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INSTITUTIONAL CHALLENGES FOR CHINA'S CHIP INDUSTRY

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Abstract

Why have Japan, South Korea and Taiwan developed advanced capabilities in designing and fabricating semiconductor chips while China has not, even though it is a larger and more powerful state? A common explanation offered is that China's efforts to develop its chip industry have been hindered by its strategic rivalry with the United States, which controls essential intellectual property and technology. However, this explanation is insufficient, and the apparent failure of China's indigenous innovation policies merits a closer look. I argue that the institutional set-up – in particular, the extent of state versus private sector involvement – explains the variation observed in East Asian states' pursuit of chip industry development. Building on previous work done by Douglas Fuller, I show that China's state-dominated institutional set-up has led it to over-allocate resources to "paper tigers", an approach that has hindered the advancement of its domestic chip industry. My argument is grounded in the seminal concept of "fragmented authoritarianism", developed by Kenneth Lieberthal and Michel Oksenberg, and stands in contrast to recent analyses of China's economic policymaking process which demonstrate how the country's state-dominated institutional set-up has played an important role in achieving rapid growth that has defied expectations of an authoritarian political system.

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[1] See https://www.nbr.org/publication/chinas-tech-policies-and-development-responding-to-great-power-competition/.

Semiconductor chips have been a "critical" technology since their inception in the 1960s.[2] Chips contain billions of transistors – tiny switches that control the flow of electric current – putting them at the heart of the electronic devices and computers that have revolutionised our world. Continuous technological advancements combined with falling costs have driven the chip industry's rise, making it a centrepiece of the global economy.[3] In 2023, global chip sales totalled US$526.8 billion,[4] and the industry is expected to be worth a trillion dollars by the end of this decade.[5]

Designing and fabricating chips therefore gives states power as well as status on the global stage. To maximise their power and status, states will rationally seek to acquire the capabilities and build the infrastructure required for their respective chip industries. However, not all states are successful in their attempts to do so. The complexity associated with chip technology has meant that only a handful of firms in a small number of states control different parts of the supply and value chain, further amplifying the chip industry's strategic value. While some East Asian states – Japan, South Korea and Taiwan – feature prominently in this elite club, the largest economy among them, China, has struggled to master advanced chip design and fabrication despite the presence of political will and significant state investment.[6]

Why have Japan, South Korea and Taiwan developed advanced capabilities while China has not, even though it is a larger and more powerful state? A common explanation offered is that China's efforts to develop its chip industry have been hindered by its strategic rivalry with the United States, which controls essential intellectual property and technology. For example, several prominent Chinese chip firms and research institutions have been placed on the US Department of Commerce's Entity List in recent years.[7] This listing is viewed as a limitation on their ability to develop advanced chip design and fabrication capabilities as their suppliers and research collaborators – even if based outside the United States – require a licence to work with them as long as US-origin IP and technology are involved.

While such efforts by the United States are undoubtedly significant, they do not amount to a blanket ban. In fact, the US government has continued to issue export licences for Chinese firms on

[2] Chris Miller, *Chip War: The Fight for the World's Most Critical Technology* (New York: Scribner, 2022), pp. 3–34.
[3] Ming-Chin Monique Chu, *The East Asian Computer Chip War* (London: Routledge, 2013), pp. 26–8.
[4] Semiconductor Industry Association (USA), "Global Semiconductor Sales Decrease 8.2% in 2023; Market Rebounds Late in Year", 5 February 2024, https://www.semiconductors.org/global-semiconductor-sales-decrease-8-2-in-2023-market-rebounds-late-in-year/.
[5] Ondrej Burkacky, Julia Dragon, and Nikolaus Lehmann, "The Semiconductor Decade: A Trillion-Dollar Industry", McKinsey & Company, 1 April 2022, https://www.mckinsey.com/industries/semiconductors/our-insights/the-semiconductor-decade-a-trillion-dollar-industry.
[6] Miller, *Chip War*, pp. 247–54.
[7] See Supplement No. 4 to Part 744 of the United States Export Administration Regulations, available at: https://www.bis.doc.gov/index.php/documents/regulations-docs/2326-supplement-no-4-to-part-744-entity-list-4/file. Examples of prominent Chinese chip firms on the Entity List include the Semiconductor Manufacturing International Corporation (SMIC, China's largest contract chipmaker, added in 2020) and Yangtze Memory Technologies Corp (YMTC, China's largest flash memory manufacturer, added in 2022).

the Entity List, including for controlled technology items related to chips.[8] In 2022, almost 70% of export licence applications involving Chinese firms on the Entity List were approved,[9] although this figure is considerably lower than the approval rate for 2021 (88%) and 2020 (94%).[10] Furthermore, China has been actively pursuing policies to promote indigenous innovation since the 2000s, with a particular emphasis on chips.[11] In 2015, China launched the "Made in China 2025" industrial policy initiative to bolster its manufacturing sector, aiming to produce 70% of its demand for chips domestically by 2025.[12]

These policies have been backed by significant state-led investment, such as through the China Integrated Circuit Industry Investment Fund – known colloquially as the "Big Fund" – which was set up in 2014 with an initial 130 billion RMB (~US$18.1 billion) and followed by a second round of 200 billion RMB (~US$27.8 billion) in 2019.[13] State-led investment has in turn been directed by high-level policy initiatives – in the ongoing 14th Five-Year Plan guiding China's overall economic and social development policies from 2021 to 2025, chips are given particular emphasis as part of a list featuring seven prioritised "frontier" technologies.[14] Furthermore, in March 2023, China's State Council – its equivalent of a cabinet – announced an initiative to restructure the Ministry of Science and Technology to streamline its focus on technological self-sufficiency.[15]

Why then have China's policies to build advanced capabilities within its domestic chip industry not achieved their desired outcomes, unlike its East Asian neighbours? Since the common explanation – that strategic rivalry with the United States has stymied China's efforts – is insufficient, the apparent failure of China's indigenous innovation policies merits a closer look. I argue that the institutional set-up – in particular, the extent of state versus private sector involvement – explains the variation observed in East Asian states' pursuit of chip industry development. Specifically, building on previous work done by Douglas Fuller, I will show that China's state-dominated institutional set-up has

