PART THREE

Economy and Society

Chapter 8

China's Economic Situation and Semiconductor Industrial Policy in 2021

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I. Introduction

In late September 2021, Evergrande Group's shares plunged on the Hong Kong Stock Exchange, triggered by the suspension of part of Evergrande Wealth's debt payments, causing Asian stock markets and even the U.S. stock market to tumble in tandem. Given the fact that China has little intention to bail out Evergrande,[1] and that Evergrande's US$300 billion debt involves 128 financial institutions in China, the market has become concerned about a systemic financial crisis, which could lead to massive civil rights movements. With a series of tightening controls imposed on large corporations, such as those on e-commerce platforms, the cram school industry, the video game industry and artists in the showbiz, it is difficult to be optimistic about China's economic prospects in 2021. In addition, the U.S.-China tensions have not eased, as the Biden administration has not relaxed its technological confrontation with Beijing compared to the Trump administration, but has instead convinced its allies to join the ranks of keeping a lid on China's

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1 Keith Zhai, "China Makes Preparations for Evergrande's Demise," *Wall Street Journal*, September 23, 2021, https://www.wsj.com/articles/china-makes-preparations-for-evergrandes- demise-11632391852.

technological ambitions. At the same time, this kind of clash between rival groups is also taking place in the current conflict in the South China Sea. Judging from the introduction of the 14th Five-Year Plan and the Dual Circulation strategy, the Chinese government's intention is to replace the foreign market with the domestic one, and to develop technological autonomy by leveraging the huge local market and the state's capital support, both of which are aimed at getting rid of the restrictions from the U.S. in pursuit of long-term domestic economic stability. China is a major manufacturer of electronic products, which are applied across a wide range of sectors, from the toy industry to the aerospace industry, making the electronics sector a growing part of its GDP and a key driver of economic growth. In the past, however, most of the critical components relied on imports. In particular, the U.S. sanctions in the recent years have made it difficult for China to acquire leading-edge chips with high computing capacity for the AI industry and 5G, which are being promoted vigorously, thus hindering the development of industries and necessitating domestic production instead of imports. If China's economy is to embrace high quality development in the future, the autonomy of the electronics industry — especially the integrated circuit (IC) sector — is not only a prerequisite for the independence of strategic industries, but also an integral part of economic prosperity.

This paper begins with an analysis of China's economic performance, followed by an examination of the country's IC industry strategies that will shape China's future economic upgrading, and concludes with a summary of the prospects for China's development of a third-generation semiconductor industry by overtaking on a bend.

II. Current Economic Situation in China

1. Poor Economic Outlook for the Second Half of the Year

According to the economic data for the first half of the year released by the National Bureau of Statistics of China (NBS) in July 2021, China's GDP grew in the second quarter of the year by 7.9 percent from the same period last year,

which was down from the 18.3 percent growth rate in the first quarter of the year. The main reason for this is that growth in the first quarter of last year was -6.8% and in the second quarter it was +3.2%, so the performance in the second quarter of this year was not as good as in the first quarter as the base period had risen significantly.

China's GDP growth rate for the first half of the year reached 12.7 percent, a substantial rise against last year. However, the two-year average growth rate was only 5.3 percent, slightly falling short of the 6 percent mark before the outbreak of the pandemic, while the economic growth showed signs of weakness from the second half of the year. Industrial production rose by 5.3% year-on-year in August, according to the newly released figures, but albeit with an increase, exhibited a gradual downward trend since the beginning of the year. While electricity and fuel consumption were both marginally higher than last year, steel, cement and vehicle sales were all lower than the same period last year. It is worth noting that electricity generation increased by just 0.2 percent year-on-year in August, a sharp drop from the more than 7 percent rise seen in previous months, and that the slowdown in generation might be responsible for the blackout at the end of September.

On top of the current slump, the outlook for the overall manufacturing industry is not promising. The Purchasing Managers' Index (PMI) for the manufacturing sector was 49.6 published by the China NBS in September 2021, falling below the 50 mark, which separates growth from contraction, for the first time, and the figures had declined for six consecutive months, with all sub-indices below 50. The China NBS attributed this to high temperatures, heavy rainfall and the pandemic, although similar indices issued by the China Caixin website in August presented a similar picture. It was clear that the manufacturing sector as a whole was under considerable pressure, and the PMI for the service sector fell below the 50 mark in August for the first time since May.[2] These indices suggest that Chinese

[2] The Non-Manufacturing Business Activity Index (NMBAI) released by the Chinese NBS plunged to 47.5 in August 2021 before rebounding to 53.2 in September.; the Services PMI was 53.4 published on Caixin.com, recovering from 46.7 in August For details, see "China's Purchasing Managers' Index in September 2021," *National Bureau of Statistics*, September 30, 2021, http://www.stats.gov.cn/tjsj/ zxfb/202109/t20210930_1822646.html; "China's Services PMI rises to 53.4 in September on Caixin.com, Back in Expansionary Territory," *Caixin.com*, October 8, 2021, https://pmi.caixin.com/2021-10-08/101783800.html.

producers and operators are wavering in their outlook on the future of the economy and that their confidence may not be as strong as official expectations for future consumption. It is estimated that real year-on-year GDP growth in China is likely to slow to 5 percent to 6 percent in the second half of the year, probably back to pre-pandemic levels.

