors production. Its relevance has a strategic value dubbed "the Silicon Shield" and is employed to hedge against potential hostilities stemming from Beijing. However, despite the distancing attempt made with the 2016 *Southbound Policy*, Taiwan remains deeply linked to China, its major economic partner.[103]

Considering its ownership of most of the foundry market across the strait, combined with the fact that Chinese chip orders doubled in 2019 and that trade towards North America amounted to 59 per cent of its revenue, TSMC has long tried to maintain friendly ties with both parties. Still, given Taipei's reliance on security and the US importance for income and reinvestments, the foundry had to comply with the restrictions issued in Washington, halting collaborations with Huawei. Yet, like many other countries, Taiwan is moving to reduce its dependence on

[102] VerWey, 'Chinese Semiconductor Industrial Policy: Prospects for Future Success', 6.
[103] You, 'Semiconductors and the U.S.-China Innovation Race'.

US semiconductor manufacturing equipment to minimise the repercussion of the trade war on its economy.

After the facts in Hong Kong, analyses registered the increasing assertiveness of the CCP and its willingness to take stronger international stances.[104] Coercive non-military actions against Taiwan have already started and included cyberattacks to steal IP, the possibility to exploit bylaws to let Huawei sue TSMC over the severed links, and threats of integrated circuit raw material restrictions, Chinese de facto monopoly. While military aggression is not ruled out, chips are estimated may be part of the motive but not the primary cause.[105]

South Korea

The rise of its semiconductor history is similar to the ones of the previous Asian countries. South Korean low wages attracted ATP facilities, and from the 1970s, domestic industries began to climb the value chain, specialising in DRAM chips. Once again, governmental support proved essential, limiting foreign investments, establishing research institutes, providing tax breaks, low-interest loans, and financing R&D and cooperative research. As a result, the 1980s witnessed the rise of *chaebols*, typical massive industrial complexes, such as Samsung, Hyundai, and LG. The intense competition among them kept pushing innovation at a rapid pace, fostering growth despite moments of market crisis. When *the US-Japan Semiconductor Agreement* was signed, Tokyo progressively reduced its DRAM export quotas, but, unable to sustain the competition, many US firms had already exited the memory market. South Korean companies took over, maintaining leadership in the semiconductor niche up to this day.[106]

[104] Michael J. Green and Evan Medeiros, 'Is Taiwan the Next Hong Kong?', 8 July 2020, https://www.foreignaffairs.com/articles/east-asia/2020-07-08/taiwan-next-hong-kong.
[105] You, 'Semiconductors and the U.S.-China Innovation Race'; Evan Burke et al., 'Survey of Chinese-Linked Espionage in the United States Since 2000', Center for Strategic & International Studies, accessed 20 July 2021, https://www.csis.org/programs/technology-policy-program/survey-chinese-linked-espionage-united-states-2000.
[106] VerWey, 'Chinese Semiconductor Industrial Policy: Prospects for Future Success', 7.

European Union

Although Europe had managed to leverage its industrial base to produce transistors already in the 1950s, the support the US provided to its domestic industry soon proved decisive and determined the breakaway needed to achieve and maintain the global leadership. Falling behind, Europe focused on discrete semiconductors devices[107], relying on imports to satisfy its demand for digital integrated circuits. Since the 1970s, many governments have attempted programmes to support their firms, with mixed results.[108] In the 1990s, to boost their efficiency, IDMs initiated a transition towards the fabless model and, from 44 per cent, the EU now accounts for less than 10 per cent of the global manufacturing capacity, with the projected status quo contraction of one more point over the next decade (Appendix 5).[109]

The current EU specialisation encompasses semiconductors for the automotive industry and industrial machinery, implying a pronounced dependence on the US for design tools and Asia for advanced chip manufacturing.[110] Worried about the increasing geopolitical tensions disrupting the supply chain as COVID-19 had just done, in December 2020, a group of EU countries announced a *European Initiative on Processors and Semiconductor Technologies*. Although the official strategy is still to be revealed in its details, there are rumours of talks with Samsung, TSMC, and Intel to repurpose existing fabs or establish new ones on the continent to produce 5 to (eventually) 2 nm semiconductors. According to the EU Industry Commissioner Breton, the goal is to reach a production amounting to 20 per cent of the global value by 2030,

[107] "Discrete semiconductors are single devices with a single function, such as transistors and diodes". *See* Toshiba, 'Basic Knowledge OfDiscrete Semiconductor Device', September 2018, 8, https://toshiba.semicon-storage.com/content/dam/toshiba-ss-v2/master/en/semiconductor/knowledge/e-learning/discrete/discrete-basic-chap1_en.pdf.

[108] Franco Malerba, 'Demand Structure and Technological Change: The Case of the European Semiconductor Industry', *Research Policy* 14, no. 5 (July 1985): 284–85, https://doi.org/10.1016/0048-7333(85)90010-1.

[109] Varas et al., 'Government Incentives and US Competitiveness in Semiconductor Manufacturing', 7.

[110] European Commission, 'Strategic Dependencies and Capabilities', Commission Staff Working Document, Internal Market, Industry, Entrepreneurship and SMEs (Brussels: European Commission, 5 May 2021), 82–90, https://ec.europa.eu/info/sites/default/files/swd-strategic-dependencies-capacities_en.pdf.

with a public-private investment of €30 billion.[111] Although nothing is official, the pursuit of digital sovereignty and the set objective need to presuppose a more protracted and expensive commitment than the one indicated by the leaked figures, considering the unavoidable time to restructure ecosystems and supply chains.

CHAPTER 4. Chinese Policies

Since the development of its first semiconductor, almost a decade after the US, Beijing has tried to help its industry gain momentum. What started as a Reaction soon turned into an attempt to build a viable Domestic Structure. China consumes 60 per cent of all the integrated circuits available on the global market, and semiconductors are its main net import. The consumption-production balance reached negative $350 billion in 2020, marking a 15 per cent year-over-year increase.[112] Even excluding the share of foreign companies based there, China accounts for 23 per cent of the global chip demand. The possession of only 5 per cent of the total chip share, primarily centred on the ATP stage, makes the country heavily reliant on imports and worried about this strategic dependence. Hence, knowing the swelling strategic role played by chips, it should not surprise the determination Beijing has been showing in its endeavour towards creating a closed-loop chip manufacturing ecosystem.[113]

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[111] Natalia Drozdiak and Helene Fouquet, 'EU Weighs Deal With TSMC, Samsung for Semiconductor Foundry', *Bloomberg*, 11 February 2021, sec. Business, https://www.bloomberg.com/news/articles/2021-02-11/europe-weighs-semiconductor-foundry-to-fix-supply-chain-risk; Drozdiak and White, 'EU Kicks Off Race to Produce Advanced Semiconductors by 2030'; European Commission, 'Member States Join Forces for a European Initiative on Processors and Semiconductor Technologies', Press Release, 7 December 2020, https://digital-strategy.ec.europa.eu/en/news/member-states-join-forces-european-initiative-processors-and-semiconductor-technologies; Akinori Kahata, 'Semiconductors as Natural Resources – Exploring the National Security Dimensions of U.S.-China Technology Competition', Center for Strategic & International Studies, 17 February 2021, https://www.csis.org/blogs/technology-policy-blog/semiconductors-natural-resources-%E2%80%93-exploring-national-security; Luca Bertuzzi, 'Leading Chip-Maker Answers EU Call to Scale up European Capacity', *Euractiv*, 10 June 2021, sec. Digital & Media, https://www.euractiv.com/section/digital/news/leading-chip-maker-answers-eu-call-to-scale-up-european-capacity/.

[112] Masha Borak, 'China Made More Chips in 2020, but Also Imported More', *South China Morning Post*, 19 January 2021, sec. Tech/Policy, https://www.scmp.com/tech/policy/article/3118327/china-boosts-semiconductor-production-2020-imports-keep-apace.

[113] You, 'Semiconductors and the U.S.-China Innovation Race'.

Alternating phases of autarky and efficiency, Chinese politics worked to take part in the innovation process, issuing over a hundred semiconductor development policies only in the last decade.[114] In this chapter, the endeavour is outlined in four main periods, the progression showing growing resolve and resources deployed to sustain the sector, remarkably after Beijing's decision to modernise its armed forces, exploit dual-use technologies, and enforce civil-military integration. Highlighting the methods employed to pursue a viable and cutting-edge technological industry allows for the analysis of the international responses to Beijing's tactics, to understand why they were often frustrated and why the slowing pace of Moore's law might finally allow China to catch up.

