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BRIEFING PAPER

China's Quest for Semiconductor Self-Sufficiency

The impact on UK and Korean industries

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About CETaS

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Executive Summary

This CETaS Briefing Paper examines how China's quest for semiconductor self-sufficiency will affect the UK and Korean semiconductor industries. The paper builds on an April 2024 CETaS Research Report that assessed the ways the UK and Korea could bolster cooperation between their semiconductor and AI industries for mutual benefit.

Since October 2022, US-led export controls have explicitly targeted the Chinese chip industry, seeking to starve it of the critical components needed to accelerate progress in artificial intelligence (AI) and military innovation. These measures, while partly successful in slowing China down in the short term, have further emboldened Beijing in its quest for self-sufficiency and dominance in numerous parts of the semiconductor supply chain. Commentators have debated China's strategic options for achieving its economic and political goals in a chip-deficient environment, but there is a need for greater focus on the second-order effects of China's domestic ambitions on countries such as the UK and Korea. Despite not being at the forefront of ongoing US-China export control disputes, they still risk being caught in the crossfire of retaliation and deepening protectionism.

China's desire for semiconductor self-sufficiency predates recent geopolitical wrangling – the Made in China 2025 policy was instituted in 2015, paving the way for three iterations of The Big Fund to support self-sufficiency efforts. Crucially, the drive to achieve self-reliance is a whole-of-society undertaking in China, supported by vast amounts of centrally directed investment.

However, as the semiconductor industry is highly R&D-intensive, an investment of hundreds of billions of dollars over several years is still no guarantee of short-term success. Some areas of the industry have benefited more than others, which will influence the type of leverage that China can exert over countries such as the UK and Korea. This paper focuses on five mechanisms through which China could gain leverage over them:

1) **Intellectual property (IP) and chip design**. ARM – a UK-based company – is one of the world's top two core IP vendors. RISC-V is an open-source standard that some believe will rival ARM's dominance in the long run. China has devoted significant resources to the development of the RISC-V ecosystem and sees this as an insurance policy should future US export controls extend to ARM products. If greater Chinese influence in the RISC-V ecosystem coincides with increased global adoption of the standard, this could create new dependencies on Chinese chip design – which could have important defence- and espionage-related implications further down the

supply chain. Nonetheless, the nexus between chip design and national security goes beyond the role of RISC-V: countries such as the UK and Korea face more fundamental questions about trust in the security of chips designed by Chinese companies, even if they deploy ARM cores.

2) **Compound semiconductors**. These are a class of semiconductors particularly relevant for the AI, defence and electric-vehicle industries, accentuating the importance of sovereign capability. Compound semiconductors are a top priority for China, and its monopolisation of the supply of critical minerals such as gallium is a key lever of influence. It is crucial to continue supporting moves to increase UK domestic capacity in compound semiconductors, while leaning further into global compound semiconductor partnerships. In this, the UK's initial agreements with countries such as Malaysia and Taiwan are positive recent developments.

3) **High-bandwidth memory (HBM) chips.** The growth in demand for AI chips has driven greater Chinese interest in the advanced memory sector, and HBM is a crucial target for China's latest iteration of The Big Fund. Although China's leading memory-chip maker has begun producing second-generation HBM sooner than expected, China's capability in many aspects of the HBM supply chain still lags behind Korea's market leaders. As China continues to step up its ambitions in the area, it is conceivable that SK Hynix/Samsung plants in China will come under heightened pressure. This context, alongside the growth in demand for *low-power* HBM chips, presents an opportunity for ARM, which should collaborate with Korean HBM providers on the development of architecture and IP for these chips.

4) **Mature-node vulnerabilities**. China's strength in mature-node chips – those produced at 28 nanometres (nm) and above – is well-recognised, augmented by rapidly expanding markets for electric-vehicle batteries and solar cells. Members of the G7 (and other like-minded countries) have expressed concern that this could lead to oversupply in the global market and the dumping of certain chips that drives prices down – tempting UK and Korean companies to become reliant on them. This could leave Chinese chipmakers in control of a strategically important segment of the semiconductor market.

5) **Policy coordination**. Recent years have seen even greater central oversight of all aspects of China's semiconductor strategy. This has allowed for a more precise focus in areas such as semiconductor manufacturing equipment and has made it

> easier for Beijing to control domestic partnerships and collaborations. The designation of supply chain-wide responsibilities to companies such as Huawei makes it increasingly difficult for UK or Korean firms to know who they are collaborating with in China. The move has a wide range of national security implications, as China's implementation of its military-civil fusion strategy continues apace. In this context, there are lessons for the UK and Korea in aligning science and tech policy coordination in the broader context of new security and defence agreements with other allies in Europe and Asia.

The UK and Korea occupy very different positions in the global semiconductor supply chain, but both countries will be affected by China's quest for self-sufficiency in their own ways. They should approach this challenge collectively rather than individually. In the context of deepening UK-Korea collaboration, and new relevant agreements with allies such as India and the EU, there is no better time for the UK to prioritise this partnership.

Policy Recommendations

Table 1. Measures to boost resilience against China's semiconductor industrial policy

UK domestic policy	UK international policy
The UK National Semiconductor Institute (NSI) – announced under the previous government but not yet established – should **coordinate with corresponding bodies in partner countries to minimise strategic vulnerabilities to Chinese industrial policy.** The UK NSI should also focus on **easing information flows** between different UK semiconductor clusters and Catapult centres, particularly on their investment activities. This would engender a more unified 'Team UK' approach to the global semiconductor market.	The UK should work with key allies such as Korea to initiate more detailed **contingency plans in the event of Chinese oversupply in the mature-node chip market**, and seek to join existing discussions on the topic led by the European Commission. This should build on G7 countries' recent endorsement of a mechanism to share information with one another to support supply chain crisis coordination.[1]
The emphasis on removing red tape and **infrastructural barriers** as part of the UK's new industrial strategy should prioritise the needs of **UK semiconductor companies**. The costliness of planning delays is underscored by the extremely competitive global environment, the pre-existing scale-up and expansion challenges facing UK startups, and the criticality of the UK	To combat the **espionage risk** posed to physical hardware, there is a need to work with allies to establish a **verification framework for enhanced chip security.** While existing programmes such as Digital Security by Design address the security of chip architecture, this would focus on the provenance of chip supply. In the UK, the effort would be led by the National Cyber Security Centre.

[1] "G7 Industry and Technology Ministers convene in Rome to advance industrial competitiveness, digital innovation and sustainable digital transformation," Ministry of Enterprises and Made in Italy, 10 October 2024, https://www.mimit.gov.it/en/media-tools/news/g7-industry-and-technology-ministers-convene-in-rome-to-advance-industrial-competitiveness-digital-innovation-sustainable-digital-transformation.

semiconductor industry to economic and national security.	
In light of China's **leverage in critical mineral markets** such as gallium – a key compound in semiconductor components – the UK Government should consider how it can more **closely align its semiconductor policy ambitions with its critical minerals strategy** to reduce exposure to Chinese trade policy.	To combine the **UK's strengths in design and IP with Korea's strengths in manufacturing and memory devices**, both countries should explore the feasibility of a **Prototype Co-R&D Centre** that focuses on servicing requirements in their defence sectors and future AI data centres.
The ChipStart incubator established in the 2023 National Semiconductor Strategy should be placed on **a longer-term footing**, and should receive sufficient funding to **incentivise UK startups to plan and build long-term operations in the UK**.	The UK should capitalise on the complementarity between its **strengths in compound semiconductors and Korea's focus on energy-efficient semiconductors**. Both countries should encourage their industries to scope out joint research and investment opportunities at this crucial juncture.
Given the significant overlap between the semiconductor priorities of China and the UK, the UK Government should prioritise the **access to the cybersecurity support and secure research advice that key UK semiconductor assets** need to maintain their advantage.	The UK's participation in **the EU's Chips Joint Undertaking** presents a crucial opportunity in the context of the UK Government's **reset of diplomatic relations with the EU** and the renewed emphasis on making Europe a globally competitive manufacturing force. The UK Government should ensure that mechanisms are in place to **align the different strands of the UK's engagement with the EU's science and tech ecosystem.** Additionally, the UK should seize opportunities with third parties in this context, such as a newly announced

	funding opportunity with Korea on advanced packaging.
The UK Government should explore the opportunities presented by ARM's forthcoming entrance into the AI chip market for UK semiconductor startups, as a means of **securing greater sovereignty in the AI supply chain**.	Korea should lead an initiative to identify suitable third-party countries with which to develop a **more inclusive technology- and knowledge-sharing semiconductor ecosystem, with the UK as the primary European partner.** This network should differentiate itself from China's more extractive approach in places such as Southeast Asia.

Introduction

Countries such as the US, China, India, Japan and Korea are investing tens of billions of dollars in their semiconductor industries to insulate domestic supply chains from external volatility. While recent financial incentives from the US and European governments have been encapsulated in flagship legislation – via the US CHIPS and Science Act and the European CHIPS Act – similar incentives in China sprawl across numerous vehicles, with some estimating that the Chinese chip industry has received more than $150 billion in government support since 2014.[2] This period has been defined by near-limitless resources, a large and protected market, and a sophisticated global espionage strategy.[3] In its quest for "national rejuvenation," China is prepared to employ a whole-of-state approach, using a wide range of state levers to achieve its technological goals.[4]

China's resolve for indigenous innovation has only been strengthened following the intensification of US export controls. De-risking is also moving apace in China, with domestic Chinese telecoms providers ordered to replace chips from AMD and Intel in their infrastructure by 2027.[5] China recognises that, to achieve its goals in domains such as AI, it must overcome a chip-deficient environment and quicken its drive for self-sufficiency across the semiconductor supply chain.

