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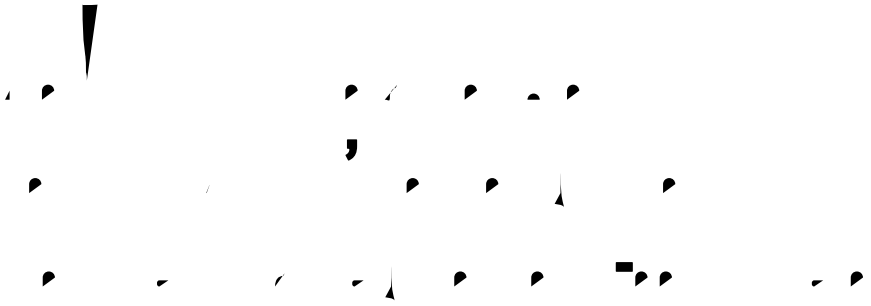

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Semiconductors are a critical input to production of information and communication technology and many other goods. e major economies want to be able to produce chips at home to avoid excessive dependence on supply chains in an increasingly unpredictable world, where trade is being compromised because of national security concerns. China was rst in terms of timing and scale of funding to support its its semiconductor industry. Since 2015, China has spent $150 billion upgrading its semiconductor industry. Success, however, has been limited. China's massive industrial policy e ort has been most successful in increasing capacity for assembls 3s (suli.s)-4nr asmd1ces°' ° a number of lessons. First, chip fabr xed asset investment and, therefore, large subsidies, but with no guarantee of success. Second, one reason for the underwhelming results of China's semiconductor policy is US containment, through export controls and other measures. In this respect, the EU should nd it easier than China to upgrade its chips industry but, given the costs, focusing on the highest-end part of the supply chain would be the best approach. Assembly and production of lower-end semiconductors already face overcapacity, given the nancial resources already invested by China.

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1 Introduction

Semiconductors are China's main import item, ahead of oil. ey are a critical input to information and communication technology production, which China dominates globally, and also to other industries which China either already dominates (solar panels) or wants to dominate (electric vehicles and 5G-ready telecommunications hardware, among others).

Chinese policymakers are fully aware of their country's semiconductor production limita-

Funds). e rst investment fund, created in 2014, raised $21 billion[3] (139 billion renminbi) to

In addition to the two big national-level funds, at least 15 local government funds have been created at city or provincial level, totalling at least $25 billion in capital to invest in the sector (SIA, 2021). National Big Funds and local government funds might have channelled up to $150 billion to support the Chinese semiconductor industry from 2014 to 2020 (OECD, 2019; Congressional Research Services, 2021).

While funding relies mainly on state-controlled entities, including state-owned enterprises and local governments, investments also target privately-owned enterprises. In fact, reliance on market forces was the official strategy in the 2014 guidelines to increase the return on the public funds. The strategy was also for the Big Funds to remain minority investors. Overall however, ownership linkages are opaque, making it difficult to identify the ultimate beneficial owners (OECD, 2019). While the state-controlled funds are not majority investors in most firms, the state has become a majority shareholder in most medium- and large-sized semiconductor enterprises in China (OECD, 2019).

Beyond the funds described above, government support for the semiconductor sector is also provided through government grants, tax incentives and low interest loans, for an amount estimated to hover around $50 billion (SIA, 2021). Tax breaks were introduced to encourage the production of higher-end semiconductors. Firms that have operated for more than 15 years were exempted from corporate income tax for up to 10 years if they manage to produce 28 nanometer (nm) chips or below[6]. Producers of chips from 65nm to 28nm, were exempted from corporate income tax for five years, and could get a 50 percent discount on the corporate rate for the next five years. Additional financial support comes in the form of borrowing at below-market rates; banks were encouraged to support the sector. There are also tax incentives for the conducting of research and development (R&D), with companies allowed to deduct from its taxable income 200 percent of its R&D costs. While these measures have supported the chip industry in China, they have created distortions globally, especially given the sheer size of China's market.

The government also supports semiconductor producers in raising equity on the Shanghai Stock Exchange (SSE) Science and Technology Innovation Board (STAR Market), established in 2019. On the SSE STAR Market, 17 percent of companies were in the chips sector in January 2021, nearly half of which worked in design. China's regulatory environment has also helped when mass producing new semiconductors, including by easing consumer protection measures. Lastly, semiconductor companies, both for fabrication and assembly, have been offered land at below market prices.