1956-1990

China developed its first semiconductor in 1956 and promptly recognised it as a priority in the *Outline for Science and Technology Development, 1956–1967*. The event marked the beginning of a Soviet-organised, self-sufficient industry oriented to the military use of the technology and therefore entirely sustained by state-sponsored R&D and state-owned facilities. However, in 1965 and for the following decade, the Cultural Revolution interrupted all progress, so that Xiaoping's reforms found an extremely backwards industry, with standards incompatible with the international ones. Indigenous development was then abandoned for efficiency, and the *Computer and Large-Scale IC Lead Group* was created to advance the industry.[115]

Under the 6th Five-Year Plan (1981-1985), the Group supervised the import of entire second-hand production lines, hoping to kickstart the domestic sector. Yet the effort was met with

[114] John VerWey, 'Chinese Semiconductor Industrial Policy: Past and Present', *Journal of International Commerce & Economics*, 2019, 9.
[115] VerWey, 10.

limited success, and in 1986 Chinese semiconductors were still five generations behind the leading-edge, implying ten to fifteen years of development.[116]

1990-2002

Given the inability to meet the fixed quotas and the growing domestic demand,[117] the CCP decided to focus on only five companies instead of thirty. They were endowed with capital in order to pursue joint ventures and facilitate the transfer of technology. While many partnerships were started, the boldest one was included in the 8th Five-Year Plan (1991-1995). Dubbed *Project 908*, it devised a collaboration with US Lucent Technologies to create a cutting-edge Chinese IDM. However, when the terms were finally agreed upon and the deal licensed by US authorities, the technology employed was already outdated by almost a decade, frustrating Beijing's ambitions. Consequently, the 9th Five-Year Plan (1996-2000) launched *Project 909*. The joint venture was established between the Chinese Huahong and the Japanese NEC to produce DRAM chips. While production started on time, in 2002 the memory chips market experienced a negative swing, leading to conspicuous losses and the repurposing of Huahong as a foundry. Moreover, in the attempt to avoid the delay characterising the first try, the project secured little know-how transfer, for it had employed only Japanese engineers.[118]

2002-2014

Despite the illustrated failures, Beijing did not cease pursuing the creation of a viable domestic semiconductor ecosystem. Even more so after 2005, when it became the major semiconductor consumer in the world.

[116] General Accounting Office, 'Rapid Advances in China's Semiconductor Industry Underscore Need for Fundamental U.S. Policy Review', 10.
[117117] In 1989, the gap production/consumption was roughly of 300 billion units, but already in 1995, it had grown to 4.5 billion. *See* Majerowicz and Medeiros, 'Chinese Industrial Policy in the Geopolitics of the Information Age: The Case of Semiconductors', 17.
[118] VerWey, 'Chinese Semiconductor Industrial Policy: Past and Present', 11; Majerowicz and Medeiros, 'Chinese Industrial Policy in the Geopolitics of the Information Age: The Case of Semiconductors', 17.

In 2001, the access to the WTO, after years of negotiations, had made the Chinese market attractive to foreign firms, reducing tariffs and boosting its exports. Notably, tax incentives were offered to all the integrated circuit companies located in China, along with R&D, education, and infrastructure state investments. In the said environment, SMIC was founded and took its first steps towards becoming one of the top five foundries in the world. The support provided by the CCP proved central in making the facility the most advanced in the country, and so did the recall and recruitment of Chinese engineers from abroad, allowing SMIC to maintain just a couple of generations behind the leading companies. Besides, the fabless design portion of the supply chain was incentivised to create demand for the newly established foundries.[119]

The favourable moment in the economy intersected with the 1990s push towards the modernisation of the defence sector. To harness and combine the two currents, the 10th Five-Year Plan (2001-2005) formalised the concept of civil-military integration. In 2005, the State Council promulgated the *Medium- and Long-Term Plan for Science and Technology Development*. The policy aimed at shaping the technology landscape in the country until 2020, envisioning a unitary ecosystem in which semiconductors were the "core technology for future advances". As a consequence, Beijing revived the indigenous innovation narrative, pushing for technology transfer via targeted acquisitions and partnerships with foreign firms.[120] The importance given to integrated circuits becomes even more relevant in the light of the Chinese choice to opt for dual-use technologies to circumvent the Western arms embargo.

[119] Majerowicz and Medeiros, 'Chinese Industrial Policy in the Geopolitics of the Information Age: The Case of Semiconductors', 18–19.
[120] VerWey, 'Chinese Semiconductor Industrial Policy: Past and Present', 12.

2014-Present

Snowden blowing the whistle on PRISM gave the world a practical demonstration of the national security implications stemming from technology. The participation of US semiconductor companies in the NSA surveillance programme merely added to the autarky motives Beijing already possessed. Hence, the State Council passed laws to ensure the "controllability" of technology, granting local data storage, disclosing encryption keys and source codes, and privileging local products. US firms in China were put under pressure, as the propaganda stressed the need to boycott the eight US "guardian warriors".[121]

In 2014, the State Council issued the *National Guidelines for Development and Promotion of the Integrated Circuit Industry*, reiterating the importance of supporting its national champions with resources to promote outward foreign direct investments (FDIs) [122], generate technology transfers, encourage import substitution, and ultimately bring the semiconductor industry to an advanced level by 2030.[123] To this end, the National Integrated Circuit Investment Fund was established and endowed with the initial sum of $150 billion. Its largest shareholders are the Ministry of Finance (36.74 per cent), China Development Bank Capital Corporation (22.29),

[121] Apple, Cisco, Google, IBM, Intel, Microsoft, Oracle, Qualcomm. *See* Majerowicz and Medeiros, 'Chinese Industrial Policy in the Geopolitics of the Information Age: The Case of Semiconductors', 23; Paul Triolo, 'The Future of China's Semiconductor Industry', *American Affairs Journal* V, no. 1 (Spring 2021), https://americanaffairsjournal.org/2021/02/the-future-of-chinas-semiconductor-industry/; Meia Nouwens, 'China's Digital Silk Road: Integration into National IT Infrastructure and Wider Implications for Western Defence Industries', *The International Institute for Strategic Studies*, February 2021, 8–9.

[122] "Foreign direct investment (FDI) is a category of cross-border investment in which an investor resident in one economy establishes a lasting interest in and a significant degree of influence over an enterprise resident in another economy. Ownership of 10 percent or more of the voting power in an enterprise in one economy by an investor in another economy is evidence of such a relationship. FDI is a key element in international economic integration because it creates stable and long-lasting links between economies. FDI is an important channel for the transfer of technology between countries, promotes international trade through access to foreign markets, and can be an important vehicle for economic development. The indicators covered in this group are inward and outward values for stocks, flows and income, by partner country and by industry and FDI restrictiveness." *See* OECD, 'Foreign Direct Investment (FDI)', OECD iLibrary, n.d., https://www.oecd-ilibrary.org/finance-and-investment/foreign-direct-investment-fdi/indicator-group/english_9a523b18-en.

[123] State Council, 'Guideline for the Promotion of the Development of the National Integrated Circuit Industry' (2014), https://members.wto.org/CRNAttachments/2014/SCMQ2/law47.pdf; Christopher A. Thomas, 'A New World under Construction: China and Semiconductors' (McKinsey & Company, 1 November 2015), https://www.mckinsey.com/featured-insights/asia-pacific/a-new-world-under-construction-china-and-semiconductors.

China Tobacco (11.14), but it is also subsidised by a plethora of local administrations and state-owned enterprises (SOEs).[124]

Made in China 2025

Promulgated in 2015 by the State Council, *Made in China 2025* (MIC2025) is an ambitious long-term strategy constituting the first phase in the roadmap towards achieving global technological leadership by 2049. Whereas many other policies had previously been put in place, none had such a broad scope, comparable political coordination levels, or financial backing.

The plan addresses ten sectors, including integrated circuits, and stems from the need to adapt and modernise the state economy to face future challenges, boosting its efficiency to escape the middle-income trap. Failing to do so would mean remaining stuck between developing and industrial countries, constantly dealing with pressure from both sides. Therefore, Beijing felt the urge to invest in the renewal of its underdeveloped industrial process to become a manufacturing superpower by the intermediary target of 2025. Drawing inspiration from the German *Industry 4.0* and the US *Industrial Internet* policies, MIC2025 aims at high-tech solutions to implement smart manufacturing and enhance productivity. Albeit stemming from bottom-up initiatives, Beijing's strategy is top-down. Hence, it must come to terms with the significant chasm between the political priority and the situation of its domestic industrial landscape. Determined to pursue its objective, the CCP has deployed many instruments to promote technological advancement, primarily employing financial incentives in the form of direct capital injections, low-interest loans, and tax rebates. It has been estimated that the government could tap into some 1,600 investment funds for a rough total of 4.5 per cent of GDP or $584.8 billion, a gargantuan sum if compared with the €200 million that Germany had

[124] U.S. Trade Representative, 'Findings of the Investigation into China's Acts, Policies, and Practices Related to Technology Transfer, Intellectual Property, and Innovation Under Section 301 of the Trade Act of 1974', § U.S. Trade Representative (2018), 93, https://ustr.gov/sites/default/files/section%20301%20final.pdf.

pledged for its policy.[125] The $150 billion endowed to the National Integrated Circuit Investment Fund represent 25 per cent of the total, highlighting the relevance of semiconductors in the eyes of the CCP.