By consolidating its semiconductor industry, China aims to secure technology leadership, find new growth sectors, create high-tech jobs and generate revenues that alleviate its debt issues. In the context of an impending macroeconomic slowdown, new drivers for prosperity are vital in maintaining the legitimacy and legacy of the Chinese Communist Party (CCP) leadership.[6] There are also longer-term geostrategic drivers at play. If China becomes a semiconductor superpower, this would lessen its reliance on Taiwan in the sector and could affect Taiwan's strategic value to the West. Separately, Chinese semiconductor self-sufficiency could augment the military ambitions of countries such as Russia, Iran and North Korea – as of 2023, China provided 90% of Russian microelectronics vital for advanced

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[2] "China boosts state-led chip investment," Economist Intelligence Unit, 13 March 2024, https://www.eiu.com/n/china-boosts-state-led-chip-investment/.
[3] Intelligence and Security Committee of Parliament, *China* (July 2023), 194, https://isc.independent.gov.uk/wp-content/uploads/2023/07/ISC-China.pdf.
[4] Intelligence and Security Committee of Parliament (July 2023), 123.
[5] Ryan McMorrow, Nian Liu and Qianer Liu, "China blocks use of Intel and AMD chips in government computers," *Financial Times*, 24 March 2024, https://www.ft.com/content/7bf0f79b-dea7-49fa-8253-f678d5acd64a.
[6] Lizzi C. Lee, "China's Big Fund 3.0: Xi's Boldest Gamble Yet for Chip Supremacy," *The Diplomat*, 6 June 2024, https://thediplomat.com/2024/06/chinas-big-fund-3-0-xis-boldest-gamble-yet-for-chip-supremacy/.

armaments.[7] The possibility of China's domestic chip industry acting as the guarantor for war economies such as Russia's should raise significant concerns for policymakers in the West.

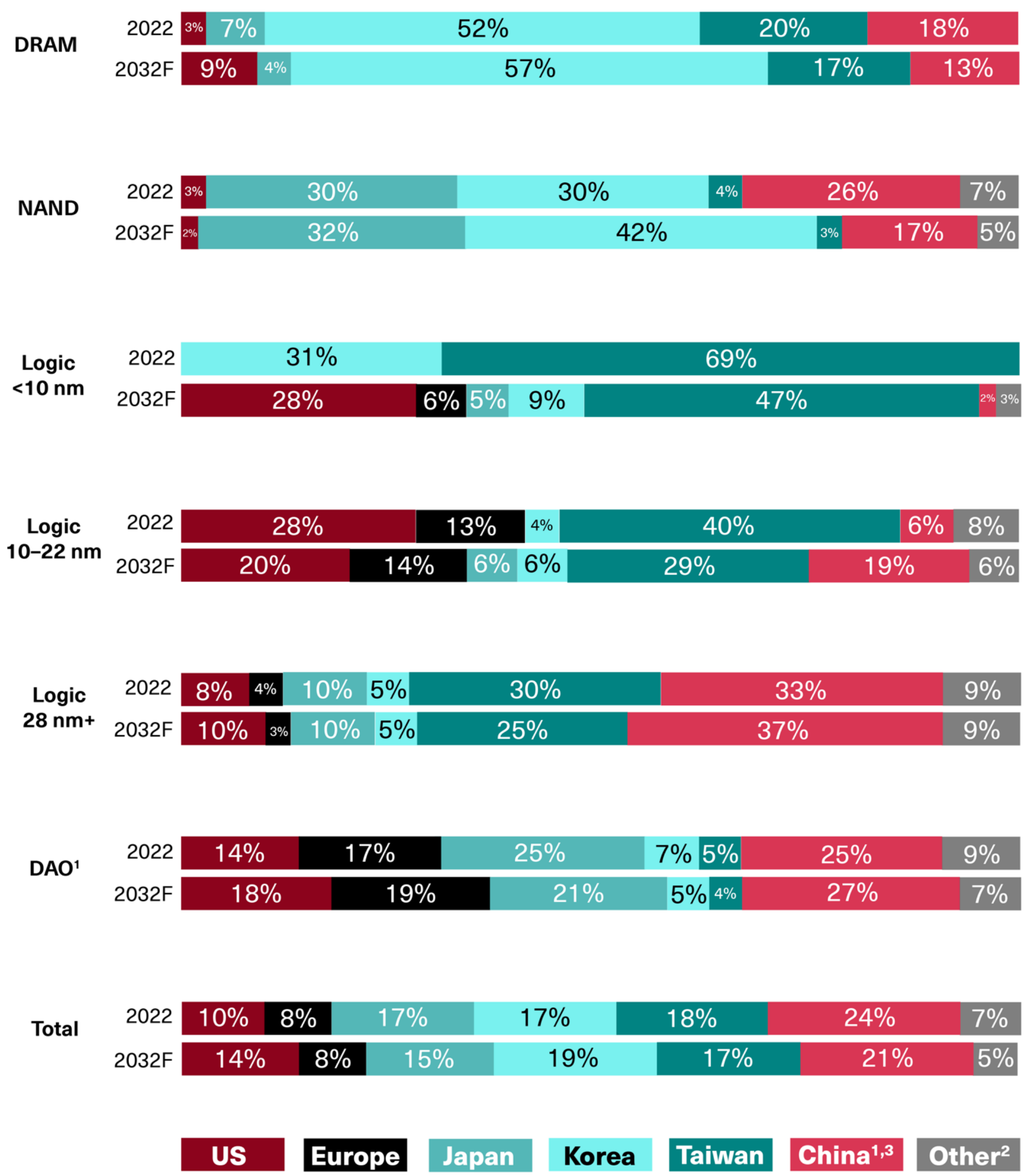
More broadly, there is a need for a more rigorous study of the second-order effects of China's quest for chip self-sufficiency on countries such as the UK and Korea. According to Boston Consulting Group and the US Semiconductor Industry Association, global 200mm+ commercial semiconductor fab capacity is projected to shift significantly by 2030. The US is expected to reach 14% of total capacity share, and China 21%. Korea, Taiwan and Japan are forecast to maintain relatively stable shares at 19%, 17% and 15% respectively. Europe's share is predicted to stagnate at 8% over the coming decade.[8] Across different chip technologies, these figures vary significantly.

From a product perspective, China is expected to see substantial growth in logic chip production, particularly in the 10-22nm and >28nm nodes. Conversely, its capacity in memory chip production (NAND and DRAM) is projected to decrease significantly.

[7] Ariel Cohen, "China's Massive Barrage in the Chip Battle," *Forbes*, 31 May 2024, https://www.forbes.com/sites/arielcohen/2024/05/31/chinas-massive-barrage-in-the-chip-battle/.

[8] Raj Varadarajan et al., *Emerging Resilience in the Semiconductor Supply Chain* (Boston Consulting Group and Semiconductor Industry Association: 2024), 14, https://www.semiconductors.org/wp-content/uploads/2024/05/Report_Emerging-Resilience-in-the-Semiconductor-Supply-Chain.pdf.

Figure 1. Global wafer fabrication capacity by technology category and region (2022–2032)



1 Discretes, analogue, and sensors and optoelectronics
2 Other includes Malaysia, Singapore, India and the rest of the world
3 Mainland China
Note: Looked at fabs with more than 5,000 wspm and 8+ inch wafer size; excluded R&D fabs. May not total 100% due to rounding.

Source: US Department of Commerce; SEMI; BCG Analysis.

The substantial projected increase in China's capacity to produce mid- to low-tech logic chips over the next decade suggests that it is likely to establish a pathway towards a self-sufficient semiconductor ecosystem for many of its strategic industries, including autonomous vehicles and smart devices. This is particularly significant because most electronics and vehicles still rely on mature-node chips.

Although China may not achieve full autonomy, its progress towards self-reliance in logic chip production is likely to have a significant impact on global semiconductor supply chains. It could fundamentally disrupt market dynamics: increased capacity in mature-node chips would raise the spectre of oversupply and significant price pressures, damaging the competitiveness of UK firms in the global market.[9] Moreover, many of China's domestic semiconductor industry priorities overlap with areas that the UK considers to be either existing strengths or avenues for future strategic advantage. This is also the case for Korea, albeit in different ways.

The landscape is further complicated by impending changes in the White House. Under President Joe Biden, US export controls have had implications for UK companies: these restrictions affected exports of equipment from vendors such as Oxford Instruments, and high-end AI chips from developers such as Graphcore. The Biden administration maintained tariffs on Chinese semiconductors that were introduced under the first Trump administration.[10] There is now building anticipation about president-elect Donald Trump's approach to tariffs and subsidies in his second term. Further tariffs may lead to increased costs across all sectors that use semiconductors, which could unduly harm smaller economies such as those of the UK and Korea. In addition, if the Trump administration imposes restrictions on Chinese chips due to trust and security concerns, it could accelerate a bifurcation in global standards between China and the rest of the world.