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[8] Karen Freifeld, "US Approved 192 Licenses for Exports to Blacklisted Chinese Firms Early 2022", Reuters, 4 March 2023, https://www.reuters.com/markets/us-approved-192-licenses-exports-blacklisted-chinese-firms-early-2022-2023-03-04/.
[9] David Shephardson, "US Approved 70% of Export License Applications from China in 2022", Reuters, 28 February 2023, https://www.reuters.com/markets/us-approved-70-export-license-applications-china-2022-2023-02-27/.
[10] Kate O'Keeffe, "US Approves Nearly All Tech Exports to China, Data Shows", *The Wall Street Journal*, 16 August 2022, https://www.wsj.com/articles/u-s-approves-nearly-all-tech-exports-to-china-data-shows-11660596886.
[11] Yin Li, *China's Drive for the Technology Frontier: Indigenous Innovation in the High-Tech Industry* (London: Routledge, 2022).
[12] Shunsuke Tabeta, "'Made in China' Chip Drive Falls Far Short of 70% Self-Sufficiency", *Nikkei Asia*, 13 October 2021, https://asia.nikkei.com/Business/Tech/Semiconductors/Made-in-China-chip-drive-falls-far-short-of-70-self-sufficiency.
[13] Erchi Zhang et al., "Five Things to Know About China's Scandal-Struck Chip Industry 'Big Fund'", *Caixin Global*, 10 August 2022, https://www.caixinglobal.com/2022-08-10/five-things-to-know-about-chinas-scandal-struck-chip-industry-big-fund-101924443.html.
[14] Arjun Kharpal, "In Battle with US, China to Focus on 7 'Frontier' Technologies from Chips to Brain-Computer Fusion", CNBC, 5 March 2021, https://www.cnbc.com/2021/03/05/china-to-focus-on-frontier-tech-from-chips-to-quantum-computing.html.
[15] Eduardo Baptista, "China to Restructure Sci-Tech Ministry to Achieve Self-Reliance Faster", Reuters, 7 March 2023, https://www.reuters.com/world/china/china-restructure-sci-tech-ministry-reach-self-reliance-faster-state-media-2023-03-07/.

led it to over-allocate resources to “paper tigers”, which have hindered the advancement of its domestic chip industry.[16]

“Paper tigers” are domestic firms that are “targets of the government’s industrial policies, and celebrated and feared in equal measure by foreign analysts. Yet the images of these firms’ technological prowess are by and large more fiction than fact.”[17] I focus on how the state-dominated institutional set-up in China’s chip industry creates competing interests that see paper tigers receiving a lion’s share of resources. My argument is grounded in the seminal concept of “fragmented authoritarianism” developed by Kenneth Lieberthal and Michel Oksenberg,[18] which “asserts that policy made at the centre becomes increasingly malleable to the parochial organisational and political goals of various vertical agencies and spatial regions charged with enforcing that policy”.[19]

Chip Industry Challenges and Theories of China’s Economic Success

My argument also stands in contrast to recent analyses of China’s economic policymaking process which seek to demonstrate how the country’s state-dominated institutional set-up has played an important role in achieving rapid growth that has defied expectations of an authoritarian political system. For example, Ang Yuen has argued that “directed improvisation” – top-down direction from Beijing complemented by bottom-up improvisation among local officials – has driven China’s economic success.[20] Similarly, Sebastian Heilmann has posited that China’s rapid growth is due to “distinctive governance methods shaped by the Chinese Communists’ own revolutionary and postrevolutionary past … [which views] policy making as a process of ceaseless change, tension management, continual experimentation, and ad hoc adjustments.”[21]

While compelling, these explanations do not fully account for China’s experience in attempting to master advanced chip design and fabrication. There are two possible reasons for this inadequacy. First, Ang and Heilmann are focused on analysing China’s economy across its various sectors, but there is considerable variation in the impact that policymaking processes have at the sectoral level. For example, why has China’s success in other sectors such as automobiles not translated into chipmaking? Like chips, automobiles have “occupied a central position in the global

[16] Douglas B. Fuller, *Paper Tigers, Hidden Dragons: Firms and the Political Economy of China’s Technological Development* (London: Oxford University Press, 2016).
[17] Douglas B. Fuller, *Paper Tigers, Hidden Dragons*, p. 5.
[18] Kenneth Lieberthal and Michel Oksenberg, *Policy Making in China: Leaders, Structures, and Processes* (Princeton, New Jersey: Princeton University Press, 1988).
[19] Andrew Mertha, “‘Fragmented Authoritarianism 2.0’: Political Pluralization in the Chinese Policy Process”, *The China Quarterly* 200 (2009): 996.
[20] Yuen Yuen Ang, *How China Escaped the Poverty Trap* (Ithaca, New York: Cornell University Press, 2016).
[21] Sebastian Heilmann, *Red Swan: How Unorthodox Policy-Making Facilitated China’s Rise* (Hong Kong: Chinese University Press, 2018): pp. 20–1.

economy … [and states] have long regarded success in the car industry as a cornerstone of industrialisation and a symbol of national development."[22]

However, unlike automobiles, chips have a much shorter – and therefore more demanding – innovation cycle driven by Moore's Law.[23] This refers to a prediction made in 1975 by Gordon Moore – an influential figure in the American chip industry from its early days in Silicon Valley – that the number of transistors on a chip will double every two years.[24] Moore's Law has guided the pace of innovation in the chip industry for decades despite frequent predictions of its demise.[25] It is also a key reason why existing industry leaders continue to maintain their market share and position, as the rapid innovation cycle forms a higher barrier to entry for other firms to scale and catch up, compared to other sectors like automobiles.

In addition to the sectoral variation in the impacts of economic policymaking, the second reason that Ang and Heilmann's explanations do not fully account for the apparent failure of China's indigenous innovation policies for chips is that the policies are state-centric and pay less attention to the role played by firms. Ang's notion of "directed improvisation" focuses on a complementary dynamic that has arisen between the centre and local officials, which has resulted in innovative policymaking approaches, but does not discuss how firms respond to this dynamic or the role they have played despite the presence of weak or imperfect market institutions. Heilmann similarly outlines a process of "adaptive governance" driven by a "guerrilla policy style", but, like Ang, attributes the success of firms to decisions made by the state.