2. Pressure from Rising Wholesale Prices

The Consumer Price Index (CPI) rose by a mere 0.8 percent in August 2021 compared to the same month last year, as there was no upward pressure on consumer prices in the wake of the pandemic, with transport and education rising more markedly by 5.9 percent and 3 percent respectively; nevertheless, the Industrial Price Index registered a considerable increase. The Purchasing Price Index for Industrial Producers increased by 13.6 percent over the same period last year, with important raw materials for production, such as fuels, power, ferrous metals, non-ferrous metals and chemicals all rising by more than 20 percent. This wave of global raw material price hikes has squeezed the profits of small and medium-sized enterprises, and as a result, China is set to introduce new tax breaks and fee reductions this year, following last year's 2.5 trillion yuan tax cut, which is expected to reach 700 billion yuan.[3]

Meanwhile, consumer spending continued to be sluggish. Although the total retail sales of consumer goods recorded a year-on-year increase of 18.3 percent between January and August, the monthly growth rate of the total sales declined steadily from 15.8 percent in April to 2.3 percent in August. Apart from the short-term impact of the floods and the pandemic, private consumption has not rebounded after the outbreak was brought under control, and export growth is likely to remain weak in the second half of the year and the economy is under increased downward pressure. The pessimistic sentiment towards the economy was also reflected in loan demand, with new medium and long-term loans to enterprises/ business amounting to 521.5 billion yuan in August, down by over

[3] "Ministry of Finance: New Tax Cuts and Fee Reductions Expected to Exceed 700bn Yuan for the Year," *China Business Network*, July 30, 2021, https://www.yicai.com/news/101126304.html.

200 billion yuan year-on-year, while short-term loans fell by 114.9 billion yuan, indicating a lack of demand for entity financing. As a result, some reports suggested that China's GDP would struggle even more in the second half of the year than it did in the first, and that policies to support economic growth would be needed.[4] In summary, in the face of sluggish demand, economic growth in 2021 is driven primarily by government investment and imports and exports.

3. Relaxed Monetary and Infrastructural Facilities Boost the Economy

On the monetary front, a 0.5 percent reduction in the reserve requirement ratio (RRR) for financial institutions was announced on July 15. The across-the-board reduction, which was estimated to release around 1 trillion yuan in long-term funds, also contributed to an 8.2 percent increase in broad money (M2),[5] in August, which was not reflected in the availability of private funds. As the gap between M2 and narrow money (M1) growth had widened since May, from 2.2 percent to 4 percent in August, this means that private funds had shifted to less liquid savings or time deposits, indicating that people preferred to put their funds in less liquid time deposit accounts to earn interest, rather than in demand deposits, which can be withdrawn at any time for investment purposes, which reflected the market's pessimistic outlook on future economic trends. This downbeat assessment was also translated into an increment in private financing, which rose by 2.96 trillion yuan in August, down 629.5 billion yuan from a year earlier.[6]

New infrastructure construction, led by the government, is a key driver of economic growth. The combined government and private investment in new infrastructure construction projects between 2021 and 2025 will amount to 10.6 trillion yuan, with a further investment of around 2 trillion yuan per year.[7] For

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[4] "Macro Policy Tone May be Stable with Some Relaxation in the Second Half of 2021," *China Business Network*, August 4, 2021, https://www.yicai.com/news/101130259.html.

[5] According to the People's Bank of China, M0 refers to cash in circulation, narrow money (M1) refers to M0 plus entities' demand deposits (of which corporate demand deposits account for about 80 percent), and broad money (M2) means M1 plus corporate time deposits, residential savings deposits, and other deposits.

[6] "RMB Loans up 1.22 tn Yuan in August," *People's Daily Online*, September 11, 2021, http://finance.people.com.cn/BIG5/n1/2021/0911/c1004-32224176.html.

[7] "China Significantly Expands New Infrastructure Construction Investment," *cn.nikkei.com*, January 25, 2021, https://zh.cn.nikkei.com/china/ceconomy/43560-2021-01-25-05-00-00.html.

example, 718,000 5G base stations were open at the end of 2020 and 993,000 at the end of August 2021.[8] In ultra-high voltage, the State Grid Corporation of China invested 460.5 billion yuan in 2020, rising to 473 billion yuan this year.[9] Moreover, to achieve the goal of carbon neutrality, investment in new energy sources such as wind power and solar energy will be stepped up on an ongoing basis.

4. Outside-in Development Strategies

Due to the high degree of uncertainty in the external economy, China's development strategy has shifted to internal circulation. The U.S. government's trade war and technological confrontation with China has made it difficult for many Chinese companies to gain access to advanced and critical technologies. In the wake of the pandemic, the supply chain is not only decoupled and disrupted, but the global outbreak control is out of sync and the economic recovery is uneven. Additionally, the possible shift in monetary policy towards tightening in the U.S. Federal Reserve System (Fed) has added to the external uncertainty and has created potential concerns for import and export growth. In May 2020, Xi Jinping unveiled a new "dual circulation" development pattern in which domestic economic cycle plays a leading role while international economic cycle remains its extension and supplement. This new dual circulation strategy, which centers on the expansion of domestic demand, is designed to address the situation where the global supply chain is partially broken under the onslaught of the pandemic, with raw materials unable to come in from abroad, overseas staff unable to enter, and goods unable to be exported, bringing work and production to a standstill.[10] From China's perspective, the trade protectionism, U.S. interest-based unilateralism and even bullying practices pushed by then U.S. president Donald Trump since

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[8] "Latest Information: China Has Built the World's Largest 5G Network," *Chinese government portal*, January 31, 2021, http:// www.gov.cn/xinwen/2021-01/31/content_5583838.htm; "China Leads the World in 5G Adoption: 993,000 5G Base Stations Opened and Built," *China Service Trade Guide website*, September 10, 2021, http://tradeinservices.mofcom.gov.cn/article/szmy/hydt/202109/119606.html.