This paper provides a detailed analysis of the Chinese semiconductor landscape and assesses its externalities for the UK and Korean semiconductor industries. The paper also suggests measures that the UK can implement to bolster its domestic strengths in the industry and to mitigate the potentially negative effects of China's approach to semiconductors, both unilaterally and in cooperation with key partners such as Korea.

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[9] Lizzi C. Lee, "China's Big Fund 3.0: Xi's Boldest Gamble Yet for Chip Supremacy," *The Diplomat*, 6 June 2024.
[10] Jowi Morales, "US to increase tariffs on Chinese semiconductors by 100% in 2025 – officials say it protects the $53 billion spent in the CHIPS Act," *Tom's Hardware*, 15 May 2024, https://www.tomshardware.com/tech-industry/semiconductors/us-to-increase-tariffs-on-chinese-emiconductors-by-100-in-2025-officials-say-it-protects-the-dollar53-billion-spent-on-the-chips-act.

1. China's Semiconductor Landscape

There is no doubt about the importance of science and technology (S&T) to the Chinese leadership's bid to fulfil its global ambitions. In a speech at the Nationwide S&T Conference, Chinese President Xi Jinping emphasised this point:

> *"Although China's S&T undertakings have made great progress, our original innovation capabilities are still relatively weak, some key and core technologies (关键核心技术) are controlled by others (受制于人) and there is a shortage of elite S&T talents. We must further enhance our sense of urgency, give further impetus to S&T innovation, and seize the commanding heights of S&T competition and future development."*[11]

The reference to key technologies being controlled by foreign powers underlies a core tenet of Chinese policymaking in the 2020s: the centrality of self-sufficiency across technological supply chains. This section of the paper explores the implications of that push for self-sufficiency, examining the institutional vehicles the CCP has put in place to fulfil its aspirations. The paper then considers the areas of strength and weakness in China's semiconductor sector.

1.1 Centrality of self-sufficiency: Made in China 2025

Semiconductors are crucial to China's self-sufficiency goals because they sit at the intersection of national security and high-tech growth industries identified by the CCP.[12] Indeed, as early as 2014, President Xi noted that "semiconductors [are] a core technology that China should produce domestically" and a key plank of China's pledge to "mobilise all means … to wrest technological supremacy from the United States and other nations."[13]

That was the year China published its National Integrated Circuit (IC) Promotion Guidelines to accelerate support for its chip industry, laying the foundations for the publication of the Made in China 2025 plan a year later. The latter set the ambitious goal of 70% self-

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[11] Ben Murphy, *Translation: Xi Jinping: Speech at the Nationwide S&T Conference, National Science and Technology Awards Conference, and the Conference of Academicians of CAS and CAE* (CSET Georgetown: June 2024), 4, https://cset.georgetown.edu/publication/xi-jinping-cas-cae-conference-speech-2024/.
[12] Antonia Hmaidi, *Huawei is quietly dominating China's semiconductor supply chain* (MERICS: April 2024), 3, https://merics.org/en/report/huawei-quietly-dominating-chinas-semiconductor-supply-chain.
[13] Stephen Ezell, *How Innovative is China in Semiconductors?* (Information Technology and Innovation Foundation: August 2024), 31, https://www2.itif.org/2024-china-semiconductors.pdf.

sufficiency in semiconductors by 2025 (a target China will fall short of by a significant margin) and provided the strategic framework under which the Big Fund would operate.[14]

It is important to appreciate the scale of Chinese investment since 2014 and the influence the CCP exerts on the sector's trajectory. Subsidies have flowed to the semiconductor industry from central, provincial and municipal Chinese governments, as well as state-owned enterprises in the tech sector. According to the Information Technology and Innovation Foundation, China "has probably invested the equivalent of the US CHIPS Act [in the semiconductor industry] virtually every year since 2014."[15]

Lower taxes, R&D tax credits, tariff reductions and exemptions for domestically produced or imported equipment are just some of the advantages provided to domestic firms. Moreover, subnational governments in China sell land to Chinese semiconductor companies at reduced prices.[16] This is particularly relevant considering that 43% of registered capital across the Chinese semiconductor industry is either directly or indirectly owned or controlled by the Chinese state.[17]

Therefore, it is no surprise that China's 14th Five-Year Plan (2021–2025 inclusive) upped the ante by designating semiconductors as an explicit strategic tech priority, requiring a whole-of-society effort to achieve self-reliance. For example, electric-vehicle makers have been asked to boost their purchases from local automotive chipmakers to hasten the move towards independence from Western imports.[18]

1.2 The Big Fund III

The Big Fund (I, II and III) has acted as China's most centralised instrument for directing money to the domestic semiconductor industry. The most recent iteration of the Big Fund dedicated an extra $47.5 billion to the sector, exceeding the $39 billion in direct incentives

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[14] Sarah Ravi, *Taking Stock of China's Semiconductor Industry* (Semiconductor Industry Association: July 2021), 3, https://www.semiconductors.org/wp-content/uploads/2021/07/Taking-Stock-of-China's-Semiconductor-Industry_final.pdf.

[15] Stephen Ezell, *How Innovative is China in Semiconductors?* (Information Technology and Innovation Foundation: August 2024), 32.

[16] Andrew David et al., *Foundational Fabs: China's Use of Non-Market Policies to Expand its Role in the Semiconductor Supply Chain* (Silverado Policy Accelerator: October 2023), 14, https://cdn.sanity.io/files/0wfzc71x/production/4061d4fb69f1253928edd51f752c558e0d02fe8c.pdf

[17] Sarah Ravi, *Taking Stock of China's Semiconductor Industry* (Semiconductor Industry Association: July 2021), 3.

[18] Stephen Ezell, *How Innovative is China in Semiconductors?* (Information Technology and Innovation Foundation: August 2024), 34.

Washington introduced via the US CHIPS and Science Act.[19] The table below sets out the key elements of the three iterations of the Big Fund.

Table 2. The Big Fund (2014–2024)

Big Fund I (Sep 2014) *98.7 billion RMB*	**Big Fund II (Oct 2019)** *204.2 billion RMB*	**Big Fund III (May 2024)**[20] *344 billion RMB*
• Heavy focus on IC manufacturing, semiconductor design, packaging and testing, and semiconductor equipment and materials. • Move away from pure state support to welcome a more market-driven approach.[21] • Nurture of significant domestic players such as the Semiconductor Manufacturing International Corporation (SMIC).	• Increased focus on more specialised segments of supply chain, e.g. etching machines and testing equipment. • Greater emphasis on achieving self-reliance in the supply chain, resulting in more investment in areas such as electronic design automation (EDA). • Corruption scandals and bad investment choices exposed need for better oversight. • Geopolitical tensions overshadowed	• Major focus on equipment for chip manufacturing to reduce dependence on Western companies such as ASML, and to develop indigenous industry. • Development of large semiconductor manufacturing plants and components for HBM; priority given to advanced chip tech for AI and disruptive emerging technology such as chiplets. • 19 founding stakeholders, leaning on centralised, state-controlled financial backing.

[19] "China sets up third fund with $47.5 bln to boost semiconductor sector," *Reuters*, 27 May 2024, https://www.reuters.com/technology/china-sets-up-475-bln-state-fund-boost-semiconductor-industry-2024-05-27/.
[20] Investments from The Big Fund III are expected to commence in 2025.
[21] Lizzi C. Lee, "China's Big Fund 3.0: Xi's Boldest Gamble Yet for Chip Supremacy," *The Diplomat*, 6 June 2024.

	aspects of the programme.	• New duration of 15 years rather than 5, reflecting longer-term thinking and larger capital requirements. • More streamlined and specialised approach to regions receiving large allocations. Beijing, Shanghai and Shenzhen take more responsibility for the biggest projects.[22] • Prominent role for state-owned banks such as China Development Bank and Industrial and Commercial Bank of China.

Table 3. Key industry players[23] [24]

Big Fund I	Big Fund II	Big Fund III
• Anji Micro (安集科技) • Zhejiang Juhua (浙江巨化)	• NAURA (北方华创) • AMEC (中微公司) • SMIC (中芯国际)	*Current landscape:* Chinese companies in the manufacturing, equipment and

[22] Yuan Gao, "China's Betting Nearly $48 Billion on Renewed Chip Tech Plan," *Bloomberg*, 28 May 2024, https://www.bloomberg.com/news/newsletters/2024-05-28/is-a-48-billion-chip-fund-enough-for-china-to-withstand-us-sanctions.
[23] Yuan Da Securities, "The Third Phase of the Big Fund Officially Sets Sail, Accelerating Self-Reliance and Control in the Semiconductor Industry: A Special Research on the Semiconductor Industry," 2024 (in Chinese).
[24] Hua Fu Securities, "Steady Recovery of Market Conditions, Frequent Innovations on Multiple Fronts: Mid-term Strategy Report for the Electronics Industry in 2024," 2024 (in Chinese).