3 Assessment of China's strategy of state support

China provides more support to its chips industry than any other economy. China has invested massively in chip companies, when compared with global peers (Figure 3). The Big Funds have also provided vast support to international mergers and acquisitions (M&A) in the sector. China became the second biggest player after the US in semiconductor firm M&As, though it has fallen further behind since 2017 when Beijing introduced additional measures to control capital outflows (OECD, 2019).

6 Microchips are measured in nanometres (nm), with a lower nm indicating a more advanced chip. Chips are presently being produced down to 3nm. See for example https://www.asml.com/en/technology/all-about-microchips/microchip-basics, and Arjun Kharpal, 'Samsung aims to make the world's most advanced chips in 5 years, as it plays catch up with TSMC', *CNBC*, 4 October 2022, https://www.cnbc.com/2022/10/04/samsung-aims-to-triple-production-for-most-advanced-chips-by-2027.html.

Figure 3: Estimated total government support provided to semiconductor rms, 2014-2018

Source: OECD (2019). Note: * indicates Chinese firms.

China's largest semiconductor rms have attracted the biggest shares of state support since the two Big Funds were set up. In particular, Hua Hong Semiconductor, JCET, SMIC and Tsinghua Unigroup have received equity funding of about $10 billion, which represents slightly less than half of the funding available from the rst national Big Fund (roughly $23 billion). ese rms are active in the industrial steps of semiconductor production: fabrication and assembly.

Figure 4: Market shares of semiconductor production steps by rm headquarter location, 2019

important home-grown semiconductor companies, Tsinghua Unigroup (see below). However, investment in the fabrication segment has yielded some success in the production of memory chips[8]. ese achievements, however, are underwhelming compared to the objective set for China's industrial policy for the sector, namely to become self-su cient in the high-end, smaller-node, chips[9].

Another important development, against the stated objective, is the increase in state participation in key players in the sector. Tsinghua Unigroup and CXMT are state controlled, and state participation in Semiconductor Manufacturing International Corporation (SMIC), China's biggest chip company, has also increased, from below 15 percent in 2004 to over 45 percent as of 2018, much of which was funded by the two Big Funds (OECD, 2019).

Moreover, Shanghai's local government, together with $1 billion in funding from the national Big Funds, set up a joint venture with SMIC[10] to build a foundry in Shanghai focusing on mid-sized chips, namely 14nm ones. In 2021, SMIC also announced plans for a new foundry in Shenzhen, based on a $2.35 billion joint investment with the local government, following the same model as the Shanghai plant. anks to such massive investments, SMIC has become the fth biggest player globally[11]. However, the company is on the US Entity List (see section 1) meaning production upgrades are suspended. SMIC cannot buy from key companies, in particular ASML, a European producer of lithography equipment, which is necessary for the fabrication of high-end smallest nodes chips (below 14nm) (NSCAI, 2021).

Tsinghua Unigroup became an integrated device manufacturer, or rm that both designs and fabricates chips, after it acquired in 2013 two of the four leading Chinese chip designers for the equivalent of $2.1 billion. e rm also collaborated with local governments and the Big Funds to invest in the construction of at least four factories producing memory chips (OECD, 2019). However, in January 2021, Tsinghua Unigroup defaulted on several bond repayments, amounting to $3.6 billion. e company continues to struggle to generate positive cash ows and remains highly indebted, making it a good example of a rm receiving huge public funds without absorbing them successfully.

Another large government-controlled chip company, Wuhan Hongxin Semiconductor Manufacturing Co (HSMC), founded in 2017, has bene tted greatly from $1.2 billion in nancial support from the Wuhan Dongxihu district government to produce 7nm and 14nm chips[12]. However, the project was suspended in 2019 following a payment default and was abandoned in 2021.

3.2 Chip assembly policy successes

Notwithstanding failed companies and lots of money spent in other areas, Chinese companies have expanded rapidly in the assembly of chips (Figure 4). But this is, by far, the least-demanding phase in the semiconductor cycle in terms of capital expenditure and know-how.

e largest Chinese player is JCET, third globally with a market share of 14 percent (Poitiers and Weil, 2021). JCET's acquisition of Singapore-based packaging and testing rm STATS ChipPAC, instrumental in JCET's success, was partly nanced by the Big Fund in 2015, raising state control to between 20 percent and 35 percent (OECD, 2019).