The resolved political push towards industrial upgrade has produced an increasing demand for technology, attracting a high number of foreign companies. This dependence had been anticipated and labelled a vulnerability. To counter the strategic chokepoint, it was compelling for MIC2025 to include an autarky facet, as demonstrated by the ubiquitous mentions of self-sufficiency and indigenous innovation concepts. Although there are few benchmarks set by the policy itself, many semi-official documents bridge the gap by establishing quantitative market shares to be fulfilled by domestic suppliers before 2025. The employment of unofficial papers is a mere expedient to avoid being caught breaching WTO rules. Said dossiers are to be considered as an integral part of MIC2025, having also been endorsed by politicians and the then-Vice Premier Ma Kai. In the section dedicated to the next-generation IT, it is specified how China needs to "develop the IC design industry, speed up the development of the IC manufacturing industry, upgrade the advanced packaging and testing industry, facilitate breakthroughs in the key equipment and materials of integrated circuits"[126].

Nurturing its own companies and progressively increasing the restrictions to foreign tech suppliers, Beijing's technological nationalism strives to substitute the former with the latter. As such, MIC2025 is closely overseen and coordinated by Beijing via the Leading Small Group for Constructing a Manufacturing Superpower. Led by the Vice Premier, it also includes members of the State Council and relevant ministries, notably the Ministry of Industry and

[125] Tianlei Huang, 'Government-Guided Funds in China: Financing Vehicles for State Industrial Policy', Peterson Institute for International Economics, 17 June 2019, https://www.piie.com/blogs/china-economic-watch/government-guided-funds-china-financing-vehicles-state-industrial-policy; Jost Wübbeke et al., 'Made in China 2025. The Making of a High-Tech Superpower and Consequences for Industrial Countries', Papers on China (Mercator Institute for China Studies, December 2016), 11–13, https://merics.org/en/report/made-china-2025.

[126] State Council, 'Made In China 2025 Technical Roadmap' (2015), 2.

Information Technology. The Small Group directs four among research institutes and expert groups, in turn managing six entities in charge of the interaction with the industry.[127] This granular presence of the Party allows for tight control of the domestic market at the disadvantage of foreign companies excluded from favoured loans, hindered by domestic standards, and less likely to be awarded contracts or certifications of trustworthiness, indispensable to sell products within the Social Credit System project. Contextually to the increasing domestic barriers, at least 20 per cent of the European industries operating in China in 2018 had been pressured into transferring their technology in exchange for market access. Particularly targeted companies were active in sectors pertinent to MIC2025.[128] Technology transfer is one of the policies employed to skip basic R&D, and its supervision is traceable to the State Council itself. The practice evolved over time: initially focused on product components, it later expanded to encompass the technology necessary to shape them, and lastly to the science behind the produced innovation. Pursuing this scope, Chinese students are sent to study abroad while foreign talent is invited, literature-review monitoring systems are set up, technology-outreach offices work within ministries, and international industrial cooperation is promoted along with targeted acquisitions.[129]

State-Owned Enterprises

While the traditional Chinese industry faces issues in the adoption of smart manufacturing, MIC2025 favours a small élite of companies already accustomed to the competing environment of the international market and able to appreciate the necessity to invest in production upgrades.

[127] Wübbeke et al., 'Made in China 2025. The Making of a High-Tech Superpower and Consequences for Industrial Countries', 14–20.
[128] European Chamber of Commerce in China, 'Business Confidence Survey 2018', European Business In China (Beijing: European Chamber of Commerce in China, 2018 2076), 39, https://www.europeanchamber.com.cn/en/publications-archive/568; VerWey, 'Chinese Semiconductor Industrial Policy: Past and Present', 17–18.
[129] William C. Hannas and Huey-meei Changg, 'China's Access to Foreign AI Technology' (Washington, D.C.: Center for Security and Emerging Technology, September 2019), 3, https://cset.georgetown.edu/publication/chinas-access-to-foreign-ai-technology/.

Despite years of reforms, SOEs still account for 40 per cent of the Chinese industrial assets and, along with a small number of private companies, they are the main entities responsible for tech-seeking FDIs.[130] These national champions are seen as successful models by the state, which provides subsidies to obtain cutting-edge technology via strategic acquisitions to leapfrog otherwise lengthy development stages. Moreover, the loans lent to the industry via investment funds allow the Party to exert even tighter control on allegedly private companies, in addition to a rigid body of law and strictly overseen economy. Many CEOs are also either connected with or directly members of the Party, granting their enterprises a significantly higher number of bank credits.[131] Through a complex and opaque scheme of ownership and funding structures, or via the control regime of the capital flow, Beijing is the puppeteer behind most Chinese FDIs.[132] Directly controlled by the Party via the State Council's State-Owned Assets Supervision and Administration Commission, SOEs represent the ultimate blend of politics and economics, exploiting the latter to promote the former. To support the post-COVID-19 recovery, Beijing's posture shifted once more towards statism. It reverted to SOEs, reaffirming the central role of the Party in and over the economy, notwithstanding the robust economic performance in the second half of 2020 and old promises of more openness.[133] The anti-monopoly case against ANT Financial further demonstrates the low tolerance for private firms gaining too much influence.[134]

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[130] Kristel Buysse and Dennis Essers, 'Cheating Tiger, Tech-Savvy Dragon: Are Western Concerns about "Unfair Trade" and "Made in China 2025" Justified?', *National Bank of Belgium*, Economic Review, ii (26 September 2019): 7.

[131] Alicia Garcia-Herrero and Jianwei Xu, 'How to Handle State-Owned Enterprises in EU-China Investment Talks', *Bruegel*, Policy Contribution, no. 18 (June 2017): 11, https://doi.org/10.2139/ssrn.3160514.

[132] Since 2000, 60 per cent of Chinese investments in the EU originated by companies of which Beijing possesses at least one fifth of the stocks.

[133] Daniel H. Rosen and Lauren Gloudeman, 'Winter 2021 Update', The China Dashboard (Rhodium Group and Asia Society Policy Institute, 12 January 2021), 2, https://rhg.com/research/the-china-dashboard-winter-2021/.

[134] Li Yuan, 'What China Expects From Businesses: Total Surrender', *The New York Times*, 19 July 2021, sec. Technology, https://www.nytimes.com/2021/07/19/technology/what-china-expects-from-businesses-total-surrender.html.

Apart from the time span and the resources involved, indications of the policies importance come from Beijing issuing orders to avoid mentioning them or downplay their significance. The mammoth top-down chain of command deployed to pursue the objective grants to the CCP granular supervision of the policy implementation. SOEs and investment funds are seen as agents in the effort, whereas the relation with private companies and their capital is often ambivalent, swinging from conceding slightly more freedoms to sudden clampdowns. While FDIs do not constitute the only method carried out by Beijing to pursue said technologies, tracking them allows to gauge the extent of the Chinese commitment abroad. Alternative relevant methods are highlighted where possible, notably, venture capital (VC) in the US and R&D partnerships in the EU.

Initial Chinese investments were focused on large-market countries possessing natural resources and poor institutional bodies, mainly in Africa or Latin America. It is not until the economic crisis of 2008-2009 that Beijing started targeting industrial countries. Following said years, Chinese FDIs in the EU and the US steadily grew, peaking in 2016 when they respectively totalled €37.3 billion[135] and $46.45 billion,[136] representing an eighteen and a ten-fold increase since 2010. The exceptional nature of 2016 is to be found in the brief relaxation of capital flow by Chinese authorities and the inadequacy or complete absence of FDIs screening mechanisms in target countries. As further elaborated in the present section, the subsequent declining value epitomises the result of amendments to said instances and the rise of geopolitical tensions.

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[135] Agatha Kratz et al., 'Chinese FDI in Europe: 2019 Update', *Rhodium Group and the Mercator Institute for China Studies*, Papers on China, April 2020, 9.

[136] Rhodium Group and The National Committee on U.S.-China Relations, 'FDI Data', The US-China Investment Hub, 2021, https://www.us-china-investment.org/fdi-data.

United States

Foreign Direct Investments

Non-screened FDIs undermine the industrial countries' leadership in the targeted sectors, threatening to pull the rug out from under their innovation plans and global positioning, primarily via duplications and transfers. Emblematic was the early case of the Pentagon-supplier Magnequench when the manufacturer of permanent magnets was acquired by Chinese SOEs. Despite initial reassurances, the production was soon uprooted from Idaho Falls to a new plant in Tianjin, granting Beijing the global leadership in the critical high-tech niche while the US now possess no significant production.[137] Under MIC2025, the trend of targeting crucial industries obtained a new impulse, and the entirety of the US semiconductor industry has received purchase offers.