[9] "State Grid Releases 2020 Social Responsibility Report: 473bn Yuan in Grid Investment in 2021," *POWER.IN-EN.com*, April 15, 2021, https://power.in-en.com/html/power-2386504.shtml.

[10] "Take the First Step, See the Refreshing New Look," *People's Daily Online*, August 3, 2021, http://politics.people.com.cn/BIG5/n1/2021/0803/c1001-32178833.html.

he took office had created the phenomenon of "reverse globalization," causing the global industrial chain, supply chain and value chain to begin to shake, and putting China's economy in unprecedented difficulties and challenges. China, as a beneficiary of globalization, must take action against this move.

In terms of internal circulation, the main objective is to bring about autonomous control of markets and technologies. To protect its market from adverse factors (trade protectionism and the COVID-19 pandemic), China has sought to orient its future economic growth towards a large domestic consumer market; and to avert the technological constraints that could undermine its economic development, the country has embarked on the localization of key technologies and products, particularly in the chip industry, which has been "seized by the throat." The external circulation under this double circulation strategy is primarily geared towards supporting the internal circulation. By promoting export sales to retain the scale of production made in China, and by drawing in foreign investment and technology to boost the quality and technological content of domestic manufacturing, the goal of replacing the external circulation with the internal circulation will ultimately be achieved.

III. China's Semiconductor Industry's Independent Development Predicament

1. Current Semiconductor Development Situation in China

Since the development of the semiconductor industry in China in the 1950s, state support has played a vital role. The 6th Five-Year Plan (1980-1985) and the 7th Five-Year Plan (1986-1990) each set out dozens of projects for the semiconductor industry, particularly in the areas of semiconductor design, testing, semiconductor manufacturing, semiconductor end-product applications, semiconductor manufacturing equipment, and basic theoretical research for national scientific and technological breakthroughs. In addition to the above, the 8th Five-Year Plan (1990-1995) also touched on the establishment of foundries (called "standard processing

lines" in China) and the development of GaAs and other power semiconductors.[11] "The 9th Five-Year Plan (1996-2000) set the goal of building 8-inch wafer fabs and developing 0.3 to 0.5 micrometer ICs as special projects, with a particular focus on developing new IC electronic components, computers and communications equipment, thereby upgrading the information systems and manufacturing equipment needed for economic and social progress. China's policies on boosting the IC industry are primarily based on tax incentives and special projects pushed by the state budget. In terms of IC manufacturing volume, 310 million units were fabricated in 1995 and 2.5 billion units were estimated in output by the year 2000, but the actual volume attained was much higher than that.[12]

The release of the "Notice by the State Council of Issuing the Several Policies for Incentivizing the Development of the Software Industry and the Integrated Circuit Industry" in 2000 and the subsequent upturn in the semiconductor industry in 2003 led to substantial growth in China's IC market and industry scale. As of the end of 2003, there were over 30 IC wafer production lines. The proportion of sub-6-inch fabs still stood at 78 percent, 8-inch fabs were not yet mainstream, and process standards had not yet reached internationally accepted levels, with processes above 0.35 micrometers representing over 80 percent of the total.[13] The 11th Five-Year Plan (2006-2010) aimed at promoting IC R&D centers and developing IC infrastructure software. In terms of wafer fabrication process, 90nm was achieved and progress was made towards 60nm to 45nm processes.

The 2011 "Notice of the State Council on Issuing Several Policies on Further

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[11] Zhongyu Yu, "The Current Status and Development Trend of the Integrated Circuit Industry in China," *Semiconductor Intelligence*, Vol. 1, 1988, pp. 7-10; Junlu Jiang, Yangyuan Wang and Yongwen Wang, "Review and Prospects of China's Integrated Circuit Science and Technology Development," *Journal of Shanghai Jiaotong University*, Vol. 26, No. 1, 1992, pp. 1-14.

[12] "The 9th Five-Year Plan for National Economic and Social Development of the People's Republic of China and the 2010 Vision Outline," *National People's Congress (NPC) website*, March 17, 1996, https://reurl.cc/EZgDM1. According to the statistical communique of 2000, the number of ICs manufactured was 5.88 billion units, for details, see "Statistical Communique on National Economic and Social Development of the People's Republic of China 2000," *Chinese government portal*, February 28, 2001, http://www.gov.cn/gongbao/content/2001/content_60684.htm.

[13] Tung-ho Shieh, "Cross-Strait IC Manufacturing Industry Development and Competition," *CTimes*, March 5, 2004, https://www.ctimes.com.tw/DispArt/tw/040305133 4I0.shtml.

Encouraging the Development of the Software and Integrated Circuit Industries,"[14] the February 2012 "Plan for Development of the Electronic Information Manufacturing Industry During the 12th Five-Year Plan,"[15] and "Plan for Development of the Integrated Circuit Industry During the 12th Five-Year Plan"[16] enabled the development environment of China's IC industry to continue to be optimized. To further expedite the growth of the IC industry, the State Council in June 2014 unveiled the "Outline of the Program for National Integrated Circuit Industry Development," which identifies five basic principles for the development of the IC industry: "Demand-led, innovation-driven, software and hardware combined, key breakthroughs, and open development."