• NAURA (北方华创) • SMIC (中芯国际) • Navtech (耐威科技) • Changchuan Tech (长川科技) • YMTC (长江存储) • Unisoc (紫光展锐) • Sanechips Technology (中兴微电子) • JCET (长电科技) • Huahong Group (华虹半导体) • AMEC (中微公司) • Tongfu Microelectronics (通富微电) • Huatian Technology (华天科技) • Giga Device (兆易创新)	• Huahong Group (华虹半导体) • Jiangsu Nata Opto (南大光电) • G-Gas (广钢气体)	materials sectors are continuing to scale up by establishing new fabs in China, but they lack profitability. First half of 2024 results: *(Net profit)* • SMIC (year on year), -45.1% • Huahong Group, -83.3% • CR Micro, -64% • NSIG, -307.4% In contrast, semiconductor equipment companies have seen strong revenue growth due to rebound gains from US pressure: *(Revenue)* • NAURA (year-over-year), +46.4% • AMEC, +36.5% • ACM, +49.3% Design, CPU, and packaging and test are performing well due to recovering demand in mobile and automotive markets in China: *(Net profit)* • WillSemi (year-over-year), +792.8% • Montage, +624.6% • GigaDevice, +53.9%

Table 4. Key stakeholders

Big Fund I	Big Fund II	Big Fund III
• Ministry of Finance China (36.47%) • China Development Bank Capital Corporation (22.29%) • China Tobacco (11.14%) • E-town Capital (10.13%) • Wuhan Financial Holdings (5.06%) • Shanghai Guosheng Group (5.06%) • China Mobile (5.06%) • China Telecom (1.42) • China Unicom (1.42%)	• Ministry of Finance China (11.02%) • China Development Bank Capital Corporation (10.78%) • Zhejing Fuzhe IC Industry Development (7.35%) • Wuhan Optical Valley Financial Holdings (7.35%) • China Tobacco (7.35%) • Shanghai Guosheng Group (7.35%) • Chengdu Tianfu International Investment (7.35%) • Chongqing Strategic Emerging Industry Investment Partners (7.35%) • E-town Capital (4.90%) • Beijing Guoyi Hospital (4.90%) • Zhongyi Capital (4.90%) • Jiangsu Jiequan IC Investment (4.90%) • Anhui Wantou Anhua Investment (3.67%) • Anhui Xinhuo IC Investment (3.67%) • Fujian Guozi IC Investment (1.47%) • Shenzhen Shenchao Keji Investment (1.47%) • Guangzhou Industry Investment Fund (1.47%) • Huangpu Investment Holdings (1.00%)	• Ministry of Finance China (17.44%) • China Development Bank Capital Corporation (10.47%) • Shanghai Guosheng Group (8.72%) • Industrial and Commercial Bank of China (6.25%) • Agricultural Bank of China (6.25%) • China Construction Bank (6.25%) • Bank of China (6.25%) • Bank of Communications (5.81%) • E-town Capital (5.81%) • Kunpeng Capital (4.94%) • Beijing Guoyi Hospital (4.36%) • State Development and Investment Corporation (2.91%) • China Tobacco (2.91%) • China Chengtong (2.91%) • Guangzhou Industry Investment Holdings (2.616%) • Postal Savings Bank of China (2.33%) • Huarun Investment (1.45%) • Guangdong Yuecai Investment (1.16%) • Zhongyi Investment Holdings (1.16%)

Table 2 demonstrates the marked shift between Big Fund II and Big Fund III. The latest iteration focuses on ensuring that China has the resources to develop and build AI-capable semiconductors without outside help.[25] This is likely to involve a dual approach combining the promotion of Chinese capabilities across the supply chain with simultaneous efforts to plug specific gaps in areas such as large foundries and HBM production.[26]

A broader strategic challenge that China will hope to meet with this investment is the reinvigoration of its national labs and innovation centres, by further integrating scientific research with commercial applications. Success in applied research relies on an awareness of changes in market dynamics. This synergy is central to China's prospects of ensuring that the quest for self-sufficiency – an inherently costly endeavour – is underpinned by an economic rationale.

1.3 Areas of strength and weakness

The large investments described above will not necessarily translate into the development of key indigenous capabilities in the short term. To understand the type of market leverage China could exercise over countries such as the UK and Korea, one needs to assess current areas of strength and weakness in the Chinese semiconductor landscape.

Compound semiconductors

Compound semiconductors made with Gallium Nitride (GaN) and Silicon Carbide (SiC) are vital not only for advanced industries such as next-generation mobile communications and electric vehicles but also for national security and defence purposes. This is due to characteristics such as their ability to operate with low power loss at high temperatures and voltages, which makes them suitable for high-current environments.[27]

China has listed compound semiconductors as a development priority in its 14th Five-Year Plan, partly because of their importance to the global electric-vehicle transition.[28] China's

[25] Yuan Gao, "China's Betting Nearly $48 Billion on Renewed Chip Tech Plan," *Bloomberg*, 28 May 2024.
[26] Henrik Bork, "China is investing significantly more money in its chip industry," *All-about-industries*, 25 June 2024, https://www.all-about-industries.com/china-is-investing-significantly-more-money-in-its-chip-industry-a-18a45e6f8fce9b0a0ee34571cb1d7963/.
[27] Helen Chiang, "China's Three-Way Recipe for Semiconductor Autonomy and Global Industry Impact," *IDC*, 26 February 2024, https://blogs.idc.com/2024/02/26/chinas-three-way-recipe-for-semiconductor-autonomy-and-global-industry-impact/.
[28] Helen Chiang, "China's Three-Way Recipe for Semiconductor Autonomy and Global Industry Impact," *IDC*, 26 February 2024.

SiC sector experienced significant growth in 2023, earning the country greater attention from renowned integrated device manufacturers.[29] Historically, China has accounted for 5% of the global SiC material market, but reports suggest that in 2024 more than 50% of global SiC wafer supply will come from China.[30] Moreover, China provides 80% of the world's supply of gallium, an element essential to compound semiconductors.[31]

To bolster domestic innovation and competitiveness in this field, China's Ministry of Science and Technology established the National Third-Generation[32] Semiconductor Technology Innovation Centre. The aim of the body is to coordinate national resources, focusing on key technologies and applications, and fostering collaboration between various stakeholders through a "1+N+X" system:

- **"1" Innovation Centre**. An open platform with advanced infrastructure, talent and research capabilities.
- **"N" Collaborative Centres**. Established in key universities, research institutes, leading enterprises and national laboratories.
- **"X" Innovation Units.** Diverse cooperation models exploring breakthrough innovations.

Complementing this effort, the Third-Generation Semiconductor Industry Technology Innovation Strategic Alliance (CASA) was established in 2015. This enhances innovation capacity by promoting collaboration between industry, academia and research institutes; upstream and downstream sectors; enterprises of various sizes; and central and regional entities.[33] Both the Innovation Centre and CASA focus on technology development and commercialisation in key areas such as equipment, micro-LEDs, power-supply technology and materials. CASA actively promotes tests of platform construction and formulates national standards to drive industrial technological development. It has also established international cooperation initiatives such as the Asia-Europe Third-Generation

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[29] Manufacturers that operate in different areas of the supply chain.
[30] "China Set to Dominate SIC Wafer Market by 2024," Astute, 9 November 2023, https://www.astutegroup.com/news/general/china-set-to-dominate-sic-wafer-market-by-2024/.
[31] Annabelle Liang and Nick Marsh, "Gallium and germanium: What China's new move in microchip war means for world," *BBC News*, 2 August 2023, https://www.bbc.co.uk/news/business-66118831.
[32] Compound semiconductors are often referred to as 'third-generation' semiconductors in Chinese discourse.
[33] Wu Ling and Zhao Lubing, "Development and Trend Outlook of the Third-Generation Semiconductor Industry," *Science & Technology Review* 39, no.14 (2021) (in Chinese).

Semiconductor Science and Technology Innovation Cooperation Centre, and is a participant in the CCP's Belt and Road Initiative.

Design and IP

China has rapidly scaled up its chip design sector in recent years, with significant support for Chinese startups coming from the government and private investors (95% of investor transactions go to local startups).[34] Many startups see it as more feasible to enter the chip design phase of the supply chain than the manufacturing stage, where entry costs can be in the billions of dollars. The Chinese authorities believe that greater chip design capability will "drag along" the development of downstream processes and upgrade the semiconductor system as a whole.[35] This includes an effort to close the gap in AI chip design: with growing demand from China's hyperscale cloud and consumer smart device market lowering barriers to entry, it is no longer surprising to see Chinese fabless firms preparing 7–5nm chip designs for AI or 5G communications.[36] China's large original equipment manufacturers increasingly engage in chip design to develop alternatives to server chips sold by US companies.[37]

However, it is important to note that Chinese startups still need to collaborate with foundry services to implement prototypes and verify performance – specifically with TSMC, which has a significant lead over alternative foundries in this domain. It is uncomfortable for Chinese design startups to rely on TSMC given the geopolitical tensions over Taiwan.