Between 2010 and the first half of 2020, Chinese FDIs in the US totalled $150.05 billion. However, the same value recorded in 2016 roughly corresponds to the sum of the successive four years, and, in the first half of 2020, the amount was at the lowest level in a decade. In 2017, Beijing had backpedalled on its decision to liberalise the capital flow, to prioritise the investments towards the high-tech sectors outlined by MIC2025. To do so, it increased the regulatory burden needed to gain governmental greenlight[138] and updated the categories in the list (Sensitive Industry Catalogue) of industries subject to additional screening, notably curtailing the booming FDIs in real estate[139]. The outcome has seen enterprises such as Evergrande Health, a Hong Kong subsidiary of the largest Chinese real estate company, reorienting part of their FDIs to buy 45 per cent of Faraday Future, a Californian producer of electric vehicles. Besides, the case is helpful to illustrate another instance of technology

[137] Jeffrey St.Clair, 'The Saga of Magnequench', CounterPunch.org, 7 April 2006, https://www.counterpunch.org/2006/04/07/the-saga-of-magnequench/.

[138] National Development and Reform Commission, 'Measures on the Administration of Enterprise Outbound Investment', Pub. L. No. 11 (2017).

[139] The categories are dubbed *encouraged, restricted,* and *prohibited*. *See* National Development and Reform Commission, 'Notice on Issuing the Overseas Investment Sensitive Industry Catalogue', Pub. L. No. 251 (2018).

transfer. As a matter of fact, after paying $800 million of the expected $2 billion, Evergrande Health halted the payments to "try to gain control and ownership over FF China and all of FF's IP. At the same time, Evergrande [wa]s preventing FF from accepting any immediate financing from other sources"[140].

In the US, the practice was formally documented in the 2018 Section 301 Report, highlighting how "[s]ince 2014, when the government issued the [*National Guidelines for Development and Promotion of the Integrated Circuit Industry*], Chinese companies and investors –often backed by state capital –have undertaken a series of acquisitions to achieve technology breakthrough, shrink the technology gap between China and advanced countries, cultivate domestic innovation clusters, and reduce China's reliance on IC imports"[141] and "the Chinese government reportedly directs and/or unfairly facilitates the systematic investment in, and/or acquisition of, U.S. companies and assets by Chinese companies to obtain cutting-edge technologies and intellectual property and generate large-scale technology transfer in industries deemed important by Chinese government industrial plans"[142]. Thus, the Trump administration decided to impose sanctions on Chinese imports, de facto initiating the trade war. Furthermore, the Committee on Foreign Investment in the United States (CFIUS) mandate was expanded through the Foreign Investment Risk Review Modernization Act (FIRRMA). While investigating risks for national security, CFIUS became able to discriminate based on the investor's nationality. FIRRMA also allowed for the examination of a broader array of transactions and retroactive scrutiny.[143] Unsurprisingly, one of the sectors the most affected by the measures has been technology. Chinese ICT FDIs dropped from $3.3 billion in 2016 to less

[140] FF Team, 'FF Statement of Evergrande Health Investment', Press Release, FF Press Room, 8 October 2018, https://www.ff.com/us/press-room/faraday-future-evergrande-statement.
[141] U.S. Trade Representative, Findings of the Investigation into China's Acts, Policies, and Practices Related to Technology Transfer, Intellectual Property, and Innovation Under Section 301 of the Trade Act of 1974, 114.
[142] U.S. Trade Representative, 5.
[143] Buysse and Essers, 'Cheating Tiger, Tech-Savvy Dragon: Are Western Concerns about "Unfair Trade" and "Made in China 2025" Justified?', 17.

than $50 million in 2019, while the Electronic and Electrical Equipment Industry experienced a drop of more than $4 billion. In fact, the only industries that faced a rise of incoming Chinese FDIs value were the less politicised ones, such as the Entertainment, Media and Education Industry and Consumer Products and Services.[144]

Venture Capital

A noticeable Chinese VC interest in the US started in 2014 with a total amount of $1.4 billion. The value peaked at $4.46 billion in 2018 and halved in the following year due to the aforementioned policies. However, the number of transactions slightly began to rise again in the first half of 2020. Given the documented waning of the investments' value, this leaning suggests that Chinese investors continue to participate in promising but small companies or start-ups.[145] Claiming such enterprises in a portfolio, even in minority stakes, allows easy access to their intellectual property, talent, and cutting-edge, disruptive technology.

An illustrative example of the direct control the Party exerts on VC funds comes from the Zhongguancun Development Group (ZDG). In 2014, the Beijing-based SOE established first in the Silicon Valley and later in Boston, partnered with Stanford and other universities, hired talent, and invested in other VC funds, including Danhua Capital[146]. The latter was tasked by ZDG with supporting and handling technologies developed by the universities. Said innovation power would then be funnelled through ZDG's Californian incubator before being directed to Beijing. Originally, Danhua Capital planned to raise a fund of $50 million. The participation of ZDG catalysed investments from private giants of the calibre of Alibaba and Baidu. Furthermore, other state-connected and owned companies pledged their contribution. Consequently, in its first two rounds, Danhua arrived to manage roughly seven times the sum for which it was initially aiming. Thus, it translated into a portfolio of 112 US companies, some

[144] Rhodium Group and The National Committee on U.S.-China Relations, 'FDI Data'.
[145] Buysse and Essers, 'Cheating Tiger, Tech-Savvy Dragon: Are Western Concerns about "Unfair Trade" and "Made in China 2025" Justified?', 10.
[146] Now named Digital Horizon Capital (DHVC).

of which relocated to China.[147] The list included industries encompassing the whole supply chain: from non-silicon materials to intellectual propriety, SME producers, and ATP-related companies.[148] Still, said VC firms are just the visible tip of the iceberg. There is an unknown number of investments that flies under the radar, thanks to the participation of Chinese limited partners in western firms. They could be composed only of state-owned limited partners, but it would be legal not to disclose the fact. This expedient allows entities not to show their name in deals, gaining stakes and the connected benefits while unbeknownst to screening bodies. Consequently, there is no means to estimate the number of start-ups into which Beijing has been able to tap. Not even the mandate expansion under FIRRMA provides means for CFIUS to investigate the matter.[149]

European Union

The number of Chinese acquisitions in the EU steadily grew from 99 in 2010 to 309 in 2016, while France, Germany, and the UK soon emerged as the "Big 3", the top FDIs destinations accounting for roughly 50 per cent of the investments' value.[150] Contrarily to the US, the EU has no CFIUS. FDIs had been regulated by the single Member States until 2017, when Germany, France, and Italy spurred the dialogue towards a common screening framework. Come into force in October 2020, the framework remains based on the national ones and aims at coordinating them by establishing guidelines and promoting the sharing of information and good practices. However, the member State where the investment occurs has the final say on the matter and can opt for the transaction approval, prohibition, or application of mitigating

[147] U.S. Trade Representative, Findings of the Investigation into China's Acts, Policies, and Practices Related to Technology Transfer, Intellectual Property, and Innovation Under Section 301 of the Trade Act of 1974, 46–48.
[148] VerWey, 'Chinese Semiconductor Industrial Policy: Past and Present', 16.
[149] Elisabeth Braw, 'How China Is Buying Up the West's High-Tech Sector', *Foreign Policy*, 3 December 2020, https://foreignpolicy.com/2020/12/03/how-china-is-buying-up-the-wests-high-tech-sector/.
[150] Tomas Dudas and Rastislav Rajnoha, 'Chinese High-Tech Foreign Direct Investments in the EU – Trends and Policy Responses', *Problems and Perspectives in Management* 18, no. 2 (25 June 2020): 320, https://doi.org/10.21511/ppm.18(2).2020.26.

measures. The cornerstone of the regulation is non-discrimination, but it inevitably overlaps with the targets of MIC2025, given the sensitive nature of the industries mentioned in both policies. Hence, states are warned to scrutinise politically motivated or SOE-driven investments while taking measures to counter possible circumvention attempts actuated via intra-EU investments involving non-EU owners. Had the framework been in place in 2018, 83 per cent of the Chinese FDIs would have been subject to screening procedures.[151] Nonetheless, acquisitions are to be evaluated case by case as thresholds are not set, deeming that even start-ups with a limited value can possess strategic value.[152]

Inevitably, as in the US, the stiffening of the environment, combined with Beijing's capital-curtailing measures, provoked a sharp decrease in the inflow of Chinese investments in the EU. The result has been Beijing coordinating alternative methods to pursue its objectives.

Foreign Direct Investments

The tendency representing the inflow of Chinese FDIs in the EU mimics the US one, peaking in 2016, when the total assets reached €160 billion, growing ten-fold in four years. In 2016, under the sector of Electronic and Electric Equipment and Machinery, China held 5.4 per cent of the total assets relative to the Manufacture of Instruments and Appliances for Measuring, Testing and Navigation and Watches and Clocks; 2.1 per cent of Manufacturing of General-Purpose Machinery; 1.6 per cent of Manufacturing of Metal Forming Machinery and Machine Tools; 1.4 per cent of Manufacturing of Other Machine Tools. Whereas most of the labels are self-explanatory, the first one appears to be too weakly connected to the goals set by MIC2025

[151] Thilo Hanemann, Mikko Huotari, and Agatha Kratz, 'Chinese FDI in Europe: 2018 Trends and Impact of New Screening Policies', *Rhodium Group and the Mercator Institute for China Studies*, Papers on China, March 2019, 18.