"Made in China 2025, launched in 2015, focuses on the IC industry and its associated specialized equipment. In terms of design, priority is given to IC intellectual property (IP) and electronic design automation (EDA) to enhance the standard of IC design; regarding IC manufacturing, breakthroughs are made in core general-purpose chips that are critical to national information and network security and the development of the electronic machine industry; with respect to packaging, emphasis is placed on high-density packaging and 3D packaging; in respect of specialized equipment, independent development capabilities are developed to upgrade the packaging industry and testing, and form a key manufacturing equipment supply capability. At this point in time, the most advanced photolithography systems are not yet within the purview of the dedicated equipment policy. During the 13th Five-Year Plan period (2016-2020), China's semiconductor manufacturing industry has made some concrete achievements,

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[14] "Notice of the State Council on Issuing Several Policies on Further Encouraging the Development of the Software and Integrated Circuit Industries," *Chinese government portal*, February 9, 2011, http://www.gov.cn/zwgk/2011-02/09/content_1800432.htm.

[15] "The Issuance of 'The Plan for Development of the Electronic Information Manufacturing Industry During the 12th Five-Year Plan'," *Chinese government portal*, February 24, 2012, http://www.gov.cn/gzdt/2012-02/24/content_2075829.htm.

[16] "The Issuance of 'The Plan for Development of the Integrated Circuit Industry During the 12th Five-Year Plan'," *Chinese government portal*, February 24, 2012, http://www.gov.cn/gzdt/2012-02/24/content_2075782.htm.

such as the commissioning of a 12-inch "specialty process" production line,[17] the mass production of 14nm process by Semiconductor Manufacturing International Corporation (SMIC),[18] and the development of 128-layer 3D NAND flash memory by Yangtze Memory Technologies Corp (YMTC), which is basically on a par with the international mainstream.[19] China has been making great strides in its wafer fabrication capabilities, as evidenced by Advanced Micro-Fabrication Equipment Inc.'s (AMEC) 5nm etch system that has been validated by Taiwan Semiconductor Manufacturing Co (TSMC),[20] and the photolithography systems that have yet to be proven.

With regard to market sales, semiconductor sales in China were booming, with sales of 884.8 billion yuan in 2020, up more than six times when compared to 2010.[21] The quality of IC manufacturing had also improved, with the average price per unit increasing from 2.2 yuan per unit in 2010 to 4.08 yuan per unit in 2019.[22] However, the quality of ICs for export has not seen any marked improvement, with the average price per unit increasing from US$0.42 in 2009 to US$0.45 in 2020,[23] with no significant rise. It is speculated that the increase in the unit price of chips but not in the export price may be due to the fact that the quality of chips manufactured in China (including foreign-owned fabs) has improved, but mainly for local assembly needs, while foreign electronic assembly plants have

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[17] The so-called "special process" ICs in China refer to IC products that do not rely on advanced manufacturing processes and high-end equipment. These products do not require the same state-of-the-art, low-nanometer processes as processors or memory, but rather special features that are tailored to the different physical requirements of the working environment. Products in this category include power components, analogue chips, RF devices, MEMS and sensors.

[18] "Gap Between SMIC and TSMC, 14nm in Mass Production, Admits 'Still a Long Way to Go' from World-class Enterprise," *Apple Daily*, November 12, 2020, https://reurl.cc/NZbDmx.

[19] Lefeng Shao, "YMTC's 128-layer 3D NAND Launched as Best in Industry," *EE Times*, April 14, 2020, https://reurl.cc/356mEO; Qingxiu Han, "YMTC's 128-layer NAND Yield not Yet in Place, China's Local Supply Chain in the Works," *DIGITIMES*, August 24, 2021, https://reurl.cc/aNZzmQ.

[20] "Shenzhen AMEC Semiconductor's 5nm Plasma Etch System Has been Validated by TSMC," *Electronic Engineering World*, December 18, 2018, http://news.eeworld.com.cn/szds/2018/ic-news121814304.html.

[21] Sales volume in 2010 was 142.4 billion yuan, see "2010 Domestic IC Industry Operation," *China Semiconductor Industry Association*, January 25, 2011, http://www.csia.net.cn/Article/ShowInfo.asp?InfoID=17076.

[22] "Yu Xiekang: China's IC Industry Enters New Stage, Gap with Foreign Countries Still Obvious," *digfamily.com*, NO.1, October 15, 2020, https://reurl.cc/2o639m.

[23] The author's calculations are based on data from the China Semiconductor Industry Association website, http://www.csia.net.cn.

little demand for China's mid- to low-end chips, which also reflects the lack of competitiveness of China's domestically-made chips in the international arena and the fact that their export prices cannot compete with similar products from other countries.

In terms of the structure of the IC industry, the IC design industry is currently dominant, with an output value of 176.64 billion yuan in the first half of 2021, accounting for 43 percent of the whole sector and making it internationally competitive; followed by the IC wafer manufacturing industry, with a value of 117.18 billion yuan, constituting 29 percent; and finally, the IC assembly, packaging and testing industry, with a value of 116.47 billion yuan, comprising 28 percent (see Table 8-1 below). In the past, assembling, packaging and testing accounted for a larger share than wafer fabrication, but was gradually overtaken by wafer fabrication in the last two years when new fab capacity began to come on stream.

Regarding production lines, China has seen a rapid expansion in chip manufacturing over the past few years, with some 200 production lines (see Table 8-2 below), of which memory chips make up the largest share, followed by logic chips. More 12-inch wafer production lines are currently being built or signed than are in operation, and at the present rate of construction, China's wafer fabrication capacity should double in the coming years.