EDA has historically been a weak link in China's supply chain but, for several decades, the country has targeted the area in the hope of accelerating the development of domestic alternatives to foreign EDA tools and core IP.[38] For example, the Big Fund II invested $125 million in EDA and IP firms. And, in 2021, 12 Chinese EDA companies in mainland China

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[34] Julia Christina Hess, *Who is funding the chips of the future? Analysis of global semiconductor startup funding activities* (Stiftung Neue Verantwortung: 19 April 2023), 3, https://www.interface-eu.org/publications/semiconductor-startup-funding-activities.
[35] Nigel Inkster, Emily Weinstein and John Lee, "Ask the experts: Is China's Semiconductor Strategy Working?" *The London School of Economics and Political Science*, 1 September 2022, https://blogs.lse.ac.uk/cff/2022/09/01/is-chinas-semiconductor-strategy-working/.
[36] Sarah Ravi, *Taking Stock of China's Semiconductor Industry* (Semiconductor Industry Association: July 2021), 2.
[37] Ramiro Palma et al., *The growing challenge of semiconductor design leadership* (Boston Consulting Group and Semiconductor Industry Association: November 2022), 21, https://www.semiconductors.org/wp-content/uploads/2022/11/2022_The-Growing-Challenge-of-Semiconductor-Design-Leadership_FINAL.pdf.
[38] John Lee and Jan-Peter Kleinhans, *Mapping China's semiconductor ecosystem in global context* (Stiftung Neue Verantwortung and MERICS: June 2021), 26, https://merics.org/sites/default/files/2021-06/China's%20Semiconductor%20Ecosystem_0.pdf.

raised more than $310 million in investment, a 54% increase from 2020.[39] At a more strategic level, China launched the National EDA Innovation Centre in June 2023 with the goal of breaking the US stranglehold on EDA software. Yet, in the medium term, China will likely make significant progress largely outside the most advanced chip nodes.[40]

To avoid dependency on technologies that might be subject to export restrictions, Chinese companies have been encouraging the adoption and promotion of open-source design technologies such as RISC-V.[41] Currently, there are two main instruction set architectures (ISAs) for designing chips: x86 (IP owned by the US-based Intel) and ARM (a UK-based company with US IP). The following table presents a selection of notable Chinese initiatives in this space.

Table 5. Chinese RISC-V initiatives

Initiative	Key takeaway
Opening of the Beijing Open-Source Chip Research Institute, co-founded by the Chinese Academy of Sciences (CAS) and other leading industry partners.[42]	Country-wide initiative to increase RISC-V uptake – leading Chinese experts to see RISC-V's open and flexible architecture as a means of disrupting the dominance of Nvidia's CUDA software.[43] CAS released a laptop built on the RISC-V architecture and an Alibaba processor.[44]
Establishment of the China RISC-V Industry Alliance comprising 194 members (as of July 2024).	Helps attract new talent and startups to China and amplifies China's global RISC-V influence. Alliance holds an annual industry

[39] Ramiro Palma et al., *The growing challenge of semiconductor design leadership* (Boston Consulting Group and Semiconductor Industry Association: November 2022), 21.
[40] Stephen Ezell, *How Innovative is China in Semiconductors?* (Information Technology and Innovation Foundation: August 2024), 12.
[41] The RISC-V foundation is European-based but has historical links to the US, which may provide a hook for export controls.
[42] Antonia Hmaidi, *Huawei is quietly dominating China's semiconductor supply chain* (MERICS: April 2024), 8.
[43] Emerging Technology Observatory, "ETO Scout," Centre for Security and Emerging Technology, 19 August 2024, https://scout.eto.tech?id=3722.
[44] Emerging Technology Observatory, "ETO Scout," Centre for Security and Emerging Technology, 14 March 2024, https://scout.eto.tech?id=3109.

	forum in Shanghai where new RISC-V chips are reviewed.[45]
Chinese company Stream Computing develops plans to build the world's largest RISC-V computing power cluster.	Commitment to constructing a global open-source RISC-V ecosystem through collaboration with European countries.[46]
Alibaba's DAMO Academy launches the Swordless Alliance.	Promotes industry cooperation on developing a computer ecosystem based on RISC-V.
RISC-V Patent Alliance	Formed out of the China RISC-V Industry Alliance to consolidate and defend IP related to RISC-V.

Nonetheless, despite high-level backing for RISC-V, Chinese companies continue to use ARM when possible, as it remains the de facto standard for many chips. But by investing in RISC-V now, China is preparing for a future in which Chinese companies cannot use ARM ISAs and cores.[47]

Advanced packaging and chiplets

China has developed a strong presence in assembly, testing and packaging (ATP). As of 2021, China accounted for 27% of the world's 484 ATP facilities. By August 2023, Chinese ATP firms held 38% of the market and included the five largest players.[48] In the last two decades, much of the market share expansion of the leading Chinese outsourced

[45] Emerging Technology Observatory, "ETO Scout," Centre for Security and Emerging Technology, 19 August 2024, https://scout.eto.tech?id=3732.
[46] Emerging Technology Observatory, "ETO Scout," Centre for Security and Emerging Technology, 6 July 2024, https://scout.eto.tech?id=3604.
[47] Antonia Hmaidi, *Huawei is quietly dominating China's semiconductor supply chain* (MERICS: April 2024), 8.
[48] Stephen Ezell, *How Innovative is China in Semiconductors?* (Information Technology and Innovation Foundation: August 2024), 21.

semiconductor assembly and test (OSATs) vendors has come through the acquisition of foreign companies.[49]

There is an increasing realisation within the semiconductor industry that packaging will be a key pillar of innovation. Packaging is crucial for the kind of high-power semiconductors needed for AI applications – a shortage of advanced packaging has been a critical bottleneck in the production of Nvidia's AI chips.[50]

One innovation that is having an important impact on the pace of change in ATP is chiplet technology. In traditional semiconductor packaging, a single die is packaged, tested and integrated into a system. With chiplets, designers can break the system into smaller individual components that are then integrated using advanced packaging techniques. This is becoming increasingly popular in high-performance computing, data centres and consumer processors.

In China, there has been an intense focus on supporting the domestic chiplet industry in the last year, partly due to a belief that chiplets could help China circumvent some export controls.[51] For example, if China cannot buy or make a single piece of a powerful chip, it could connect less-advanced chiplets that it can produce to achieve similar levels of computing power.[52]

However, there are many caveats to this. China's strength and market share in traditional packaging and testing do not necessarily translate into dominance in *advanced* packaging or chiplets – this technology is more R&D intensive compared to conventional packaging. One key success factor is whether international alliances to standardise chiplet technology (with Chinese participation) will subsume domestic Chinese alliances aiming to do the same thing.[53] This may influence whether chiplets will achieve the required level of customisability: to create synergies with chiplets, several types of chip need to have similar

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[49] Mark Lapedus, "Consolidation Hits OSAT Biz," *Semiconductor Engineering*, 18 February 2016, https://semiengineering.com/consolidation-hits-osat-biz/.
[50] Stephen Ezell, *How Innovative is China in Semiconductors?* (Information Technology and Innovation Foundation: August 2024), 21.
[51] Zeyi Yang, "Why China is betting big on chiplets," *MIT Tech Review*, 6 February 2024, https://www.technologyreview.com/2024/02/06/1087804/china-betting-on-chiplets-packaging/.
[52] Zeyi Yang, "Why China is betting big on chiplets," *MIT Tech Review*, 6 February 2024, https://www.technologyreview.com/2024/02/06/1087804/china-betting-on-chiplets-packaging/
[53] Yang, "Why China is betting big on chiplets," (February 2024).

performance.[54] Moreover, no chip designer has yet demonstrated a high-performing chip that integrates multiple chiplets fabricated on an *older* process node (e.g. 12/14nm).

It is still too early to tell whether chiplets can become a key driver of China's semiconductor independence. Some industry observers contend that "while China has made some progress, it really doesn't have that capability on the leading edge" of semiconductor ATP.[55] The country is unlikely to gain a position of leadership in the next 5–10 years. This is due to its relatively closed-off market and industry structure, and to the efforts of the US to augment its own chiplet value chain.

Talent

Like most other countries in the semiconductor landscape, China faces a perennial challenge in acquiring and retaining talent. Following criticism of the central government's Thousand Talents Plan, which aimed to attract foreign expertise through comprehensive incentives, various alternative programmes have emerged.

One notable example is the Excellent Young Scientist Fund established by the National Natural Science Foundation of China. This programme prioritises individuals with experience in overseas universities, R&D institutions or corporate research centres, and provides substantial benefits. Similarly, the Ministry of Industry and Information Technology's Qiming Plan and talent programmes from local governments are actively recruiting young talent in national strategic industries such as next-generation information technology, advanced equipment manufacturing, biotechnology and smart energy.

The influx of foreign talent is crucial to China in two main ways. First, it significantly enhances manufacturing capacity via the transfer of tacit knowledge in cutting-edge fabrication processes. Second, these programmes play an integral role in cultivating China's next generation of semiconductor specialists. This multi-level approach to talent acquisition and development underscores China's commitment to building a robust, self-reliant semiconductor ecosystem, leveraging both international expertise and domestic innovation.

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[54] Helen Chiang, "China's Three-Way Recipe for Semiconductor Autonomy and Global Industry Impact," *IDC*, 26 February 2024.
[55] Stephen Ezell, *How Innovative is China in Semiconductors?* (Information Technology and Innovation Foundation: August 2024), 21.

2. China's Market Leverage: The Impact on the UK and Korea

This section focuses on how China's domestic policy will affect the UK and Korean semiconductor industries, as well as key Chinese players' options to exercise market leverage.

2.1 Intellectual property and chip design: RISC-V, ARM and national security

Table 5 details Chinese efforts to develop the global RISC-V ecosystem. Of the 10 billion RISC-V chips shipped in 2022, more than half were made in China.[56] These investments are raising hopes in China that RISC-V could break the x86–ARM duopoly, with low cost, ease of customisation and energy efficiency making RISC-V attractive to chipmakers. Because the AI market is changing rapidly, companies need to develop various chips for different purposes, which can lead to an increase in IP costs. Therefore, ARM's pricing policy could be an inadvertent driver of RISC-V's growth.