In the chip industry, however, individual firms can have an outsize impact. Consider, for example, the importance of ASML, the Dutch firm which is the sole global manufacturer of extreme ultraviolet (EUV) lithography machines that are essential for the fabrication of the most advanced chips.[26] ASML's monopoly over EUV lithography machines did not arise due to state intervention. The largest chipmakers at the time – Intel, Samsung and the Taiwan Semiconductor Manufacturing Company (TSMC) – invested in ASML in the 2010s, making a bet that EUV lithography machines would be necessary for the chip industry to continue sustaining Moore's Law.[27]

Contrary to what Ang and Heilmann's analyses of the economic policymaking process would suggest, the state-dominated institutional set-up in China's chip industry has been a stumbling block for its advancement. The reality instead appears to be closer to what is suggested by Lieberthal and

[22] Richard F. Doner, Gregory W. Noble, and John Ravenhill, *The Political Economy of Automotive Industrialization in East Asia* (New York: Oxford University Press, 2021), p. 3.
[23] Judith Aelker et al., "Opposites Attract: An Approach to Collaborative Supply Chain Management between Semiconductor and Automotive Companies", *Industrial and Systems Engineering Review* 1, no. 1 (2013): 13–30.
[24] Chu, *The East Asian Computer Chip War*, pp. 26–7.
[25] Chu, *The East Asian Computer Chip War*, p. 27.
[26] Katie Tarasov, "ASML Is the Only Company Making the $200 Million Machines Needed to Print Every Advanced Microchip. Here's an Inside Look", CNBC, 23 March 2022, https://www.cnbc.com/2022/03/23/inside-asml-the-company-advanced-chipmakers-use-for-euv-lithography.html.
[27] Miller, *Chip War*, pp. 225–30.

Oksenberg's "fragmented authoritarianism", where "China's bureaucratic ranking system combines with the functional division of authority among various bureaucracies to produce a situation in which it is often necessary to achieve agreement among an array of bodies, where no single body has authority over the others."[28] My aim is to explain how this fragmentation of the policymaking process results in competing interests that over-allocate resources to paper tigers in the chip industry.

Comparing East Asian Chip Industry Institutional Set-ups

The methodology for this comparison adopts a shadow case approach, which "entails the examination of an ancillary or peripheral case, drawing inference from the within-case analysis of that case to shed light on the generality of claims most centrally evaluated in the core case."[29] Here, China is the core case, while Japan, South Korea and Taiwan serve as shadow cases. The specific point of comparison between the cases is the extent of state versus private sector involvement within the institutional set-up of their respective chip industries. I will therefore use the shadow cases of Japan, South Korea and Taiwan to illustrate my argument concerning China's chip industry. To provide context for the case comparison, I begin by unpacking the notion of an institutional set-up, followed by a selective overview of the global chip industry, and the position of the core and shadow cases within it.

What is an "Institutional Set-up"?

Institutions can be broadly defined as "intertemporal social arrangements that shape human relations in support of particular values".[30] "Intertemporal" refers to how institutions exist "in and through time",[31] while "social" points to the fact that institutions are created by humans and are collective in nature.[32] An "institutional set-up" simply describes the manner in which institutions have manifested – in this case, within the context of the chip industry. It can include details about norms, organisations and policies, among other facets. For my analysis here, however, I focus on a specific feature of the institutional set-up, namely the extent of state versus private sector involvement.

This feature is critical within the context of the chip industry for two reasons. First, as highlighted earlier, innovation in the chip industry has been primarily driven by Moore's Law. While private rather than public sector research and development (R&D) propels technological advancement in chips, the state nevertheless plays a critical role in terms of creating an enabling regulatory and investment environment, and in facilitating the development of globalised supply

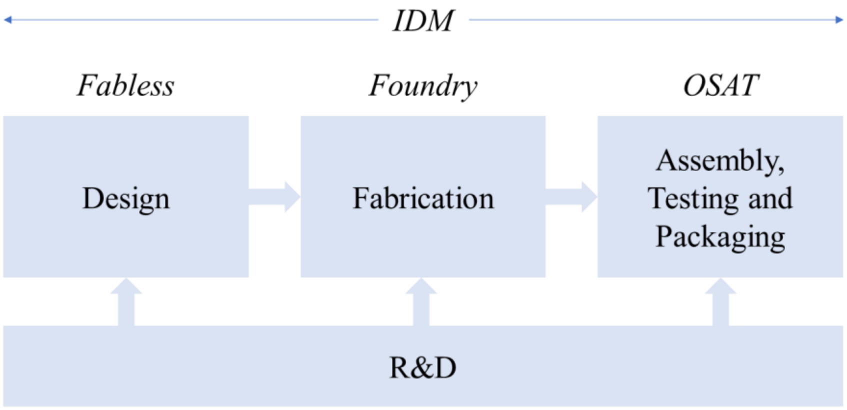
[28] Kenneth Lieberthal, "Introduction: The "Fragmented Authoritarianism" Model and Its Limitations", in *Bureaucracy, Politics, and Decision Making in Post-Mao China*, eds. Kenneth Lieberthal and David Lampton (Berkeley: University of California Press, 1992), p. 8.
[29] Hillel Soifer, "Shadow Cases in Comparative Research", *Qualitative and Multi-Method Research* 18, no. 2 (2020): 11.
[30] Joseph Jupille and James A. Caporaso, *Theories of Institutions* (Cambridge, UK: Cambridge University Press, 2022), p. 3.
[31] Jupille and Caporaso, *Theories of Institutions*, p. 4
[32] Jupille and Caporaso, *Theories of Institutions,* p. 4.

chains. The second reason for focusing on the extent of state versus private sector involvement lies in the critical nature of semiconductor chip technology. This contributes to securitisation of the chip industry and its products, as they play a vital enabling role in many other sectors beyond those catering to military purposes.[33]

The Global Chip Industry

Firms in the global chip industry are generally involved in carrying out three broad activities: design, fabrication, and assembly, testing and packaging (ATP), in addition to R&D.[34] These activities can take place within a single firm (an integrated device manufacturer, or IDM) or in separate firms.[35] The business model for the latter is referred to as "fabless" since the firm designing and selling the final chip separately engages a "pure play" foundry for fabrication and an outsourced semiconductor assembly and test (OSAT) firm for ATP.[36] Figure 1 summarises the main activities and business models of firms in the global chip industry, while Table 1 provides a non-exhaustive list of prominent IDMs, fabless firms, foundries, and OSAT firms, based on available data regarding their market share.

Figure 1: Main Activities and Business Models in the Global Chip Industry



Source: Adapted from Khan, Saif M., Alexander Mann, and Dahlia Peterson, "The Semiconductor Supply Chain: Assessing National Competitiveness", Centre for Security and Emerging Technology (Washington, DC), January 2021. https://cset.georgetown.edu/wp-content/uploads/The-Semiconductor-Supply-Chain-Issue-Brief.pdf.