Table 8-1 Structure of the IC Industry in China

Year	H1 2020	H1 2020 growth (%)	2020	2020 growth (%)	H1 2021	H1 2021 growth (%)
Industry sales (in 100 mn yuan)	3,539.0	16.1	8,848.0	17	4,102.9	15.9
IC design industry (in 100 mn yuan)	1,490.6	23.6	3,778.4	23.3	1,766.4	18.5
IC wafer industry (in 100 mn yuan)	996.0	17.8	2,560.1	19.1	1,171.8	21.3

Year	H1 2020	H1 2020 growth (%)	2020	2020 growth (%)	H1 2021	H1 2021 growth (%)
IC assembling, packaging and testing industry (in 100 mn yuan)	1,082.4	5.9	2,509.5	6.8	1,164.7	7.6
Qty of IC imports (in 100 mn units)	2,422.7	25.5	5,435.0	22.1	3,123.3	29
Amount of IC imports (in US$100 mn)	1,546.1	12.2	3500.4	14.6	1,978.8	28.3
Qty of IC exports (in 100 mn units)	1,125.6	13.8	2,598.0	18.8	1,513.9	39.2
Amount of IC exports (in US$100 mn)	505.1	10.5	1,166.0	14.8	663.6	32.0

Source: Compiled by the author based on data from the China Semiconductor Industry Association, at http://www.csia.net.cn.

Table 8-2 China's Fab Production Line Statistics

	2018		2019		2021Q2				
	In operation		In operation		In operation		Being built or signed		
	Prod line	Monthly capacity	Prod line	Monthly capacity	Prod line	Monthly capacity	Prod line	Monthly capacity	Investment
12"	10	60		90	27	118	29	132	6,000
8"	20	90		100	28	120	10	27	NA
6" and under						400			
6"	50+	200		230					
5"		90		80					
4"		200		260					
3"		50		40					
Total	100+				200				

Notes:
1. This table is an incomplete statistical source of information collected by the author from various reports.
2. The unit of production line is a piece, the unit of monthly production capacity is 10,000 pieces, and the unit of investment is RMB100 million.
Source: "Yu Xiekang: China's IC industry enters new stage, gap with foreign countries still obvious," *digfamily.com*, NO.1, October 15, 2020, https://reurl.cc/2o639m; ChipInsights, "China Wafer Fabrication Lines in Q2 2021," *Snowball*, September 16, 2021, https://reurl.cc/ MkyEVK; Yuanchuang Zhao, "Year-End Industry Roundup: China's 63 fabs Update in 2019," *EE Times*, January 3, 2020, https://reurl.cc/px5E2x.

On the whole, the problem facing China's chip manufacturing industry is that the domestic market has a large demand (consuming 24 percent of the world's electronic goods and manufacturing 35 percent of the world's electronic goods), but the technology level is not high. Despite numerous independent innovations in the country, they are not sophisticated, with some core technologies and advanced equipment relying heavily on foreign supplies, and the innovation system of the manufacturing industry dominated by enterprises, is imperfect. These products are not high-grade and short of world-famous brands.

2. Policy Instruments under the "14th Five-Year Plan"

If the order in the contents of the 14th Five-Year Plan represents policy importance, the strategic development of science and technology is the focus of the plan, as the significance of science and technology and how to develop the technology industry cover the entire second part of the plan and the first two chapters of the third part.

The 14th Five-Year Plan, which was introduced to pursue technological autonomy and control against the backdrop of the U.S.-China trade war and technology war, has not only invested heavily in the wafer manufacturing industry (see Table 8-3 below), but also in third-generation semiconductors (see the next section for analysis), chip design tools and chip manufacturing equipment, which have come to the fore in the 14th Five-Year Plan.

China's subsidies to the semiconductor industry are broadly based on three approaches: (1) direct equity injection from state funds; (2) tax and fee reductions; and (3) preferential loans (bank credit and equity financing).

China set up the "National Integrated Circuit Industry Investment Fund (the "Big Fund") Phase I in 2014 and Phase II in 2019, with a size of approximately 100 billion yuan and 200 billion yuan respectively. Both have slightly different investment directions, but they both target industries that are backed by policies at the time. The Phase I covers the entire IC industry chain, but more than half of the funds are allocated to leading semiconductor manufacturing companies, such as SMIC (approx. 21.5 billion yuan), YMTC (19 billion yuan), HLMC (11.6 billion yuan) and Tsinghua Unigroup (10 billion yuan).[24] The holding was gradually scaled down in 2019 and the Phase I is expected to be concluded in 2024. The Phase II puts emphasis on China's weaker semiconductor equipment and materials sectors, such as Advanced Micro-Fabrication Equipment Inc.

The State Council's subsidies on taxation mainly originated from the "Several Policies on Encouraging the Development of the Software and Integrated Circuit Industries" in 2000, followed by the "Notice of Several Policies on Further Encouraging the Development of the Software and Integrated Circuit Industries"[25] in the "12th Five-Year Plan" in 2011, which adopted lower income tax rates, exemptions within a given period of time (e.g. exemption of enterprise income tax on first 2 years, and half diminution from the third to the fifth year.), income tax exemptions or investment tax rebates, accelerated depreciation, etc. Along with expanding the scope of income tax incentives, some adjustments had been made under the new incentive scheme in 2011, such as the abolition of reinvestment tax rebates.[26]

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[24] Ling Fang, "Significant Progress in Domestically Produced Semiconductors! Wuhan National Memory Base Project Phase II Commences Construction," *All Weather TMT*, June 21, 2020, https://awtmt.com/articles/3596487.