Previous CETaS research describes the strategic importance of ARM to the UK semiconductor landscape.[57] The Emerging Technology Observatory's Supply Chain Explorer shows the UK has 43% of global market share in core IP, largely due to ARM's position as the top core IP vendor.[58] Notable recent developments include ARM's planned entrance into the AI chip market in 2025, with heavy investment from SoftBank and partnership with firms such as TSMC.[59] This could boost the UK semiconductor industry and open up new markets for AI hardware. Ensuring that UK semiconductor companies have access to this technology could also boost the competitiveness of the domestic AI industry.

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[56] Eduardo Baptista, "China bets on open-source RISC-V standard for chip design," *ITnews*, 5 February 2024, https://www.itnews.asia/news/china-bets-on-open-source-risc-v-standard-for-chip-design-604790.
[57] Ardi Janjeva, Seungjoo Lee, Harish Bhaskaran, Seoin Baek and Hyunjin Lee, "Semiconductor Supply Chains, AI and Economic Statecraft: A framework for UK-Korea strategic cooperation," *CETaS Research Reports* (April 2024), 42.
[58] Emerging Technology Observatory, "Supply Chain Explorer," Centre for Security and Emerging Technology, https://chipexplorer.eto.tech/.
[59] "Arm plans to launch AI chips in 2025," *Reuters*, 12 May 2024, https://www.reuters.com/technology/arm-holdings-plans-launch-ai-chips-2025-nikkei-reports-2024-05-11/.

Nonetheless, while the performance of RISC-V chips lags ARM in complex computing tasks and the RISC-V software ecosystem remains nascent,[60] the gap is closing with increasing investment.[61] China's strengths in industries such as consumer electronics and electric-vehicle companies – in parallel with its increased use of RISC-V architecture – further reinforce the growing competitiveness of Chinese chip design.[62] This could create new dependencies on Chinese chip design, particularly as the UK is importing record numbers of Chinese electric vehicles.[63] It is also problematic given that Chinese chip design capabilities could have defence and espionage-related implications, and that organisations linked to the Chinese military are also developing and promoting RISC-V.[64]

National security concerns have motivated some US lawmakers to pressure the White House into taking a more restrictive stance on US-China engagement on RISC-V.[65] While some commentators view this approach as counterproductive,[66] there are broader strategic implications for the UK. US-imposed restrictions on access or contributions to RISC-V could reinforce ARM's position as the go-to licenser of processor IP.[67] This could preserve the UK's strategic advantage in the IP market, particularly if it leads to increased ARM licensing in China itself. However, the opposite could also be true: restrictions on RISC-V could merely accelerate China's support for local semiconductor design capabilities and present longer-term challenges for ARM. Given that China's strategies in this domain are predicated on the expectation that US export controls will eventually affect its access to US and UK IP, these are scenarios that UK policymakers need to prepare for now.

In any case, it is important to distinguish between the ISA and the *implementation* of the ISA. ARM is both a proprietary ISA and a form of implementation, whereas RISC-V is an ISA

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[60] Chris Rohlf, "Notes on RISC-V Support and Security Implications," *Root Cause*, 18 January 2024, https://struct.github.io/risc-v.html.
[61] Eduardo Baptista, "China bets on open-source RISC-V standard for chip design," *ITnews*, 5 February 2024.
[62] Ardi Janjeva, Seungjoo Lee, Harish Bhaskaran, Seoin Baek and Hyunjin Lee, "Semiconductor Supply Chains, AI and Economic Statecraft: A framework for UK-Korea strategic cooperation," *CETaS Research Reports* (April 2024), 43.
[63] "Britain's unusual stance on Chinese electric vehicles," *The Economist*, 27 August 2024, https://www.economist.com/britain/2024/08/27/britains-unusual-stance-on-chinese-electric-vehicles.
[64] Eduardo Baptista, "China bets on open-source RISC-V standard for chip design," *ITnews*, 5 February 2024.
[65] Stephen Nellis and Max A. Cherney, "RISC-V technology emerges as battleground in US-China tech war," *Reuters*, 7 October 2023, https://www.reuters.com/technology/us-china-tech-war-risc-v-chip-technology-emerges-new-battleground-2023-10-06/.
[66] Nigel Cory, "The US-China Tech Conflict Fractures Global Technical Standards: The Case of Semiconductors and the RISC-V Standard," Information Technology and Innovation Foundation, 19 July 2024, https://itif.org/publications/2024/07/19/the-us-china-tech-conflict-fractures-global-technical-standards/.
[67] Tobias Mann, "Hardware hacker: Walling off China from RISC-V ain't such a great idea, Mr President," *The Register*, 7 November 2023, https://www.theregister.com/2023/11/07/proposed_restrictions_riscv/.

that only becomes useful once a company implements it as a processor core. This is particularly relevant in policy terms because the concern that a country could become dependent on Chinese chips based on RISC-V is largely a concern about cores. Consequently, it is unlikely that decisions made by the RISC-V standards body will introduce fundamental vulnerabilities that benefit China.

Moreover, the nexus between chip design and national security goes beyond the question of RISC-V. It raises a more fundamental question about trust in the security of chips designed by Chinese companies. For instance, if a Chinese design firm shipped an advanced driver assistance system that incorporated ARM cores alongside a custom NPU and a security module, this would pose a similar level of national security risk as a scenario in which the firm replaced ARM processors with those based on RISC-V.

China could also exercise market leverage through the theft of research or IP from foreign universities or companies. As the Intelligence and Security Committee of Parliament observes in its 2023 China Report, "by stealing IP, the Chinese save money on research and development, thereby lowering the overall 'to-market' cost so that they can undercut the original product and dominate the market."[68] This is also a consideration for Korean companies, albeit in more nuanced ways: Korean companies operating in China have received extensive support from the Chinese Government while contending with systematic semiconductor technology theft, forced technology transfers, antimonopoly investigations and various forms of industrial espionage.[69]

2.2 Compound semiconductors

The AI and defence sectors are likely to see growing demand for GaN compound semiconductors. As China vies for leadership in GaN technology (see section 1 on China's monopolisation of gallium supply), it may become increasingly challenging for the UK and Korea to secure access to GaN resources and develop domestic capabilities.

In addition to new materials such as GaN, new technologies such as silicon photonics are expected to have an increasing impact on AI and quantum applications. Silicon photonics is the base technology required to build photonic ICs – devices that process light (photons) instead of electricity (electrons). Photonic integrated circuits (PICs) are already being

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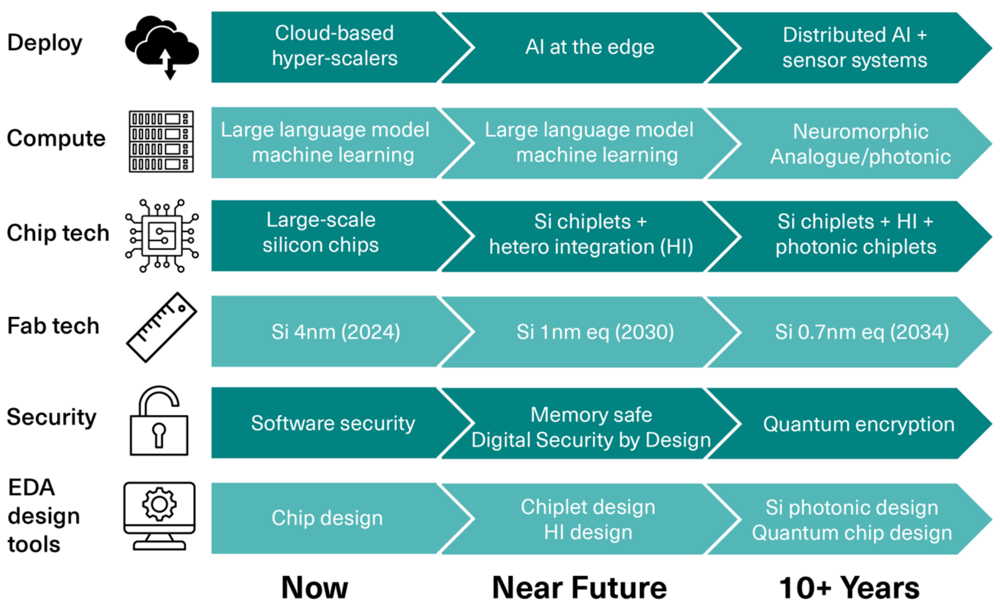
[68] Intelligence and Security Committee of Parliament, *China* (July 2023), 126.
[69] Gong Min Kyung and Shin Hyun Wook, "SK Hynix semiconductor technology 'HKMG' to China... "Estimated loss of hundreds of billions," 28 May 2024, https://news.kbs.co.kr/news/pc/view/view.do?ncd=7974342 (in Korean).

developed for neuromorphic computing, mimicking the brain to produce energy-efficient AI functions. Combining photonic chiplets with conventional silicon chiplets will lead to a step change in functionality.

Figure 2 shows how these trends will involve diversification of chip technology, a key part of which will be the evolution of cloud-based AI systems to include distributed AI at the edge (where computation is distributed across multiple edge devices or nodes for large-scale processing).

Figure 2. Future trends in AI and quantum



Source: Authors' analysis.