[33] "Securitisation" refers to a process of politicising an issue where it is "presented as an existential threat, requiring emergency measures and justifying actions outside the normal bounds of political procedure." See Barry Buzan, Ole Waever, and Jaap de Wilde, *Security: A New Framework for Analysis* (Boulder, Colorado: Lynne Rienner Publishers, 1998), pp. 23–4.
[34] Saif M. Khan, Alexander Mann, and Dahlia Peterson, "The Semiconductor Supply Chain: Assessing National Competitiveness", Centre for Security and Emerging Technology (Washington, DC), January 2021, p. 5, https://cset.georgetown.edu/wp-content/uploads/The-Semiconductor-Supply-Chain-Issue-Brief.pdf.
[35] Khan, Mann, and Peterson, "The Semiconductor Supply Chain, p. 6.
[36] Khan, Mann, and Peterson, "The Semiconductor Supply Chain, p. 6.

Table 1: Prominent Firms in the Global Chip Industry by Business Model

IDMs	*Fabless Firms*	*Foundries*	*OSAT Firms*
Intel (USA) Samsung (South Korea) SK Hynix (South Korea) Micron (USA) Texas Instruments (USA)	Qualcomm (USA) Broadcom (USA) Nvidia (USA) AMD (USA) MediaTek (Taiwan)	TSMC (Taiwan) Samsung (South Korea) UMC (Taiwan) GlobalFoundries (USA) SMIC (China)	ASE (Taiwan) Amkor (USA) JCET (China) Powertech (Taiwan) TFME (China)

While foundries and OSAT firms are relatively clear-cut in terms of classification, there is some ambiguity regarding how to classify firms as IDMs and fabless. This is because many electronics firms also design and manufacture their own chips, which would technically make them IDMs. Furthermore, some large consumer technology firms such as Apple now design their own chips in-house, which raises the question of whether they ought to then be considered fabless firms. IDMs and fabless firms can also be categorised further based on the specific market segments that they specialise in, such as logic (for data processing) or memory (for data storage).

The competitive position of the core and shadow cases within the global chip industry is are summarised in Table 2. Key indicators used for comparison are share of overall sales,[37] share of value added,[38] and state investment.[39] These indicators are not exhaustive or definitive – the aim is to provide a broad sense of market power and the level of state commitment to the chip industry. Although the data sources for Table 2 lag by two to three years, they are still relatively recent enough to be indicative of present dynamics.

[37] Semiconductor Industry Association, "2022 Factbook", May 2022, https://www.semiconductors.org/wp-content/uploads/2022/05/SIA-2022-Factbook_May-2022.pdf.
[38] Semiconductor Industry Association, "2022 State of the US Semiconductor Industry", November 2022, https://www.semiconductors.org/wp-content/uploads/2022/11/SIA_State-of-Industry-Report_Nov-2022.pdf.
[39] Deloitte (China), "Anchor of Global Semiconductor: Asia Pacific Takes Off", 2021, https://www2.deloitte.com/content/dam/Deloitte/cn/Documents/technology-media-telecommunications/deloitte-cn-tmt-semiconductor-report-en-211001.pdf.

Table 2: Competitive Position of Cases within the Global Chip Industry

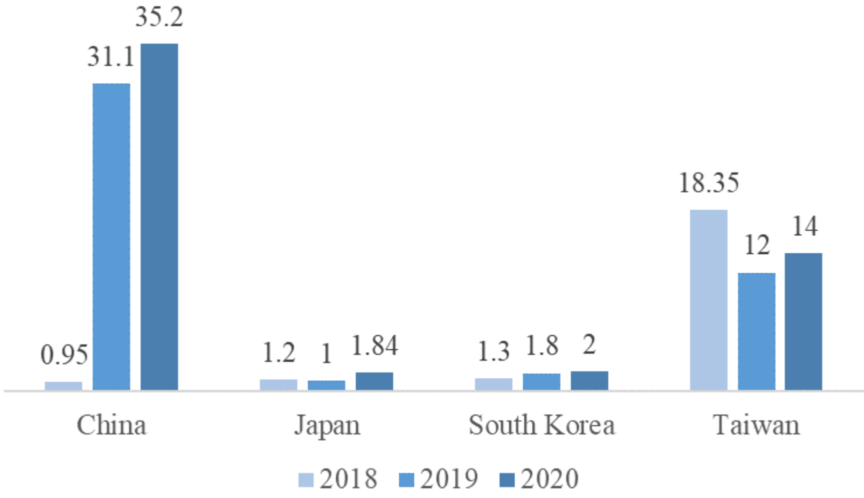
	China	*Japan*	*South Korea*	*Taiwan*
Share of overall sales (2021)	7%	9%	21%	8%
Share of value added (2021)	11%	13%	16%	10%
State investment (2020)	US$35.2bn	US$1.84bn	US$2.0bn	US$14bn

From Table 2, we can see that South Korea leads in East Asia based on its share of overall sales (21%) and value added (16%). South Korea is followed by Japan, with Taiwan and China equally poised, based on the same indicators. However, in terms of state investment, China clearly outranks the rest of East Asia, having spent US$35.2 billion in 2020. Taiwan comes in second with US$14 billion, while the level of state investment in Japan and South Korea is much lower at US$1.84 billion and US$2 billion respectively. If we compare the data from 2020 with the preceding two years, an even starker picture emerges, as China's state investment was only US$0.95 billion in 2018, but went up significantly to US$31.1 billion in 2019.[40] For the same period, the other East Asian states did not register such dramatic change in their level of state investment (see Figure 2).

However, comparing levels of state investment over time poses some challenges. Investment is sometimes "lumpy" due to the timing of policy initiatives. For instance, we could potentially explain the significant jump in China's level of state investment by pointing to the fact that in 2019, China raised a second "Big Fund" worth 200 billion RMB (~US$27.8 billion).[41] Furthermore, China's chip industry is less mature than those of its East Asian neighbours, which could also potentially explain why it is investing more to develop its industry further at this point in time. Even if we used alternative indicators such as cumulative investment over time, this would not fully account for the fact that advances in chip technology have also brought corresponding increases in the cost of setting up foundries,[42] meaning that levels of investment will still vary depending on the maturity of a state's chip industry.

[40] Deloitte (China), "Anchor of Global Semiconductor".
[41] Zhang et al., "Five Things to Know".
[42] Chu, *The East Asian Computer Chip War*, p. 27.