[25] After the State Council issued a policy notice in 2000, the Ministry of Finance also published notices in 2000 and 2002 respectively, namely the "Notice of the Relevant Tax Policies for Encouraging the Development of Software and Integrated Circuit Industry" and the "Notice of the Relevant Tax Policies for Further Encouraging the Development of Software and Integrated Circuit Industry." Following the issuance of the policy in 2011, the relevant ministries released notices in 2012 and 2015 respectively, namely the "Notice of Taxation on Enterprise Income Tax Policies for Further Encouraging the Development of Software and Integrated Circuit Industries" and the "Notice of Taxation on Enterprise Income Tax Policies for Further Encouraging the Development of Integrated Circuit Industries."

[26] For more information on tax relief measures for the IC industry, see Li Sun and Qiang Chi, "Review and Analysis of Corporate Income Tax Policies for the Software and IC Industry," *International Taxation*, Vol. 6, 2016, pp. 63-67.

Table 8-3 IC Industry Scale Planning during the 14th Five-Year Period in China's Provinces/Autonomous Regions/Direct-controlled Municipalities
Unit: RMB 100 mn

Location / Year	2021	2022	2023	2025	Subtotal
Anhui	1,000				1,000
Beijing				3,000	3,000
Guangdong				4,000	4,000
Hubei		1,000			1,000
Shandong		1,000			1,000
Shaanxi				2,000	2,000
Shanghai	2,440				2,440
Sichuan		1,500		2,000	3,500
Zhejiang				2,500	2,500
Chongqing		350			350
Gansu				200	200
Hebei				200	200
Hunan				300	300
Jiangxi				500	500
Liaoning				800	800
Tianjin			400		400
Total	3,440	3,850	400	15,500	23,190

Source: ChipInsights, "The 14th Five-Year Plan for IC Industry Development Planning and Industry Scale Targets by Region," WeChat official account, September 10, 2021, https://reurl.cc/Ok5DKg.

In terms of loan financing, the 2011 "Several Policies on Further Encouraging the Development of the Software and Integrated Circuit Industries" had guided local governments to establish loan risk compensation mechanisms and intellectual property pledge loans and guarantee services. The "Outline of the Program for National Integrated Circuit Industry Development" released in 2014 stated that it "supports the Export–Import Bank of China in stepping up its services to IC enterprises within its scope of business, encourages and guides the China Development Bank and commercial banks to increase their credit support to the IC industry on an ongoing basis, and innovates credit products and services tailored to the needs and characteristics of the IC industry." Under this policy, the China Development Bank issued loans of 107.8 billion yuan and 123.8 billion yuan in 2017 and 2018 respectively.[27]

With such policies in place, China has subsidized the semiconductor industry to the tune of US$50 billion over the past two decades.[28] While this has been beneficial to the development of China's semiconductor industry, it has not solved the problem of over-reliance on foreign chips and has resulted in over-subsidization, leading to the phenomenon of "botched" semiconductor fab construction projects such as Wuhan Hongxin and Guangdong Haixin. More than a dozen "failed" semiconductor plants are currently out of operation,[29] most of which have no plans for actual construction, let alone production. The main reason for the shutdown and construction suspension is mostly due to funding issues (disruption of capital, lack of availability of funds).

In 2020, the 14th Five-Year Plan saw a shift to a different approach to granting subsidies. The "Notice on the Issuance of Several Policies to Promote the High

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[27] "China Development Bank: Giving Full Play to Countercyclicality and Strengthening Services to the Real Economy," *China Development Bank*, January 2, 2019, http://www.cdb.com.cn/xwzx/khdt/201901/t20190122_5815.html.

[28] "Poor Results of Big Spending? FT: China's 1.4 Trillion Yuan Subsidy to Chip Industry in 20 Years is 100 Times that of Taiwan," *Liberty Times*, October 26, 2020, https://ec.ltn.com.tw/article/breakingnews/3332698.

[29] Atkinson, "A Look at China's Top 10 Tech Busts, with HSMC Still Topping the List," *Financial News*, January 18, 2021, https://reurl.cc/730Zx5; "After HSMC, QXIC also Collapses with 180 Taiwanese Engineers Left with no Jobs," *Liberty Times*, May 23, 2021, https://reurl.cc/Gbjz3G; Ning Xu, "HSMC's 100bn Yuan Fraud Project Ends, a Repeat of the 'Backyard Furnaces' Project," *Voice of America*, March 6, 2021, https://reurl.cc/ WXxe9y.

Quality Development of Integrated Circuit and Software Industries in the New Period"[30] promulgated on August 4, 2020 not only introduced more preferential income tax and value-added tax subsidies for more advanced processes node projects, but also took a progressive approach to reducing the eligible recipients and preferential measures according to the technological threshold of the process. In addition, it also stresses investment risks to avoid overlapping investments and vying for talents.

3. Semiconductor Development Predicament and the Way Out

Since the Trump administration-imposed sanctions on ZTE Corp in 2017 for violating the embargo on Iran, and with the arrest of Huawei Technologies Co's founder's daughter Meng Wanzhou in Canada in 2018, the U.S. Department of Commerce in May 2019 placed Huawei and 70 of its affiliates on an "Entity List," making it impossible for the Chinese company to purchase electronic parts from the U.S. without U.S. permission. A year later (2020), the U.S. escalated sanctions against Huawei, requiring that any semiconductor chip using U.S. technology or design must first secure a U.S. export license before it can be sold to the company, even if it is manufactured outside the U.S. In December 2020, the U.S. Department of Defense (DoD) officially blacklisted Semiconductor Manufacturing International Corp (SMIC), leading the U.S. Department of Commerce to add SMIC to its Entities List. Since then, the U.S. has completely blocked China's ambition to forge ahead in advanced manufacturing processes (less than 5 nanometers).