[152] European Commission, 'Guidance to the Member States Concerning Foreign Direct Investment and Free Movement of Capital from Third Countries, and the Protection of Europe's Strategic Assets, Ahead of the Application of Regulation (EU) 2019/452 (FDI Screening Regulation)', 25 March 2020, 1–2; European Commission, 'Annex to the Guidance to the Member States Concerning Foreign Direct Investment and Free Movement of Capital from Third Countries, and the Protection of Europe's Strategic Assets, Ahead of the Application of Regulation (EU) 2019/452 (FDI Screening Regulation)', 25 March 2020, 1–4.

to be the most relevant. However, the segment description underlines how it comprises the production, among other things, of several industrial controlling mechanisms, radars and GPS devices, aeronautical systems and instruments, hence bridging the theoretical gap with Beijing's political ambitions. Moreover, between 2015 and 2017, Chinese investors concluded 10 M&A deals registered under Manufacturing of Electronic Component and 21 under Manufacturing of Other Special Equipment. The first category includes companies producing electronic capacitors as well as connectors and resistors, semiconductors, microprocessors, electron tubes, bare printed circuit boards, integrated circuits, wafers, display components, etc. The second comprehends traditional and high-tech sector industrial machines, but also aircraft launching gear and aircraft carrier catapults.[153]

The relevance of dual-use technologies and export control is well synthesized by the case of Dynex Semiconductor. Its acquisition by a Chinese SOE company led to the transfer of technology and knowledge necessary to manufacture insulated-gate bipolar transistor chips, a critical constituent for aircraft carriers' latest generation of electromagnetic catapults. Beijing was then able to undermine an advantage Washington was planning to maintain for years.[154]

According to the Rhodium Group, the 2016 Industrial Machinery and Equipment segment accounted for €5.6 billion of the total Chinese FDIs in Europe, well behind the 11.8 in ICT. Overall, the Chinese shopping list kept including companies producing the components and the intrinsic know-how necessary to kickstart a domestic industry in need of a third and fourth industrial revolution. Only in 2018 the capital inflow started bearing the regulatory policies marks. FDIs targeted less politicised market segments, and 2019 data legitimised the trend, despite a 33 per cent decrease year-over-year. Nonetheless, ICT remained the sector with the highest number of transactions. Features of the class were the acquisitions of the British Global

[153] European Commission, 'Foreign Direct Investment in the EU', 13 March 2019, 25–35.
[154] Kirchberger and Mohr, *The Economics of the Global Defence Industry*, 16:50.

Switch, part of the Dutch NXP Semiconductor, and the whole German start-up Data Artisans. The latter underlined once more how the Chinese interest is not limited to mature companies.[155] Unfortunately, both databases neglect companies with less than ten employees, adding to the lack of quantitative data regarding start-ups.

Besides, there are three noteworthy leanings in the datasets. The first is the number of M&A made by individuals or families. In 2017, 33 deals fulfilled the parameters, marking a 150 per cent increase from the sum of M&A concluded in the whole preceding decade. The fact is relevant because the actual ownership often remains dubious, as the registered person might be a dummy for politically exposed persons, money laundering schemes, or just hiding the real owners. The second stresses a similar issue and regards the increasing role played by Offshore Financial Centres (OFCs). In 2016, they ranked third (after North America and EFTA) with an 11 per cent share in the number of controlled EU companies and fifth (3.8 per cent) in terms of total assets. Once again, the privacy of the owners is kept concealed. The best guess could be carried out by relying on the OFCs' stock data. Although it appears that China accounts for 22 per cent of the capital, the notion provides a mere indication of the bias produced by FDIs stemming from said locations.[156] The third aspect is deepened in the following subsection.

R&D Partnerships

The Chinese curtailment policies and the European framework made it difficult for Chinese companies to finalise deals in the EU, accelerating the transition from the quest for technology to the one for the science behind innovation. Accordingly, many firms chose to boost existing R&D partnerships and establish new ones with EU companies, universities, governments, and institutions. While the trend can prove useful for both parties involved in instances such as the collaboration for the COVID-19 vaccine testing, given the Chinese top-down approach and the

[155] Kratz et al., 'Chinese FDI in Europe: 2019 Update', 11–14.
[156] European Commission, 'Foreign Direct Investment in the EU', 11–12.

lack of EU regulations, R&D partnerships constitute a new danger, threatening both economic and military competitiveness. Examples, to name a few, include the collaborations on disruptive technologies and their components, such as the Galileo satellite system (resulted in a dual-use Chinese version) and space research, metal additive manufacturing, semiconductors, Machine Learning and Artificial Intelligence, Biotechnology, Big Data-driven surveillance (including facial, speech and voice recognition) and the testing of such products in the EU market. However, even in the case of new restrictions, Chinese firms have already proven to be extremely flexible and persistent, adapting to the mounting pressure by modifying their angle of engagement. Huawei is probably the instance par excellence. After being added to the US Entity List, the company started a global campaign to retain a positive image, engaging in philanthropic projects and employing public figures as spokespersons.[157] Moreover, even in countries that prevented the company from building their 5G network, Huawei partners with the private firms doing so. It also managed to join the ranks of Chinese VC companies scouting the market auditing start-ups in innovation hubs as they do in the US.[158]

Why China Has Not Caught Up Yet

In 1906, when the British positive plunging released it, the Dreadnought instantly made all previous battleships obsolete under every aspect and granted the UK the victory in the naval arms race. Yet, a mere decade later, Wilhelmine Germany was able to deploy a navy with similar performances, in spite of a fairly short shipbuilding tradition.[159] Since the second industrial revolution, technology has experienced an exponential increase in complexity, meaning that innovation through imitation became longer and more complex. The higher entry

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[157] Nouwens, 'China's Digital Silk Road: Integration into National IT Infrastructure and Wider Implications for Western Defence Industries'.
[158] Braw, 'How China Is Buying Up the West's High-Tech Sector'.
[159] Andrea Gilli and Mauro Gilli, 'Why China Has Not Caught Up Yet: Military-Technological Superiority and the Limits of Imitation, Reverse Engineering, and Cyber Espionage', *International Security* 43, no. 3 (February 2019): 173–78, https://doi.org/10.1162/isec_a_00337.

barriers hindered latecomers, counterbalancing the advantages offered by better market information, already-developed supply chains, pools of trained human capital, and freeriding on third-party basic R&D. Imitation started to imply the deployment of absorptive capacity via material and non-material components such as research centres, laboratories, machinery, skilled workforce, and substantial investments.

As outlined by the rounds of policies, Beijing attempted various approaches to catch up with the advanced semiconductor industry but mainly employed financial means. Since 2014, China has invested $150 billion (twice the global annual expenditure on R&D) in its semiconductor industry, pledging $1.4 trillion before 2025.[160] Chinese integrated circuit manufacturing incentives can amount to 40 per cent of the total cost of fab ownership; equipment is leased at preferential rates and insured by the state against flaws; loans are below market rates, and state funds directly invest in companies.[161] Yet not all that glitters is gold. Despite decades of effort, China is still not at the forefront of the industry and, while rising complexity is the root cause to blame, this section declines it in the main underlying factors frustrating Beijing ambitions.

Although its latest plans are well funded and thoroughly planned, China remains plagued by inefficiencies. Even funds overlap with each other, inflating the actual value of the investments. As for its defence sector, the semiconductor industry is heavily reliant on SOEs, entailing Soviet-like cumbersome bureaucracy, poor management, and production redundancies. The lack of proper competition stifles innovation and creates companies dependant on state subsidies: between 2014 and 2018, the total support to the top four manufacturing industries exceeded their revenues up to 30 per cent.[162] SMIC has leveraged two decades of private and

[160] Lulu Yilun Chen et al., 'China's Got a New Plan to Overtake the U.S. in Tech', *Bloomberg*, 20 May 2020, sec. Technology, https://www.bloomberg.com/news/articles/2020-05-20/china-has-a-new-1-4-trillion-plan-to-overtake-the-u-s-in-tech.

[161] Thomas, 'Lagging but Motivated: The State of China's Semiconductor Industry'; Varas et al., 'Government Incentives and US Competitiveness in Semiconductor Manufacturing', 9–10.