8 Memory chips are semiconductors used for digital data storage. Logic chips process information to complete tasks.

9 See footnote 6.

10 *B be Ne* , 'Top China Chipmaker to Invest $8.9 Billion in Shanghai Plant', 3 September 2021, https://www.bloomberg.com/news/articles/2021-09-03/top-china-chipmaker-to-invest-8-9-billion-in-shanghai-plant.

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3.3 Some strides in design, driven by the private sector

Possibly an even more signi cant is the strides taken by some Chinese private companies specialising in chip design. China's global market share grew from 5 percent in 2010 to 15 percent in 2019[13]. But Mainland China remains behind Taiwan and far behind the US in global market share (Figure 4). Furthermore, China's design sector has taken a hit since 2019 as it is has become exposed to US sanctions. HiSilicon, Huawei's subsidiary and China's biggest chip fab, has been under US sanctions since 2020, resulting in the cancellation of its fabrication contract with TSMC and leaving the rm unable to get its most cutting-edge designs produced. In the upstream part of the value chain, China also remains exposed to US trade restrictions and US rms remain market leaders in design software.

4 General conclusions onChina's industrial policy

Because of its strategic importance and capital-intensity, China has poured huge amounts of money into developing its semiconductor industry. e challenges posed by US export restrictions have been a further trigger for the rapid deployment of funds into the industry. e objective is clearly ambitious: reaching self-su ciency through the rise of national champions in the di erent steps of semiconductor production – design, fabrication and assembly.

e objective has been achieved for the last part of cycle, assembly. is has however the least value added and is the least strategically important of the three phases. In terms of fabrication, producing standard chips, especially for memory cards, has become feasible in China but these are clearly not the highest-end chips. e availability of funds for Chinese companies to assemble – and in some cases produce – low-end chips and, in particular, memory cards, has resulted in overcapacity and the collapse of prices. Furthermore, export restrictions on software design or manufacturing equipment, imposed by the US and some like-minded countries (such as the Netherlands), are making it even harder than it already was for China to move up the ladder.

All in all, and taking into account the massive nancial support, estimated at $150 billion, China's industrial policy of developing an advanced chip industry has so far yielded mixed results, at best. External reliance on semiconductors, especially high-end chips, continues unabated, even after the acquisition of foreign rms and building of fabrication plants. One reason for this coild be the increasingly limited role of the private sector in the context in which state funding has increased state control over the sector. In addition, companies receiving such large amounts of funds have not been able to absorb them, and have become over-leveraged, leading to defaults in the case of several large companies.

is development is not unusual in highly-competitive sectors where money cannot buy upgrades. Indeed, the semiconductor sector is characterised by a high level of specialisation and concentration, with the US having leverage over several of the key bottlenecks in the production process. Along with the US export controls it faces, China is limited in its ability to secure production of high-end chips by shortages of talent. China has not succeeded in achieving its very speci c objectives and timeline for becoming self-reliant and bypassing technological barriers.

But more time will be needed for a full appraisal of the outcomes of China's massive investments in the semiconductor industry. China began supporting its semiconductors

13 Joel Hruska, 'Chinese Chip Designers Can't Meet Mandated Goals Without US Technology', ExtremeTech, 26 June 2019, https://www.extremetech.com/computing/293932-chinese-chip-designers-cant-meet-mandated-goals-without-us-technology.

sector in 2014, giving less than a decade for which a preliminary evaluation can be done. So far, China's ambitious chip industrial policy has certainly grown its domestic high-tech ecosystem and secured some market presence in the first steps of the value chain. But it remains short of its overblown goals of mastering the most high-tech segments.

The current state of the market reflects these realities. In design, the US is dominant and leverages export restrictions. China has not managed to become self-reliant, although strides have been made, possibly thanks to the greater role of the private sector. In the fabrication segment, China remains confined to mature technologies. In assembly, which is both less competitive and less strategic, China has managed to increase its global market share. For the Chinese government, the US sanctions regime in the chips sector represented an opportunity for an alignment of interests between private and public entities[14], as both aim to shed reliance on the US (Duchâtel, 2021). However, China has not managed to overcome the bottlenecks and monopolies of companies such as ASML and TSMC. These high-tech bottlenecks are set to endure in the medium to long term, making full supply-chain decoupling impossible. This will be especially the case with new sanctions hitting the sector, in the form of bans on exports to Russia by the largest semiconductor producers globally, except those in China (Marcus *et al*, 2022).

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