In terms of advanced manufacturing processes, the U.S. ban has prevented SMIC from acquiring a long-standing order for extreme ultraviolet lithography (EUV) machines from ASML Holding NV, a Dutch photolithography systems house, which has kept SMIC's manufacturing process at 14nm. However, this restriction has only compelled China to change its development strategy and

[30] "Notice of the State Council on the Issuance of Several Policies to Promote the High Quality Development of Integrated Circuit and Software Industries in the New Period," *Chinese government portal*, August 4, 2020, https://reurl.cc/Mk6DKn.

move forward in a roundabout way. First of all, SMIC is experimenting with a new process technology to attain "7nm-like" performance. For example, SMIC has developed the "N+1" process, which is claimed to offer a 20 percent boost in performance over the existing 14nm, a 57 percent reduction in power consumption, a 63 percent shrinkage in logic area, and a 55 percent decrease in system area per chip, with chip stability and power consumption close to that of the 7nm process, albeit not quite as good as the true 7nm process.[31] This is an attempt by China to break through the limitations of the chip process without relying on EUV technology.

Second, the capacity of the mature process technology node is being expanded. According to Semiconductor Equipment and Materials International (SEMI), eight new fabs are slated to be built in China between 2021 and 2022.[32] Also, the "White Paper on China Wafer Fabrication Lines" published by ChipInsights indicates that as of the end of Q2 2021, there are 29 12-inch fabs under construction or under contract, with an investment amount of up to 600 billion yuan and a planned monthly capacity of 1.32 million pieces; and 10 8-inch fabs with a projected monthly capacity of 270,000 pieces.[33] In particular, SMIC plans to commit US$8.87 billion to build a 28nm 12-inch foundry production line in Shanghai with a capacity of 100,000 pieces per month.[34] The expansion of the mature process capacity is not only in response to the strong demand for the process for automotive chips, but also to meet China's demand for chips other than high-end ones for mobile phones. The abandonment of 7nm or 5nm chip fabrication only affects the high-end handset business. The technology of 14nm node is more than sufficient for chips that do not require advanced processes, such as automotive chips and power management chips, which using micrometer or sub-

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[31] Jih-hsing Yang, "SMIC's N+1 Process Breakthrough Sends Shares Soaring," *Commercial Times*, October 13, 2020, https://ctee.com.tw/news/china/350574.html.

[32] "SEMI: New Fab Construction Expected to Drive Significant Increase in Equipment Spending," *SEMI*, June 23, 2021, https://www.semi.org/zh/new-fab.

[33] ChipInsights, "China Wafer Fabrication Lines in 2Q 2021," *EETimes*, September 16, 2021, https://www.eet-china.com/mp/a77879.html.

[34] Chen-i Lin, "SMIC Spends NT$248bn on 12-inch Fab," *Economic Daily News*, September 4, 2021, https://money.udn.com/money/story/5604/5721141.

micrometer technology node. Moreover, it is beneficial to maintain the expansion of mature production capacity in order to draw in foreign high-tech talents on a continuous basis, and to sustain exchanges with foreign equipment suppliers to avoid decoupling of the supply chain. This shows that China is now setting its sights on non-advanced chips that are not restricted by the U.S., so that it can retain its basic operations, preserve the stability of its supply chain, maintain technology exchanges with foreign countries, and waiting for the lifting of the U.S. ban.

IV. China's Third Generation Semiconductor Development

In recent years, the trend of 5G and electric vehicles has made high-frequency, high-power, high-temperature-resistance, high-breakdown-voltage and high-current-density semiconductor components a necessity, leading to a steep increase in demand for power components. Compared to traditional semiconductor, such as silicon (Si) and germanium (Ge) in the first generation, and gallium arsenide (GaAs), indium phosphide (InP) and gallium arsenide (AlGaAs) in the second generation, third generation semiconductors have superior physical properties such as high temperature and voltage resistance, fast switching and high efficiency (low loss) (see Table 8-4 for details). The third generation of semiconductors can be classified into silicon carbide (SiC) and gallium nitride (GaN) materials. GaN has a high breakdown field, high saturation electron velocity and excellent thermal conductivity due to its large band gap, giving it a higher power RF capability[35] and making it an essential material for 5G base stations, where power applications are better at low and medium voltages. On the other hand, silicon carbide (SiC) performs better at high voltages (>600 volts) and is suited for high power applications such as electric vehicles, charging stations, UPS and power supplies. Due to the high efficiency and low dissipation characteristics of third generation semiconductors, the size of the components is significantly reduced, and

[35] "A Primer on GaN and 3 Reasons It Outperforms Other Semiconductors in RF Applications," *Qorvo*, April 20, 2017, https://reurl.cc/734lxk.

the low dissipation characteristics generate less heat energy, eliminating the need for larger heat dissipation designs than traditional silicon-based power components such as Si-MOSFETs or insulated gate bipolar transistors (IGBTs), so that they can be applied across four China's new infrastructure construction projects: 5G infrastructure, new energy vehicle charging piles, ultra-high voltage and rail transportation. Further, their light weight is of great benefit in aerospace operations and is therefore highly valued in military applications, making third generation semiconductors a product of economic and military strategic importance to China.