[162] OECD, 'Measuring Distortions in International Markets: The Semiconductor Value Chain', Trade Policy Papers (Paris: OECD, 12 December 2019), 8, https://doi.org/10.1787/8fe4491d-en.

state resources and still lags four years behind. Additionally, after selling 17 per cent of its stakes to the National Integrated Circuit Investment Fund, most of its board seats were filled by state officials, bringing the related inefficiencies in the heart of the crown jewel of domestic foundries.[163]

Another facet of the issue is epitomised by the over-enthusiastic capital spending conducted by local governments. The goldrush spirit triggered by national stimuli led to so many failed or stagnant chip companies that the CCP was forced to warn the administrations of their liability in case of further waste. Moreover, with over 50000 entities listed as semiconductor companies, the investment impetus risks shattering against a myriad of realities, most of which are focused on expanding manufacturing capacity and neglect the R&D-driven innovation sought by Beijing.[164]

Given the difficulties experienced by domestic firms, most of the Chinese human capital interested in working in the sector studies and works outside the country or for foreign firms, causing a brain drain and undermining plans for self-reliance. The diaspora has been estimated around 400000 scientists and scholars, making it paramount to invest in recruiting and recalling programmes. Universities started to offer specific courses and institute visiting programs both for students and PLA-affiliated researchers. Plans to attract talents have been met with mixed success. While only a few thousand accepted to participate, some leading figures answered the call, among which UMC and TSMC senior engineers, leading researchers, and the former's CEO.[165] However, given the technological sophistication, vast portions of knowledge have become tacit, acquired through cycles of experience gained and retained by people and organisations. The enormous number of trade-offs and procedures makes tacit knowledge hardly codifiable and slow to diffuse, guarding the first movers' advantage as latecomers are

[163] VerWey, 'Chinese Semiconductor Industrial Policy: Prospects for Future Success', 14–15.
[164] Wübbeke et al., 'Made in China 2025. The Making of a High-Tech Superpower and Consequences for Industrial Countries', 22–27.
[165] VerWey, 'Chinese Semiconductor Industrial Policy: Prospects for Future Success', 16–17.

destined to imitate obsolete technology. Malerba synthesized the concept positing that "the mechanism of appropriation d[oes] not lie in patent protection (rather ineffective and easy to circumvent in the semiconductor industry), but in lead times and learning curves (which have characterized the industry since its beginning) and in the increasing complexity of technology (which made it difficult for imitators to replicate successful innovations)"[166]. The implications are that, to imitate, states need to access a sufficient number of the people involved in the process, for blueprints are often not enough, and single individuals cannot master the whole operation.[167] The Chinese efforts to promote a domestic semiconductor industry, evolving from components to technology and finally science, demonstrates the growing CCP awareness that the lack of a proper Domestic Structure condemns it to "reinvent the wheel over and over again"[168].

The last bottleneck is embodied by the US efforts to counter dual-use technology exports to China. Despite their questionable efficiency after the Wassenaar Arrangement, they managed to keep Beijing two generations behind the leading edge. Notably, under the Trump administration, CFIUS oversight was broadened to include critical technologies and scrutinise hostile takeovers. In 2018, the US Department of Commerce (USDOC) drafted an Entity List, progressively including Huawei, SMIC, ZTE, and entities deemed culprit of human rights abuses, links with the PLA, and/or IP theft.[169] The tariffs imposed following the Section 301 Report showcased the Chinese reliance on US chips,[170] strengthened Beijing commitment

[166] Malerba, 'Demand Structure and Technological Change', 284.
[167] Gilli and Gilli, 'Why China Has Not Caught Up Yet', 162–69.
[168] VerWey, 'Chinese Semiconductor Industrial Policy: Prospects for Future Success', 10.
[169] Bureau of Industry and Security, 'Addition of Entities to the Entity List, Revision of Entry on the Entity List, and Removal of Entities From the Entity List', Pub. L. No. 246, 83416 (2020), https://www.federalregister.gov/documents/2020/12/22/2020-28031/addition-of-entities-to-the-entity-list-revision-of-entry-on-the-entity-list-and-removal-of-entities.
[170] The US move almost put ZTE and Hikvision out of business overnight, hindering Chinese 5G rollout plans. Yet the CCP chose not to include any US semiconductor firm in its retaliatory list, despite imports had totalled $10 billion in 2017. *See* VerWey, 'Chinese Semiconductor Industrial Policy: Prospects for Future Success'.

towards autarky, and initiated the trade war.[171] The USDOC has also expanded the definition of Foreign Direct Product Rule, making licences mandatory to employ any US technology, discouraging supply chain firms from working with Chinese companies. The compliance of advanced SEM such as ASML[172] is proving a hassle for China, as the upstream segment influences the pace of manufacturing. Targeting the machinery and equipment sector means gravely impairing Beijing, whose plans have been mostly directed to actual semiconductor production. To counter the move, in 2020, China stockpiled manufacturing equipment for $32 billion,[173] and, in January 2021, the Chinese Ministry of Commerce passed a bylaw to discourage firms from compliance with the US restrictions, allowing its domestic companies to sue foreign ones, as Huawei promptly did with TSMC.[174]

Possible Developments

China plans to address 21 per cent of the capacity generated by 2030 (Appendix 3), reaching almost a quarter of the global manufacturing capacity, the share of demand generated today by its domestic OEMs.[175] While allowing for increased control over a domestic supply chain, a bigger footprint would also produce the advantages associated with scaled-up operations and clustering for integrated circuit companies concentrated in an area gain in performances, visibility, and collaboration. The creation of an ecosystem results in synergies sharing and reducing costs, cutting downtimes, duplicated functions, and possible supply chain disruptions.

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171 U.S. Trade Representative, Findings of the Investigation into China's Acts, Policies, and Practices Related to Technology Transfer, Intellectual Property, and Innovation Under Section 301 of the Trade Act of 1974.
172 Stu Woo and Yang Jie, 'China Wants a Chip Machine From the Dutch. The U.S. Said No.', *Wall Street Journal*, 17 July 2021, sec. Business, https://www.wsj.com/articles/china-wants-a-chip-machine-from-the-dutch-the-u-s-said-no-11626514513.
173 James Mayger et al., 'China Stockpiles Chips, Chip-Making Machines to Resist U.S.', *Bloomberg*, 2 February 2021, sec. Technology, https://www.bloomberg.com/news/articles/2021-02-02/china-stockpiles-chips-and-chip-making-machines-to-resist-u-s.
174 You, 'Semiconductors and the U.S.-China Innovation Race'.
175 Antonio Varas and Raj Varadaraja, 'How Restrictions to Trade with China Could End US Leadership in Semiconductors' (Boston Consulting Group, 9 March 2020), 8, https://www.bcg.com/publications/2020/restricting-trade-with-china-could-end-united-states-semiconductor-leadership.

Furthermore, the manufacturing capacity expansion will accelerate the learning curve, allowing a faster innovation catch-up.

However, the US restrictions, remarkably on SME, are likely to counterbalance the advance of Beijing's manufacturing capabilities. The upstream segment is dominated by US, Dutch, and Japanese firms[176] granting early access and higher margins to their (licenced) customers. High entry barriers have kept the Chinese SME sector extremely backwards, as highlighted by the modest objectives set for it in the policies. Thus, despite the massive investments, China is unlikely to achieve independence before the next five to ten years: the gap to bridge is huge and not merely economic, being grounded in ecosystems established over decades of research and investments.

Instead, Beijing seems to have set itself on a "fast-follower"[177] course, for the catch-up pace slows near the leading edge. It still can keep up importing material not subject to controls while developing a Domestic Structure able to provide indigenous innovation. Undeterred by the persisting challenges, Beijing appears to be determined to pursue its goals, possessing the political resolve and financial backing to enforce its strategic planning. To this end, technology transfers via the aforementioned means are likely to continue, evolving and adapting to the circumstances. As a matter of fact, the voiced concern that the COVID-19 crisis might have spurred new rounds of aggressive Chinese buying has not materialised, possibly as an effect of the broadened CFIUS mandate and the establishment of the EU screening framework. Therefore, in 2020, to counter the curtailing measures, the CCP implemented the *Dual Circulation* strategy, postulating that growth should be driven by both internal and external circulations. Whereas the former includes indigenous innovation and domestic demand and

[176] Overall, they possess more than 90 per cent of the global SME market. *See* Industry and Analysis, 'Semiconductors and Related Equipment', 2016 Top Markets Report (U.S. Department of Commerce, International trade Administration, July 2016), 19, https://legacy.trade.gov/topmarkets/pdf/Semiconductors_Top_Markets_Report.pdf.

[177] Bitzinger, *Arming Asia*, 68.

supply chains, the latter encompasses foreign technology, capital, and demand. The new policy facet possibly unveils a renewed attempt to steer free of foreign dependence and further reduce economic engagement with the global market. Whether the course will actually be pursued and to what degree it will affect industrial countries is too soon to evaluate.[178]

Notwithstanding its ability to shift resources and due to the mentioned impediments, China is going to miss its MIC2025 goal of reaching 70 per cent of integrated circuit self-sufficiency by 45 to 30 percentage points. Even in 2030, with a quarter of the global capacity, it seems unlikely Beijing will be able to create an ecosystem on par with the one built over longer timespans.

Before diving into structured projections, it is helpful to remind how, despite the aggressive rhetoric, the two major contenders remain critically mutually dependant, with China representing 40 per cent of the US semiconductor total revenue.[179] To provide another metric, with the beginning of the trade war, the median year-over-year revenue growth of the top US chip firms dropped from 10 to 1 per cent.[180] The Boston Consulting Group developed two scenarios based on the effect the US restrictions might have in the mid to long term to foresee how they might affect the semiconductor market. Published in March 2020, they rely on older data and do not account for the recent development such as the shortage and the considerations on the plans to address the 2030 white space. Nonetheless, they report the main drivers and their interactions. The scenarios are presented correlated, when possible, by evidence to exemplify and try to assess which might prove more accurate in gauging the present situation.