Figure 2: State Investment in the Chip Industry by East Asian States (US$ billion)

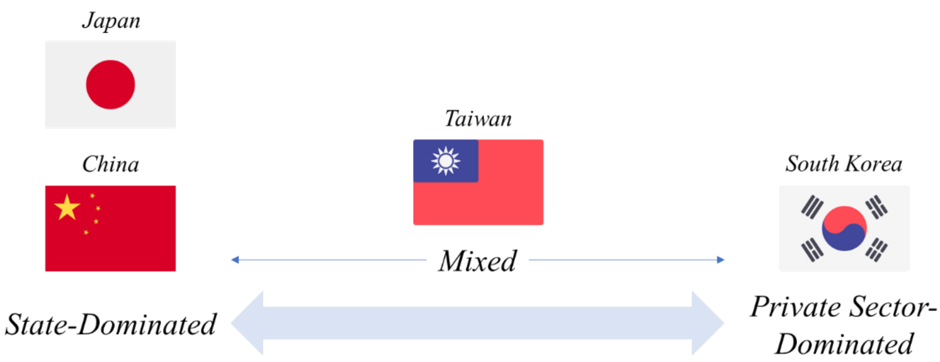


Source: Adapted from Deloitte (China), "Anchor of Global Semiconductor: Asia Pacific Takes Off", 2021. https://www2.deloitte.com/content/dam/Deloitte/cn/Documents/technology-media-telecommunications/deloitte-cn-tmt-semiconductor-report-en-211001.pdf.

Framework for Comparison

Figure 3 summarises the extent of state versus private sector involvement for the cases considered. There are three possible classifications, which can be placed on a spectrum ranging from state-dominated to mixed and then to private-sector dominated. The classifications are meant to signal the dominant actor shaping the chip industry but are not monolithic and do not discount the complex interactions between states, firms, and other players within the chip industry of the cases considered – this is addressed in the individual sub-sections on each case that follow. While classifying chip industries as "state-dominated" or "private sector-dominated" is relatively straightforward, the "mixed" classification opens the question of the threshold applied. Rather than define an unavoidably subjective threshold, I use the individual sub-section for Taiwan to explain why its chip industry is not easily classified at either end of the spectrum.

Figure 3: Overview of East Asian States' Chip Industries by Extent of State versus Private Sector Involvement



There is also a temporal factor at play in the case comparison. For instance, South Korea and Taiwan have moved from a starting point at the state-dominated end of the spectrum since the inception of their chip industries between the 1970s and 1980s, although to differing degrees. As highlighted earlier, the impact of policy initiatives is lumpy in nature, and the chip industry is certainly not static given Moore's Law. There is therefore a possibility that all the cases could be positioned differently along the spectrum in future. With the recent global resurgence of industrial policy focused on the chip industry, there is potential for the cases to move towards the direction of state-dominated involvement.

Japan (State-Dominated)

The chip industry in Japan is concentrated in Kyushu's "Silicon Island" and is the world's third largest.[43] Although Japan's chip industry has lost global market share compared to its heyday in the 1980s, it still controls a significant share of value-added segments that provide inputs for fabrication, particularly in equipment (27% in 2021, behind the United States' 42%[44]) and in materials, where it is a global leader (52% in 2020[45]). Key firms in Japan's chip industry include Kioxia (memory IDM; spun off from Toshiba), Renesas (logic IDM), Sony (IDM), and Tokyo Electron (equipment).

In 2021, Japan's Ministry of Economy, Trade, and Industry (METI) announced the "Strategy for Semiconductors and the Digital Industry" to achieve what has been described as Japan's "last chance" to regain a dominant position in the global chip industry.[46] METI's strategy emphasised revitalising the domestic manufacturing base, with a focus on joint ventures with overseas foundries and upgrading suppliers.[47] This approach represents a significant shift in strategy and a large increase compared to the previous levels of state investment highlighted in Figure 2. For example, Japan provided ¥476 billion (~US$3.2 billion) in 2022 to a TSMC joint venture with Sony and Denso to build a foundry in the Kumamoto Prefecture of Kyushu.[48] In the same year, a ¥93 billion (~US$623 million) subsidy was granted to a Kioxia–Western Digital joint venture in the Mie Prefecture of Honshu.[49]

Although the state through METI plays a key role in making plans, setting overall industry strategy and backing this up with policy measures and investment, Japan's state-dominated

[43] Semiconductor Industry Association, "2022 State of the US Semiconductor Industry".
[44] Semiconductor Industry Association, "2022 State of the US Semiconductor Industry".
[45] Deloitte, "Anchor of Global Semiconductor".
[46] Yuri Kageyama, "Japan Vies for 'Last Chance' as Major Global Chip Producer", AP, 11 November 2022, https://apnews.com/article/technology-business-japan-82eb85980ec714d1ca9f5edbd513ae7e.
[47] Ministry of Economy, Trade, and Industry, Japan, "Strategy for Semiconductors and the Digital Industry" (English Summary), 2021, https://www.meti.go.jp/english/press/2021/pdf/0604_005a.pdf.
[48] "Japan Gov't to Allocate up to 476 Bil. Yen for TSMC Chip Plant", Kyodo News, 17 June 2022, https://english.kyodonews.net/news/2022/06/a9cea4013c02-japan-govt-to-allocate-up-to-476-bil-yen-to-tsmc-chip-plant.html.
[49] "Japan to Give 92.9 Bil. Yen Subsidy to Kioxia-Western Digital Chip Plant", Kyodo News, 26 July 2022, https://english.kyodonews.net/news/2022/07/034fc15ce458-japan-to-give-929-bil-yen-subsidy-to-kioxia-western-digital-chip-plant.html.

institutional set-up within its chip industry retains significant involvement of the private sector and research institutions in defining policy implementation. This is seen in the ongoing "Next Generation Beyond 2nm Project" (B2P) initiated by METI to create a domestic base in Japan for advanced chips that are beyond the current technology frontier.[50] The B2P initiative involves two tracks – one to set up a R&D collaboration platform, and the other to create a supporting manufacturing facility to commercialise technologies developed through the R&D platform.[51] The latter – Rapidus – was incorporated in 2022 with a consortium of eight prominent Japanese firms participating through initial investments of ¥1 billion each (~US$6.7 million) on top of the state's ¥70 billion (~US$469 million).[52]

South Korea (Private-Sector Dominated)