This is why recent moves to increase UK domestic capacity are necessary. They include the allocation of a share of £99 million in funding to Cardiff University to lead a new compound semiconductor manufacturing hub[70] and a £22 million DSIT investment in two Innovation and Knowledge Centres (IKCs) in Southampton and Bristol. The Southampton IKC, known as CORNERSTONE, is the world's only open-access silicon photonics foundry creating PICs. The Bristol IKC, known as REWIRE, focuses on wide-bandgap compound semiconductors to

[70] "Cardiff will lead UK manufacturing hub," CS Compound Semiconductor, 20 May 2024, https://compoundsemiconductor.net/article/119382/Cardiff_will_lead_UK_manufacturing_hub.

help the UK achieve its net-zero ambitions.[71] In addition, the Ministry of Defence's acquisition of Octric Semiconductors in Newton Aycliffe creates a sovereign UK capability in Gallium Arsenide,[72] while a proposed expansion of the Newport Vishay chip factory promises to focus on R&D in compound semiconductors.[73]

Yet there is still work to be done. A handful of large deals account for a high proportion of total investment in UK semiconductor companies each year, and a relatively small number of companies receive consistent year-on-year investment.[74]

This speaks to the importance of foreign investment and partnerships: China's increased presence in the compound semiconductor space should drive greater collaboration between the UK and its partners. A recent memorandum of understanding between the UK's Compound Semiconductor Catapult and the Sarawak Government in Malaysia is one example of this.[75] Closer cooperation with the Taiwan semiconductor industry could be another counterbalancing measure. A report published as part of the UK-APAC Tech Growth Programme (which helps UK tech companies expand across the Asia-Pacific) highlighted the fact that Taiwan has a nascent midstream compound semiconductor industry but needs the world-leading technology being developed by many UK firms.[76] Encouragingly, Oxford Instruments has already agreed on a cooperative research project with the Industrial Technology Research Institute in Taiwan for the development of next-generation compound semiconductors.[77]

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[71] Sarah Brady, "UK invests £22m into semiconductor research for net zero and AI," *Verdict*, 7 February 2024, https://www.verdict.co.uk/uk-invests-22m-into-semiconductor-research-for-net-zero-and-ai/?cf-view.

[72] UK Ministry of Defence and The Rt Hon John Healey MP, "UK Defence supply chain bolstered to support armed forces," 27 September 2024, https://www.gov.uk/government/news/uk-defence-supply-chain-bolstered-to-support-armed-forces.

[73] Gavin Thomas, "Newport Wafer Fab: Semiconductor plant takeover gets go-ahead," 1 March 2024, https://www.bbc.co.uk/news/uk-wales-68449303.

[74] Barclays Eagle Labs, *A review of the UK's semiconductor clusters* (September 2023), https://www.beauhurst.com/wp-content/uploads/2023/09/Beauhurst-Barclays-Eagle-Labs-report-A-review-of-the-UKs-semiconductor-clusters.pdf.

[75] Samuel Aubrey, "Sarawak out to develop compound semiconductors with UK firms," *Borneo Post*, 24 April 2024, https://www.theborneopost.com/2024/04/24/sarawak-out-to-develop-compound-semiconductors-with-uk-firms/.

[76] Tom Miller, "Report Highlights Opportunities for UK Tech Across Taiwan's Semiconductor Sector," *Intralink*, May 2024, https://www.intralinkgroup.com/en-GB/Latest/News/May-2024/Report-highlights-opportunities-for-UK-tech-across.

[77] Chun-Yi Lee, Andrew Yeh and Leo Shaw, *Securing the UK's Semiconductor Supply Chain in an Era of Geopolitical Uncertainty* (China Strategic Risks Institute: January 2023), 9, https://static1.squarespace.com/static/61d5a7bdbb804663a82e154a/t/649d6764d584aa7b9f2d0d31/.

The trajectory of the UK's compound semiconductor industry will be heavily influenced by the extent to which it can balance the need for international collaboration and investment with the need to block certain deals on national security grounds. The former will help the country stay competitive vis-à-vis China, while the latter will deter investors.[78]

2.3 High-bandwidth memory chips

From a Korean perspective, the most concerning aspect of China's aggressive industrial policy is in the advanced memory sector. China has recognised the importance of HBM as a key component of AI semiconductors, particularly as it faces challenges in AI research and development due to US export controls on AI chips. This has led China to incorporate HBM into its plans for Big Fund III (see section 1). Indeed, China's leading memory chip maker, ChangXin Memory Technologies, started producing second-generation HBM this year, earlier than expected.[79] While Korea's SK Hynix currently leads the HBM sector, the gap with its competitors is narrowing as they pour more resources into HBM development.

Nonetheless, China still has relatively immature capability in many aspects of HBM, such as DRAM core-die quality, die assembly and advanced packaging. Although China recently began mass production of HBM2, there will be a large gap between the performance of its memory devices and those of more advanced providers in Korea and the US.

From a security perspective, it is notable that SK Hynix maintains key factories in the Chinese cities of Wuxi and Dalian. The Chinese Government could ostensibly target these facilities with measures such as hostile takeovers of Korean SMEs that have engineering technology essential for HBM and aggressive talent recruitment.

Korea needs to establish a comprehensive technology protection framework for HBM. To maintain and expand its lead in the sector, Korea's Government and companies need to match or exceed China's large-scale investments in next-generation technologies[80] (SK Hynix has already announced significant HBM investments through to 2028).[81] For a dual

[78] Debbie Woods and Devyani Gajjar, *Supply of semiconductor chips* (UK Parliament POSTnote 721: 2 May 2024), 15, https://researchbriefings.files.parliament.uk/documents/POST-PN-0721/POST-PN-0721.pdf.
[79] Lee Hee-kwon, "China, which is speeding up its semiconductor independence, has the possibility of producing 2nd generation HBM within the year," *JoongAng Daily*, 5 August 2024, https://www.joongang.co.kr/article/25268687 (in Korean).
[80] Shim Woo-il, "Investment in the localization of next-generation equipment… HBM's super-gap foundation is solidified," *Seoul Economics*, 5 June 2024, https://www.sedaily.com/NewsView/2DACI09IH2 (in Korean).
[81] "South Korea's SK Hynix to invest $75 billion by 2028 in AI, chips," *Reuters*, 30 June 2024, https://www.reuters.com/technology/south-koreas-sk-hynix-invest-75-bln-by-2028-ai-chips-2024-06-30/.

approach focused on protection and promotion, it will be vital for Korea to cultivate a trusted and mature innovation ecosystem with reliable partners such as the UK.

In this regard, it is notable that the boom in on-device AI is leading to growing demand for *low-power* HBMs from domestic companies such as SK Hynix and foreign firms such as Qualcomm and Meta. This presents an opportunity for ARM, which will need to collaborate with top-tier HBM providers to accelerate the development of architecture and IP related to low-power HBMs, providing a clear avenue for UK-Korea partnership in the sector.

2.4 Mature-node vulnerability and its national security implications

The mature-node chip market is far more pervasive across global supply chains than technologies such as RISC-V and compound semiconductors, increasing the importance of China's leverage in the domain. China's share of global mature-node production is expected to grow from 31% in 2023 to 39% in 2027.[82] Rapidly expanding markets for electric vehicles, batteries and solar cells will further augment this mature-node strength, providing the impetus for China to establish many new mature-node chip factories.[83] TrendForce reports that China is planning or constructing at least 32 large-scale wafer fabrication plants, which focus on the 28nm+ processes widely used for commodity chips in household appliances and the car industry.[84]

Countries such as the US, the UK and Korea are worried that China will use the resulting oversupply to dump certain types of chips on the international market, driving prices down and inducing foreign manufacturing firms to buy more of them.[85] Domestic subsidies allow Chinese semiconductor firms to compete in markets without the need for market-based rates of return, severely disrupting the established economics of innovation in the industry. Normally, firms depend on profits from one generation of semiconductor products to

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[82] Stephen Ezell, *How Innovative is China in Semiconductors?* (Information Technology and Innovation Foundation: August 2024), 17.

[83] Philip Blenkinsop, "US, EU eye Chinese legacy chips in new semiconductor accord," *Reuters*, 5 April 2024, https://www.reuters.com/technology/us-eu-eye-chinese-legacy-chips-renewed-semiconductor-accord-2024-04-05/.

[84] Dan Robinson, "Fear of commodity chip flood sparks EU probe into China silicon ambitions," *The Register*, 8 July 2024, https://www.theregister.com/2024/07/08/eu_china_commodity_chips/.

[85] Ardi Janjeva, Seungjoo Lee, Harish Bhaskaran, Seoin Baek and Hyunjin Lee, "Semiconductor Supply Chains, AI and Economic Statecraft: A framework for UK-Korea strategic cooperation," *CETaS Research Reports* (April 2024), 27.

finance R&D for the next generation, but aggressive subsidisation by the Chinese state upends this.[86]

The European Commission has responded to concerns about this by beginning discussions with European chipmakers on China's growing production of commodity silicon.[87] If Chinese production prices Western manufacturers out of the market, China's chipmakers could gain control of a strategically important segment of the global semiconductor industry. This issue is strategically important partly because mature-node chips are constantly being refined in line with new requirements and applications – and are foundational to the aerospace and defence sectors.[88]

In the medium-to-long term, China's mature-node ecosystem will likely gain a strong foundation relative to the one TSMC currently has in leading-edge nodes today. Given that the mature-node market tends to be less profitable than that at the leading edge, the Chinese Government's subsidy policy is a crucial asset in this endeavour.