Perpetuation of the Status Quo

In this scenario, the US restrictions remain in place, and there is no further escalation. As a consequence, companies would likely shift supply chain portions out of China to avoid damage

[178] Kevin Yao, 'What We Know about China's "Dual Circulation" Economic Strategy', *Reuters*, 15 September 2020, sec. APAC, https://www.reuters.com/article/china-economy-transformation-explainer-idUSKBN2600B5.
[179] You, 'Semiconductors and the U.S.-China Innovation Race'.
[180] Varas and Varadaraja, 'How Restrictions to Trade with China Could End US Leadership in Semiconductors', 4.

to their business, as EMS companies Foxconn and Wistron did in 2020 and 2021, moving to Vietnam and India parts of their Apple assembly to minimise the impact on their revenues.[181] Customers would avoid Chinese products out of concern that US restriction might compromise their quality, as it already happened to Huawei smartphones. Additionally, both Chinese firms on the Entity List and those who are not would proactively seek new suppliers and components, either because forced or to reduce their exposure to US technology, benefitting third countries (Appendix 6). In fact, following the announcement of the tariffs in 2018, Huawei and other firms underwent plans to develop in-house chips. Yet, the trend can also be ascribed to a broader post-globalisation sentiment inducing countries and companies to seek local alternatives to the actual supply chain, seeking protection from geopolitical disruptions.

The scenario also estimates the negative reflection on most US semiconductor companies, as 73 per cent of them might be replaced by Chinese or foreign suppliers. The result would be US firms losing up to half the total revenues because of restrictions or substitutions. The first effects would be visible within two to three years in segments whose outputs are products with short lifecycles, such as consumer electronics. Losses would force US companies to heavily cut their annual investment in order to maintain the same ratio of R&D to revenue. In turn, the cut would produce a decline in innovation, jamming the mechanism vital to maintaining the lead and reducing the US market share by an estimated 8 points.[182]

Technology Decoupling

The second scenario hypothesises an escalation of the tensions up to a complete US technology export ban to China, combined with the latter's retaliation interdicting more US devices, possibly consumer electronics. The responses of Chinese device manufacturers would vary depending on the availability of alternatives. In the case of established non-US suppliers,

[181] You, 'Semiconductors and the U.S.-China Innovation Race'.
[182] Varas and Varadaraja, 'How Restrictions to Trade with China Could End US Leadership in Semiconductors', 12–15.

assuming they would manage to remain competitive without the banned leading-edge equipment, Chinese purchases would likely shift towards those domestic suppliers and, in their absence, to foreign ones, if allowed to sell despite the ban. In the third case, lacking established non-US suppliers, China would be forced to step up its indigenous alternatives. The consequences would entail the development of new design tools and possibly new semiconductor architectures, resulting in the potential loss of competitiveness on the international market, causing disruption in the short term and an effective decoupling in the longer one. However, the domestic demand would be forced to converge on the developed alternative, making up for three-quarters of the losses.

In this scenario, global semiconductor innovation would likely slow in the short term, and the segment would lose up to $3.5 trillion.[183] In the mid to long term, the US integrated circuit market share would drop up to 18 points, whereas most of the revenue would go to third countries, such as South Korea, able to temporally satisfy the Chinese demand. Nonetheless, the forced impulse towards indigenisation would boost Beijing's plan, and the industry would reach the upper estimate for the 2025 self-sufficiency goal (40 per cent). In the longer term, it could be able to achieve up to 85 per cent of self-reliance, gaining 30 per cent of the global market share. Losing its first place, the US semiconductor industry would follow the downward path illustrated in the Perpetuation of the Status Quo scenario. However, the vicious cycle would be deeper and harsher, considering that Beijing would not stop at its domestic market but would use its scale to leverage low prices and erode further global market share. [184]

Projecting the development of the Chinese semiconductor industry over the mid and long term is a complex task. Inferring current trends as a linear progression could risk neglecting the vast

[183] Adam Segal, 'The Coming Tech Cold War With China', 7 July 2021, https://www.foreignaffairs.com/articles/north-america/2020-09-09/coming-tech-cold-war-china.

[184] Varas and Varadaraja, 'How Restrictions to Trade with China Could End US Leadership in Semiconductors', 16–22.

array of variables underlying the creation of a viable cutting-edge domestic semiconductor industry and excluding revolutionary breakthroughs. Still, some trends are worth noticing, for they are likely to shape the progression, at least in the short term.

The Perpetuation of the Status Quo scenario better describes the current situation, though with the reservations expressed before. Yet, the Technology Decoupling is a lingering option as demonstrated by continuous small escalations such as the 2020 addition of SMIC to the Entity List or the Chinese Ministry of Commerce's bylaw. Furthermore, while the Biden administration seems to have opted for a multilateral approach to the matter, the restrictions are set to remain in place, at least for the time being.[185] Still, the very same measures put in place to hinder Beijing could end up setting forth its success, as shown in both scenarios. While addressing the white space may provide a solution to the US manufacturing issues, the loss of the Chinese market revenues would impact its whole ecosystem, and little seems to be done in this regard. In the short to mid-term, the supply chain is destined to remain globalised. Attempting to change this aspect unilaterally would trigger mechanisms strangling a brittle structure, with dangerous repercussions. Ideally, a multilateral approach would guarantee shared practices and mutual assurance. However implausible in the light of the ulterior geopolitical motives, the risk is a prisoner's dilemma where states will strive for their autarky and efficiency, further slowing the global pace of semiconductor innovation, favouring Beijing.

CONCLUSION

The analysis sought to answer the question of semiconductor relevance as part of the defence realm. To reach such a conclusion, the conditions allowing for politics to influence technology had to be circumstantiated. Focusing on the case study of China has allowed the delineation of responses and perimeters. Beijing was an ideal candidate for its enormous centralisation of

[185] Chris Miller, 'Biden Opens Sneaky New Front in Trade War Against China', *Foreign Policy*, 22 June 2021, https://foreignpolicy.com/2021/06/22/biden-semiconductors-south-korea-china-trade-war/.

power, modernisation ambitions, and the export controls shaping its choices regarding armaments. Therefore, in the first chapter, the historical relevance of technology for state strategy has been highlighted through autarky-efficiency trade-off, then declined into the unique field of dual-use technologies and the related efforts pushing for market regulation. Introducing semiconductors allowed for a brief outline of their development and growing relevance, setting the stage for the analysis on global dependencies illustrated in the third chapter. The second chapter discussed the troubled relationship between technology and society, finding the temporal nexus enabling their interaction and eschewing hard determinism. The concept of technological momentum legitimised the renewed relevance attributed to policies, given the first signs hinting at the predicted end of Moore's law. The digression on Buzan's theory allowed to build the case demonstrating the relationship between the Chinese defence industry and technology, underlining the tension towards the creation of a viable Domestic Structure and the precise choice to opt for dual-use technologies in order to enforce modernisation. The fourth chapter dived deeper into the Chinese case study, examining the efforts undertaken since the 1950s, emphasizing the economic and security dependencies worrying the CCP.

After several unsuccessful attempts, the *National Guidelines for Development and Promotion of the Integrated Circuit Industry* and MIC2025 possess the backing necessary to set the Chinese integrated circuits sector in motion, embodying the relevance of policies in building a considerable mass and gradually picking up the pace. Yet, given the imposed limitations, China struggles to produce advanced components both in the civil and military sectors, slowing its modernisation plans but, through the priority conferred to the pursuit of dual-use technology and the civil-military integration efforts, the gap is narrowing.

The chasm with the leading edge seems unlikely to disappear completely were it not for the forecast loss of momentum due to the slowing down of Moore's law and the US restrictions' side effects that might provide the conjuncture allowing China to get up to speed.

Future work should focus on analysing the situation once semiconductor development is substantially slower than the postulated one, assessing the validity of what was illustrated, examining the degree of independence reached by China in 2025, using the benchmark to draw a new outline.