South Korea's chip industry, which is primarily based in Seoul and the surrounding Gyeonggi Province, is the world's second largest, behind that of the United States, and the largest for memory chips.[53] It has a strong share in the high value-adding design segment at 20% in 2021, again behind the United States' 49%.[54] Global industry leaders within South Korea's chip industry include Samsung and SK Hynix, which are memory IDMs, but Samsung also operates a significant "pure play" foundry business, which is second only to TSMC's in terms of global market share – 15.8% versus 58.5% in Q4 2022.[55]

Given that chips accounted for approximately 20% of total exports in 2020,[56] it is unsurprising that the state has paid close attention to the chip industry. In 2021, South Korea announced the "K-Semiconductor Strategy", which provides support for infrastructure development through tax credits and subsidies while aiming to develop a geographical cluster called the "K-Semiconductor Belt".[57] If successful, South Korea's chip industry would have invested US$450 billion by 2030 to develop the world's largest chip manufacturing cluster.[58] A key shift envisaged by this strategy is to push South Korea's chip industry beyond its stronghold in fabricating memory chips and build market share in logic chips, an area currently dominated by Taiwan's TSMC.[59]

[50] Scott Foster, "Japan's Grand Plan to Home Grow 2nm Chips" *Asia Times*, 14 November 2022, https://asiatimes.com/2022/11/japans-grand-plan-to-home-grow-2nm-chips/.
[51] "Japan Firms Form New Company for Domestic Production of Next-Generation Semiconductors", *The Japan News*, 11 November 2022, https://japannews.yomiuri.co.jp/business/companies/20221111-70167/.
[52] Kageyama, "Japan Vies for 'Last Chance' as Major Global Chip Producer".
[53] Semiconductor Industry Association, "2022 State of the US Semiconductor Industry".
[54] Semiconductor Industry Association, "2022 State of the US Semiconductor Industry".
[55] Joanne Chiao and Eden Chung, "Total Revenue of Top 10 Foundries Fell by 4.7% QoQ for 4Q22 and Will Slide Further for 1Q23, Says TrendForce", *TrendForce*, 13 March 2023, https://www.trendforce.com/presscenter/news/20230313-11612.html.
[56] Joyce Lee and Hyunjoo Jin, "South Korea Government, Samsung Team Up for Self-Sufficiency After Japan Export Curbs on Chip Material", Reuters, 14 September 2020, https://www.reuters.com/article/us-southkorea-japan-chip-analysis-idINKBN26501U.
[57] Jin-Seo Yu, "In Chip War, Korea Spends Big to Stay Ahead of China", *Asia Times*, 1 July 2022, https://asiatimes.com/2022/07/in-chip-war-korea-spends-big-to-stay-ahead-of-china/.
[58] Byung-Yeul Baek, "Korea to Create World's Largest Chip Manufacturing Complex", *The Korea Times*, 14 May 2021, https://www.koreatimes.co.kr/www/tech/2021/05/133_308778.html.
[59] Samuel K. Moore, "South Korea's $450-Billion Investment Latest in Chip Making Push", IEEE Spectrum, 26 May 2021, https://spectrum.ieee.org/south-koreas-450billion-investment-latest-in-chip-making-push.

Although the state plays a role in supporting the chip industry, South Korea can still be considered to have a private sector-dominated institutional set-up. This is because Samsung and SK Hynix, the leading players within South Korea's chip industry, exert significant political influence as *chaebols* (large family-run conglomerates). Samsung alone accounts for approximately 20% of South Korea's annual GDP.[60] In 2020, private sector R&D accounted for 79% of total expenditure as a share of GDP, compared to 12% for the state and 9% for research institutions.[61] An example of the private sector's dominance within the South Korean chip industry's institutional set-up can also be seen in how Samsung provided subsidised equipment for a national chip material testing facility opened in 2020 as part of a state-led plan to wean the chip industry off Japanese suppliers following a trade dispute in 2019.[62]

Taiwan (Mixed)

Hsinchu is the home of Taiwan's chip industry, which is the fifth largest globally and contains the world's largest "pure play" foundry by market share, TSMC.[63] Taiwan is dominant globally in both mid-stream fabrication (58.8% in 2020) and downstream ATP (40% in 2020) and has a significant share in the materials segment (15% in 2020).[64] In addition to TSMC, global industry leaders in Taiwan's chip industry include MediaTek (fabless chip design for mobile devices and automobiles), UMC (originally an IDM, today a foundry), ASE (world's largest OSAT firm), and Powertech (OSAT).

As in Japan and South Korea, the roots of Taiwan's chip industry lie in state-led initiatives.[65] Although it has pared down its holdings over the years, the state – through its National Development Fund – continues to maintain a 6.38% stake in TSMC, the "crown jewel" of its chip industry, and retain its status as the firm's single largest shareholder, according to TSMC's 2022 annual report. In a move targeted at the chip industry, Taiwan passed legislative amendments in early 2023 to facilitate tax breaks for domestic firms developing new technologies and participating in global supply chains.[66] This was arguably Taiwan's attempt at an industrial policy for its chip industry following similar initiatives made by other states. Meanwhile, local authorities in Kaohsiung, located in the southern part of the island, are aiming to develop a new chip industry cluster called the "Southern Semiconductor S Corridor" to shift the focus away from Hsinchu in the north.[67]

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[60] Yoo-Chul Kim, "Samsung Could Revive 'Control Tower' to Become More Agile", *The Korea Times*, 18 October 18 2022, https://www.koreatimes.co.kr/www/tech/2023/05/419_338020.html.
[61] Ku-Hyun Jung, "The Changing Face of South Korea's Business Sector Amid Global Competition", In *How South Korea Is Honing a Competitive Edge*, ed. Chung Min Lee (Washington, DC: Carnegie Endowment for International Peace, 2022), https://carnegieendowment.org/2022/11/22/changing-face-of-south-korea-s-business-sector-amid-global-competition-pub-88420
[62] Lee and Jin, "South Korea Government, Samsung Team Up".
[63] Semiconductor Industry Association, "2022 State of the US Semiconductor Industry".
[64] Deloitte, "Anchor of Global Semiconductor".
[65] Miller, *Chip War*, pp. 163–70.
[66] Chien-Ling Liu, Sean Lin, and Frances Huang, "Latest Step Taken to Pave Way for Taiwan Version of CHIPS Act," *Focus Taiwan*, 1 May 2023**,** https://focustaiwan.tw/business/202305010006.
[67] Christina Lin, "The 'Southern Semiconductor S Corridor' and the Role of Taiwan Industry in US-China Competition", *Global Taiwan Brief* 8, no. 5 (2023): 10–12.