2.5 Policy coordination

This paper covers the various plans, funds and advisory groups that China has established in support of its semiconductor industry. By early 2023, however, the Chinese Government determined that these investments and the "scientist-led approach" were not producing the desired results.[89] It called for even greater top-down policy coordination, leading to the establishment of the new Central Science and Technology Commission under the direction of Vice Premier Ding Xuexiang. Overseeing all aspects of China's semiconductor strategy, the commission is tasked with improving the coordination of R&D between the state and industry, and with directing further investment in basic research and talent development.[90]

The accelerated effort to gain independence in the semiconductor manufacturing equipment space is an example of this top-down approach in action. In the first half of 2024,

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[86] Stephen Ezell, *How Innovative is China in Semiconductors?* (Information Technology and Innovation Foundation: August 2024), 18.
[87] Dan Robinson, "China outspending US, Taiwan, and South Korea combined on chipmaking kit," *The Register*, https://www.theregister.com/2024/09/03/china_spending_big_on_chipmaking/?td=keepreading.
[88] Sujai Shivakumar, Charles Wessner and Thomas Howell, *The Strategic Importance of Legacy Chips* (CSIS: March 2023), https://www.csis.org/analysis/strategic-importance-legacy-chips.
[89] Paul Triolo, "A New Era for the Chinese Semiconductor Industry: Beijing Responds to Export Controls," *American Affairs* 8, no. 1 (Spring 2024), 29-52.
[90] Jimmy Goodrich, "China's Evolving Semiconductor Strategy," UC Institute on Global Conflict and Cooperation, 29 May 2024, https://ucigcc.org/blog/chinas-evolving-semiconductor-strategy/.

China spent more on chipmaking equipment than the US, Taiwan and Korea combined.[91] The Chinese leadership recognises that it is particularly vulnerable in this domain, due to the monopolies held by Western firms such as ASML. The promotion of partnerships and collaboration between Chinese manufacturing equipment firms and fabs is one way to spur indigenisation efforts, but Chinese manufacturing equipment companies are struggling to find buyers that are open to collaboration on the refinement process.[92] To avoid such bottlenecks, centralised mechanisms can provide incentives to ensure these companies prioritise domestic rather than international collaborations.

Another example of policy coordination in action is the Xinchuang National Project, which aims to localise servers and databases. China's Government and state-owned enterprises will purchase the products of this project, while all related policies will be led by the National Development and Reform Commission.

A greater level of policy coordination allows the Chinese Government to allocate strategically significant roles to individual companies. Huawei is a prime example of this: its vertical integration of the supply chain and close ties to many companies within that chain make it a key coordinator of China's lithography supply chain.[93] Meanwhile, Huawei's development of Kirin chips – which are suitable for use in Chinese-made electric vehicles – help address shortcomings in China's capacity to develop automotive-grade chips.[94] And the company's work on developing AI chips (the latest being the Ascend 910C) poses an increasing challenge to the status of Nvidia's leading products in China.[95]

Striking the right balance in Korean industry's relationship with China remains a significant challenge: factories in China account for 40% of total capacity for producing Samsung's flash memory chips and 40–50% of SK Hynix's DRAM chips.[96] SK Hynix will also be wary of

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[91] Dan Robinson, "China outspending US, Taiwan, and South Korea combined on chipmaking kit," *The Register*, 3 September 2024.

[92] Owen Daniels, *The PRC's Domestic Approach* (CSET Georgetown: September 2023), 17, https://cset.georgetown.edu/publication/the-prcs-domestic-approach/.

[93] "China Secretly Transforms Huawei into Most Powerful Chip War Weapon," *Bloomberg*, 1 December 2023, https://www.bloomberg.com/graphics/2023-china-huawei-semiconductor/.

[94] Emerging Technology Observatory, "ETO Scout," Centre for Security and Emerging Technology, 26 July 2024, https://scout.eto.tech?id=3655.

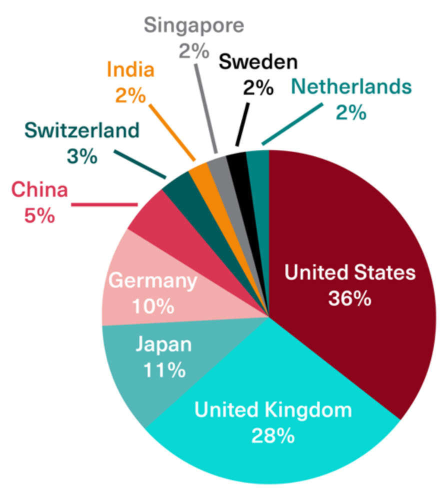
[95] "Huawei readies new AI chip to challenge Nvidia in China, WSJ reports," *Reuters*, 13 August 2042, https://www.reuters.com/technology/artificial-intelligence/huawei-readies-new-ai-chip-challenge-nvidia-china-wsj-reports-2024-08-13/.

[96] Sheila Chiang, "Samsung, SK Hynix get indefinite waivers to ship U.S. chip equipment to their China factories," *CNBC*, 10 October 2023, https://www.cnbc.com/2023/10/10/samsung-sk-hynix-get-indefinite-waivers-on-us-chip-equipment.html.

an anticipated strengthening of US export controls on HBM:[97] its fabs are already unable to import extreme ultraviolet equipment, which will gradually push them towards producing older chips.[98]

Additionally, for companies in the UK and Korea, decisions on cooperation and supply become more challenging if they cannot verify their business partners. This is especially germane given the well-documented ties between Huawei and China's military and security apparatus.[99] As the CCP tasks more companies with the achievement of strategic goals, and as China accelerates the implementation of its military-civil fusion strategy, it will become increasingly difficult to identify which parts of China's supply chain are safe to engage with.[100] This could have significant long-term implications for businesses in the UK and Korea that currently rely on collaboration with Chinese partners: 5% of the UK's major semiconductor firms have parent companies based in China.[101]

Figure 3. Parent company location of 61 major UK semiconductor firms



Sources: Mapping (De)Globalization; Fame132; Orbis Database133; Refinitiv Eikon.

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[97] Lee Hae-jun, "The U.S. prevents access to China's AI semiconductor technology; GAA, HBM additional regulatory review," *JoongAng Daily*, 12 June 2024, https://www.joongang.co.kr/article/25255770 (in Korean).
[98] Yun Hee-hun and Park Su-hyeon, "Prolonged export controls on China could harm SK Hynix, even if designated as VEU," *The Chosun Daily*, 27 February 2024, https://www.chosun.com/english/companies-en/2023/12/19/P7NVYQINORD7DOPRCM6GICE4QQ; Martin Chorzempa, *How US chip controls on China benefit and cost Korean firms* (Peterson Institute for International Economics: July 2023), https://www.piie.com/publications/policy-briefs/how-us-chip-controls-china-benefit-and-cost-korean-firms.
[99] Antonia Hmaidi, *Huawei is quietly dominating China's semiconductor supply chain* (MERICS: April 2024), 9.
[100] Hmaidi, *Huawei is quietly dominating China's semiconductor supply chain* (April 2024), 9.
[101] Debbie Woods and Devyani Gajjar, *Supply of semiconductor chips* (UK Parliament POSTnote 721: 2 May 2024), 12.

3. Conclusion: Boosting Resilience and Reinforcing Strengths

The UK government's new industrial policy plans will need stability and certainty for innovation, delivered through a long-term approach to supporting public and private R&D, bolstering skills and growing exports.[102] This requires progress on long-standing innovation weaknesses, such as an inability to recruit enough diverse talent; a lack of access to finance for capital expenditure; and an overreliance on overseas manufacturing and prototyping facilities, which risks IP leakage.[103]

The challenge is accentuated by the scale of China's investment in its technology and manufacturing industries. The country has continually exceeded the expectations of market-watchers, with the result that Korean factories in China are facing pressure from local competition quicker than they expected. In recent years, Korea has anticipated this challenge by designating various national critical technologies and reinforcing protections for SMEs and innovative startups through incentives.

The US CHIPS and Science Act R&D programme popularised the "Lab-to-Fab" motto – bridging basic technologies to mass production and the market. The UK has strengths in the "Lab" (i.e. fundamental research) while China has strengths in the "Fab" (i.e. manufacturing). For the UK to address its shortcomings on the latter side of the equation and expand its current lab-based capabilities into the proof of concept/prototype area, it will need to deepen its partnerships with countries such as Korea, Taiwan and Japan.

Optimisation is a key success factor in the semiconductor industry, affecting every link in the value chain – from design to development, mass production, packaging, and testing and verification. Korean semiconductor companies have an advantage in optimisation because they operate a business model based on integrated device manufacturing. In the era of AI competition, the semiconductor value chain is becoming fragmented once again, thereby weakening optimisation. If the UK and Korea are to collaborate successfully in the face of these challenges, they will need to keep optimisation front of mind – bridging the gap

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[102] Robert D. Atkinson, "Growing Advanced Industries in the United Kingdom Will Be a Heavy Lift for Starmer's Labour Government," Information Technology and Innovation Foundation, 5 August 2024, https://itif.org/publications/2024/08/05/growing-advanced-industries-in-the-uk-will-be-a-heavy-lift-for-starmer/.

[103] Royal Academy of Engineering, *Strategic advantage through science and technology: exploring the UK semiconductor innovation ecosystem* (March 2023), 11.

between the UK's strengths in design and IP and Korea's strengths in manufacturing and memory devices.

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