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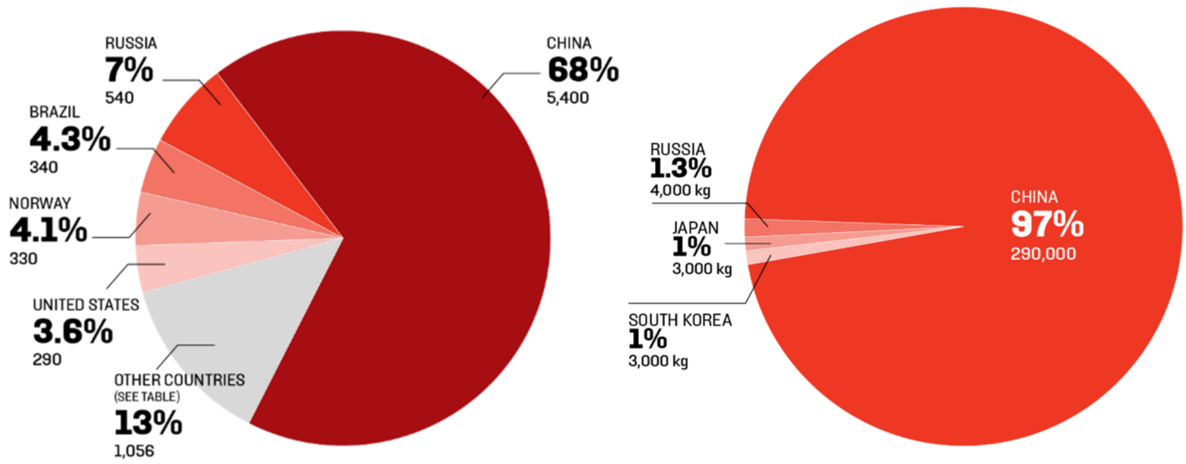
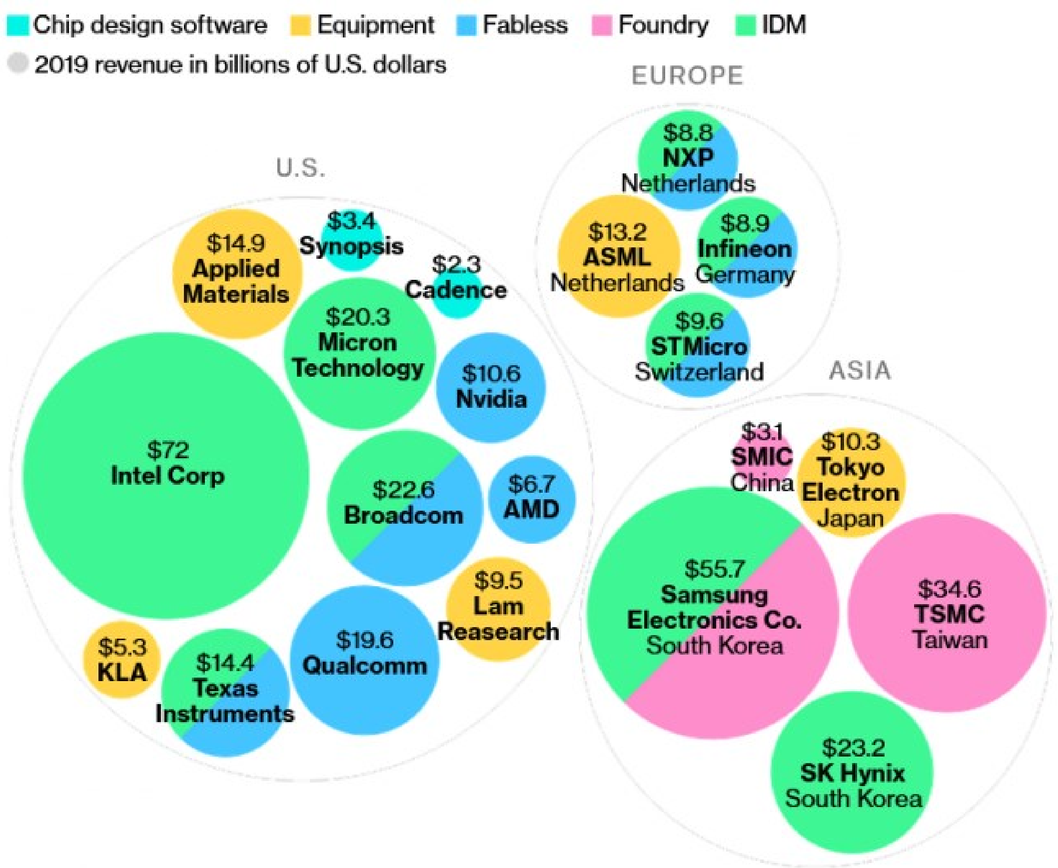
APPENDICES

Appendix 1: 2020 world production and reserves of Silicon (left, thousand metric tons) and Gallium (right, kilograms).



Appendix 2: Geographical distribution and revenues of supply chain stages.

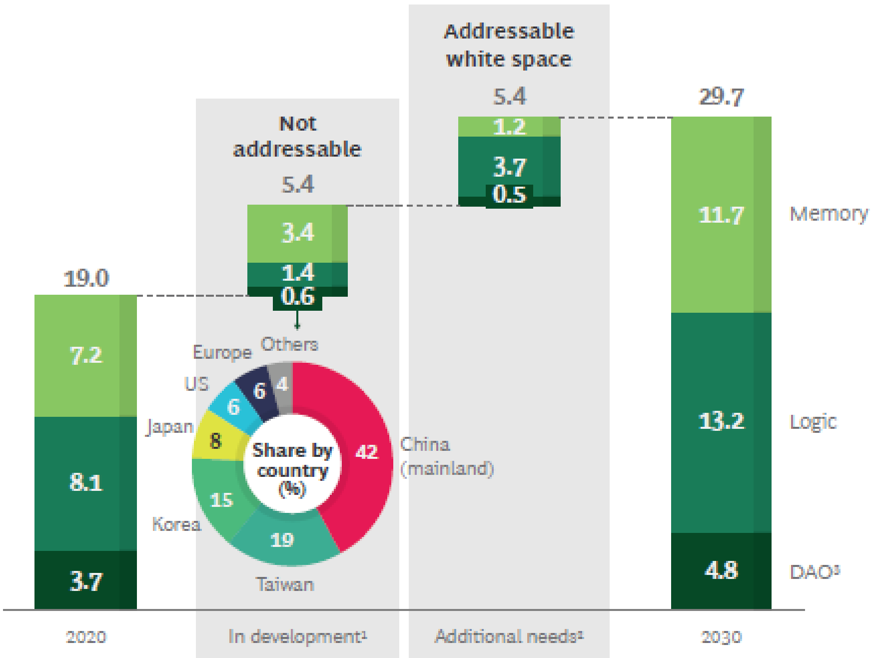


Appendix 3: projected incremental 2020-2030 global capacity by development status (million wafers per month).

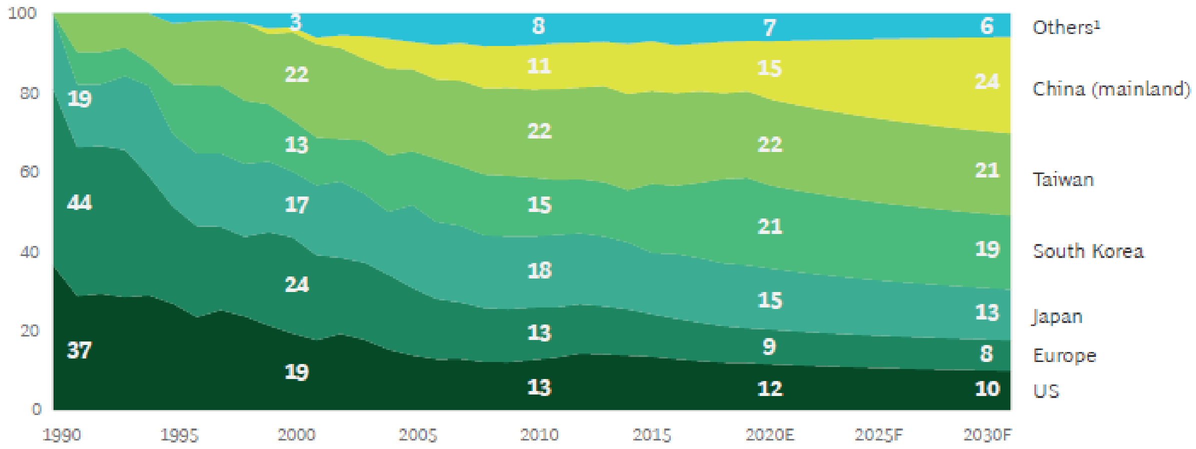
	US[1] (%)	Japan (%)	S. Korea (%)	Taiwan (%)	Singapore (%)	Asia avg.[2] (%)	China[3] (%)	Germany (%)	Israel (%)
Capex reductions									
Land	50	75	100	50	100	85	100	100	75
Construction and facilities	10	10	45	45	25	33	65	35	45
Equipment	6	10	20	25	30	20	35	5	30
Opex reductions									
Labor and benefits	5	5	5	5	15	7	33	7	5
Tax reductions[2]									
Corporate tax	–	–	60	–	35	30	75	–	74
State tax	100	–	–	–	–	–	–	–	–
Property tax	100	100	100	–	–	60	–	–	–
Overall	**10–15**	**~15**	**25–30**	**25–30**	**25–30**	**~25**	**30–40**	**10–15**	**~30**

Source: BCG analysis.

Appendix 4: comparison of government incentives on the first ten years across locations.



Appendix 5: percentage of global manufacturing capacity by location, Status Quo projections.



Appendix 6: percentage of global semiconductor market share.