Nevertheless, Taiwan's private sector holds significant influence over the direction of its chip industry. Beyond TSMC, industry heavyweights such as MediaTek and ASE also play an important role. For example, in 2023 MediaTek pushed to grow Taiwan's participation in the design segment by purchasing Intel's 5G PC modem business unit.[68] Prior to this, it also partnered Purdue University in the United States to set up a chip design centre outside traditional industry concentrations, with a design team located within Purdue's campus.[69]

"Fragmented Authoritarianism" in China's Chip Industry

As a framework for understanding policymaking in China, "fragmented authoritarianism", in the words of Mertha and Brødsgaard, "challenges alternative explanations that claim that it is primarily power or the aggregation of a rational division of labour and interest that drive policy outcomes in China".[70] Fragmented authoritarianism instead argues that "power can be easily manipulated, even effectively 'vetoed', at the policy implementation stages and that policy rationality is constantly being undermined by the self-interested, short-term, and parochial calculations of institutional actors whose support is essential for the policy to even remotely succeed."[71] Fragmented authoritarianism is the other side of the coin that Ang and Heilmann credit with innovative policymaking processes which have led to economic growth and development in China.

Earlier, I described how Ang and Heilmann's views of the economic policymaking process in China do not fully account for the apparent failure of indigenous innovation policies for the chip industry's development owing to variation in the impact that policymaking processes have at the sectoral level, as well as the limited attention paid to the role of firms. Here, I build on this and the case comparison which showed how mixed and private sector-dominated institutional set-ups in other East Asian states' chip industries have contributed to their success in terms of developing advanced capabilities and dominance within specific value-adding segments.

In contrast to Japan, South Korea and Taiwan, China's state-dominated institutional set-up in its chip industry operates within the context of fragmented authoritarianism, which results in "a constellation of policy outcomes that often bears little resemblance to the policy-makers' original intent in spirit if not letter, but which takes into account all of the various interests of bureaucratic actors all the way down the line."[72] The interests of these bureaucratic actors compete with those of the top

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[68] Anton Shilov, "Intel Disconnects 5G Modem Business, Sells to MediaTek", *Tom's Hardware*, 25 March 2023, https://www.tomshardware.com/news/intel-quits-laptop-modem-biz.
[69] MediaTek, "MediaTek Announces Commitment to Open New Semiconductor Design Centre at Purdue University in Indiana", 29 June 2022, https://corp.mediatek.com/news-events/press-releases/mediatek-announces-commitment-to-new-semiconductor-design-center-at-purdue-university-in-indiana.
[70] Andrew Mertha and Kjeld Erik Brødsgaard, "Introduction", in *Chinese Politics as Fragmented Authoritarianism: Earthquakes, Energy and Environment*, ed. Kjeld Erik Brødsgaard (London: Routledge, 2016), p. 3.
[71] Mertha and Brødsgaard, "Introduction".
[72] Mertha and Brødsgaard, "Introduction".

leadership within the Chinese Communist Party (CCP) and the high-level policy objectives they have prioritised. This then leads to over-allocation of resources to paper tigers within China's chip industry.

Noting that China attempted to follow in the footsteps of its East Asian neighbours "by pursuing giant corporations with advantages of scale and scope economies",[73] Fuller points to "how the political incentives for local officials negatively affect the management of, and consequently the upgrading outcomes within China's development zones".[74] In his view, "formal political incentives for investment and economic growth … are conducive only for industrial investment rather than longer-term upgrading of industrial activities."[75] These observations not only stand in contrast to Ang and Heilmann's views of China's policymaking process but also indicate why China has struggled to keep up with the rapid cadence of innovation in the chip industry laid out by Moore's Law. Evidence for this is seen in high-profile failures of chipmakers that received funding from China's Big Fund. The dynamic that emphasises investment over upgrading can be attributed to competing interests, since the Ministry of Finance is the largest shareholder, which means that the CCP's political objectives need to be balanced against those of the fund's managers.[76]

An example of a high-profile failure is Tsinghua Unigroup, a holding company of the Beijing-based Tsinghua University, which is one of China's top-ranked research institutions. Between 2013 and 2019, Tsinghua Unigroup acquired more than 20 firms in a bid to fast-track its progress towards achieving self-sufficiency in chips.[77] Some of these acquisitions were funded by the Big Fund, which disbursed more than 50 billion RMB (~US$7 billion) to Tsinghua Unigroup between 2018 and 2021.[78] By July 2021, having been stretched by approximately 200 billion RMB (~US$27.8 billion) in liabilities, Tsinghua Unigroup began court-mandated bankruptcy proceedings, and its former chairman, Zhao Weiguo, was detained and placed under investigation for corruption.[79] A year later, in 2022, executives at the helm of the Big Fund, including its head, Ding Wenwu, were also placed under investigation for corruption, a development that has cast a shadow over its future.[80]

Another high-profile failure, Hongxin Semiconductor Manufacturing Co (HSMC), was set up in 2017 as a joint venture with the Dongxihu district government of Wuhan, China's ninth-biggest city and the capital of Hubei province in the Central-South administrative region.[81] HSMC's promise rested on it having hired Chiang Shang-Yi – a highly regarded ex-TSMC industry veteran – who was in turn

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[73] Fuller, *Paper Tigers, Hidden Dragons*, p. 43.
[74] Fuller, *Paper Tigers, Hidden Dragons*, p. 44.
[75] Fuller, *Paper Tigers, Hidden Dragons*, p. 48.
[76] Zhang et al, "Five Things to Know".
[77] Barry van Wyk, "Mayhem in China's Semiconductor Industry as 'Chips Madmen' are Arrested", The China Project, 1 August 2022, https://thechinaproject.com/2022/08/01/chinas-microchip-great-leap-forward-has-also-ended-in-chaos/.
[78] Van Wyk, "Mayhem in China's Semiconductor Industry".
[79] Van Wyk, "Mayhem in China's Semiconductor Industry".
[80] Jing Chen, "China's Chip Industry 'Big Fund' Crackdown: Corruptions or Failed Investments?" *ThinkChina*, 12 August 2022, https://www.thinkchina.sg/chinas-chip-industry-big-fund-crackdown-corruptions-or-failed-investments.
[81] Emily Feng, "A Cautionary Tale for China's Ambitious Chipmakers", NPR, 25 March 2021, https://www.npr.org/2021/03/25/980305760/a-cautionary-tale-for-chinas-ambitious-chipmakers.

responsible for helping the firm acquire a deep ultraviolet (DUV) lithography machine from ASML in 2019 that was only one generation behind the most advanced EUV (extreme ultraviolet) lithography equipment.[82] However, HSMC's founders were not only chip industry outsiders but also had criminal intent.[83] Despite receiving 15.3 billion RMB (~US$2.1 billion) in state investment over almost three years, HSMC failed to produce a single chip; Chiang resigned in July 2020 and the Dongxihu district government took over HSMC with no clear plans for its revival.[84]

Further evidence of the impact from competing interests is seen in the way the Big Fund has allocated its investments to different parts of the supply chain. According to an assessment by the US-based Semiconductor Industry Association, almost 70% of investments by the Big Fund have been focused on the fabrication and ATP segments.[85] One reason for this is that the CCP's "campaign-style catch-up strategy seeks a short-cut approach for quick success … [that] goes against almost every factor and requirement for a successful IC [integrated circuit, i.e., chip] sector, including long-term accumulation of R&D input and talent dedicated to it."[86] As a result, China's chip industry is making slower progress in the design, intellectual property and technology development segments,[87] which in turn affects its ability to build more advanced capabilities.

Prospects for China's Chip Industry Institutional Set-up

However, China has attempted to address the shortcomings of its indigenous innovation policies for chips by doubling down on the industry's state-dominated institutional set-up, even though this has not yielded desired results. For example, the CCP has created centralised policy coordination mechanisms called leading small groups (LSGs), which aim to bring together relevant parts of the bureaucracy to "exchange opinions and discuss issues relating exclusively to the group's given task … [thereby increasing] cross-department interactions, which is [sic] believed to facilitate the flow of information and help achieve coordination."[88]

After launching the 2014 Outline for Promoting and Developing the National Integrated Circuit Industry, China's State Council set up a corresponding LSG the same year to facilitate the policy's implementation, led by then Vice Premier Ma Kai, who was supported by the then minister of industry

[82] Feng, "A Cautionary Tale".
[83] Jordan Schneider, "Billion Dollar Heist: How Scammers Rode China's Chip Boom to Riches," *ChinaTalk*, 30 March 2021, https://www.chinatalk.media/p/billion-dollar-heist-how-scammers.
[84] Kevin Xu, "China's 'Semiconductor Theranos': HSMC (From the Archive)," *Interconnected*, 14 February 2023, https://interconnect.substack.com/p/chinas-semiconductor-theranos-hsmc.
[85] Semiconductor Industry Association, "Taking Stock of China's Semiconductor Industry", 13 July 2021.
[86] Alex He, "China's Techno-Industrial Development: A Case Study of the Semiconductor Industry", Centre for International Governance Innovation (Canada) Papers No 251, May 2021, p. 21, https://www.cigionline.org/static/documents/documents/no.252%20web.pdf.
[87] John Lee and Jan-Peter Kleinhans, "Mapping China's Semiconductor Ecosystem in Global Context: Strategic Dimensions and Conclusions", Stiftung Neue Verantwortung (Germany), June 2021, pp. 21–33, https://www.stiftung-nv.de/sites/default/files/chinas_semiconductor_ecosystem.pdf.
[88] Jiying Jiang, "Leading Small Groups, Agency Coordination, and Policy Making in China", *The China Journal* 89, no. 1 (2022): 3.

and information technology, Miao Wei.[89] But "[i]t is unclear to what extent the national IC LSG remains active or involved in policymaking [concerning chips]."[90] This is because of other subsequently created LSGs with overlapping tasks, which inadvertently creates competing interests, even if they appear to be working towards the same broad goal.

For example, there is a LSG for "Establishing a Manufacturing Superpower" responsible for implementing the "Made in China 2025" initiative that includes a focus on increasing self-sufficiency in chips,[91] and another on "National Science and Technology", which aims to review existing science and technology strategies, plans and policies, including those concerning chips.[92] Given its focus on manufacturing, the work of the LSG for "Establishing a Manufacturing Superpower" would appear to prioritise the fabrication and ATP segments. On the other hand, the LSG for "National Science and Technology", which covers research and innovation, would emphasise the design, intellectual property and technology development segments. In a situation where trade-offs need to be made on resource allocation, it is unclear how the LSG on "Development of the National Integrated Circuit Industry" would coordinate with these other LSGs, or which group would have the final say.

Nevertheless, there are some signals that China may be shifting its approach away from backing paper tigers. In December 2022, there were reports of a planned support package for chipmakers amounting to 1 trillion RMB (~US$139.1 billion),[93] which suggested continuity with the Big Fund approach, but on an even larger scale. However, in early 2023, these plans were abruptly put on hold, which pointed to a rethink of the state's approach towards developing the chip industry.[94] This is further supported by reports that China intends to allow its more successful chip firms to have greater involvement in state-backed research projects.[95] Only time will tell whether such a shift results in a broader reconfiguration of the institutional set-up within China's chip industry away from over-allocating resources to paper tigers.

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[89] Lee and Kleinhans, "Mapping China's Semiconductor Ecosystem", p. 13.
[90] Lee and Kleinhans, "Mapping China's Semiconductor Ecosystem", p. 13.
[91] Max Zenglein and Anna Holzmann, "Evolving Made in China 2025: China's Industrial Policy in the Quest for Global Tech Leadership", MERICS Papers on China No 8, Mercator Institute for China Studies (Germany), July 2019, p. 29, https://merics.org/sites/default/files/2020-04/MPOC_8_MadeinChina_2025_final_3.pdf.
[92] Yun Gao, "China Establishes National Sci-Tech Leading Group", CGTN, 8 August 2018, https://news.cgtn.com/news/3d3d414e34557a4d79457a6333566d54/share_p.html.
[93] Julie Zhu, "Exclusive: China Readying $143 Billion Package for Its Chip Firms in Face of US Curbs", Reuters, 14 December 2022, https://www.reuters.com/technology/china-plans-over-143-bln-push-boost-domestic-chips-compete-with-us-sources-2022-12-13/.
[94] "Battered by Covid, China Hits Pause on Giant Chip Spending Aimed at Rivalling US", *Bloomberg*, 4 January 2023, https://www.bloomberg.com/news/articles/2023-01-04/battered-by-covid-china-hits-pause-on-giant-chip-spending.
[95] Qianer Liu, "China Gives Chipmakers New Powers to Guide Industry Recovery", *Financial Times*, 21 March 2023, https://www.ft.com/content/d97ca301-f766-48c0-a542-e1d522c7724e.

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