Table 8-4 Differences in Physical Properties between Silicon-based and Third-generation Semiconductors

Materials Property	Si	SiC-4H	GaH
Band Gap (eV)	1.1	3.2	3.4
Critical Field 106 V/cm	.3	3	3.5
Electron Mobility (cm2/V-sec)	1450	900	2000
Electron Saturation Velocity (106 cm/sec)	10	22	25
Thermal Conductivity (Watts/cm2 K)	1.5	5	1.3

Source: Microsemi, P. P. G. "Gallium nitride (GaN) Versus Silicon Carbide (SiC) In the High Frequency (RF) and Power Switching Applications," Digi-key (2014), https://reurl. cc/956ylv, p. 2.

As noted above, the market for third generation semiconductors holds great potential for growth. Regarding power devices, the global market for SiC elements was around US$700 million in 2020 and is projected to grow to US$4.7 billion by 2026, representing an annual compound growth rate of 40 percent (as shown in Figure 8-1).[36] In addition, the GaN market is exhibiting similarly high growth rates, surging to more than US$100 million in 2020 from merely over US$10 million in 2019, and will reach US$1.2 billion by 2027, a compound growth rate of 35.4 percent.[37]

[36] "The Global Silicon Carbide Power Semiconductor Market was Valued at USD 628.72 Million in 2020, and it is Expected to Reach USD 4708.71 Million by 2026, Registering a CAGR of 42.41% During the Period 2021-2026," *Global News*, July 20, 2021, https://reurl.cc/Q6R0W0.

[37] "The Global GaN Semiconductor Device Market Size is Estimated to be USD 19.4 Billion in 2021 and is Projected to Reach USD 24.9 Billion by 2026, at a CAGR of 5.2%," *Global News*, June 18, 2021, https://reurl.cc/jgWxlL.

1. Policy Instruments for China's Third Generation Semiconductors

China's "Made in China 2025," initiated in 2015, states that "a breakthrough in the manufacturing and application of key components and materials such as high-power power electronic devices and high-temperature superconducting materials achieved will bring about industrialization capabilities."[38] Since then, the policy of backing third generation semiconductors has begun to take shape. Other than some policies and subsidies for overall semiconductor development, such as the "Special Integrated Circuit Projects Strongly Backed by the Ministry of Science and Technology" and the 13th Five-Year Plan for the Development of National Strategic Emerging Industries" in 2015, the State Council's policies specifically targeting third-generation semiconductors are the "Belt and Road Initiative Plan for Cooperation in Scientific and Technological Innovation" in 2016. The third generation of semiconductors is explicitly addressed as one of the new materials in the new material development section of the Plan's focus areas.[39]

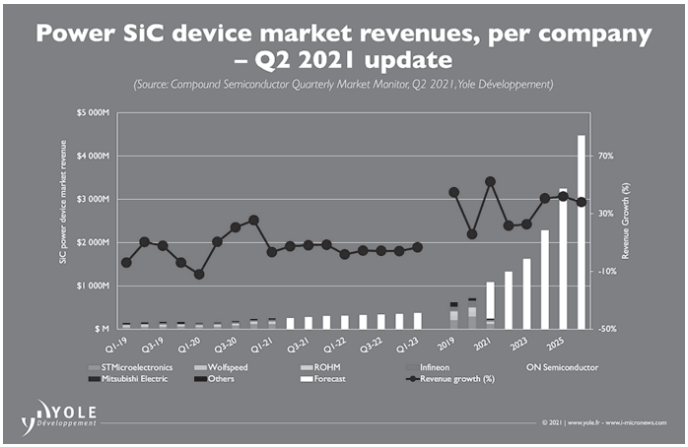

Figure 8-1 Revenue and Estimates of SiC Manufacturers in Recent Years

Source: Quoted from "Silicon Carbide Device Market to Exceed $4bn by 2026," *Semiconductor Today*, July 23, 2021, http://www.semiconductor-today.com/news_items/2021/jul/yole-230721. shtml.

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[38] "GaN Power Device Market Outlook-2027," *Allied Market Research*, May 2020, https://reurl.cc/956yev.

[39] "Notice on the Issuance of the 'BRI Plan for Cooperation in Scientific and Technological Innovation'," *State Council Press Office*, September 14, 2016, https://reurl.cc/52ve1y.

Additionally, the policies sponsored by the ministries and commissions are presented in Table 8-5 below.

Table 8-5 Subsidy Policies for Developing Third Generation Semiconductor Industry

promulgated year-month	Department in Charge	Name of Policies	Objectives
2016-12	National Energy Administration	13th Five-Year Plan for Energy Technology Innovation	Research on the stable preparation technology of 8-inch silicon carbide (SiC) substrates and realize the mass production of 6-inch SiC crystal substrates; develop GaN single crystal growth technology with breakdown voltage greater than 5kV, realize mass production of 6-inch GaN single crystal substrates, and research key technologies for low-cost domestic production of high-power LED encapsulants. It is expected to be completed by 2023.
2016-12	Ministry of Industry and Information Technology, National Development and Reform Commission	Guide to the Development of the Information Industry[40]	1. Develop production lines for specialized processes such as analogue and digital-analogue hybrids, MEMS, power electronics, high-voltage circuits, RF circuits and for compound ICs. 2. Step up efforts in areas of "more than Moore", promote the construction of special process production lines and the development of third-generation compound semiconductor products, and expedite innovation in new materials, structures and processes.

[40] "Notice of the Ministry of Industry and Information Technology and the National Development and Reform Commission on the Issuance of the Guide to the Development of the Information Industry," *Ministry of Industry and Information Technology*, February 9, 2017, https://ppt.cc/fG4fvx.

promulgated year-month	Department in Charge	Name of Policies	Objectives
2017-4	Ministry of Science and Technology	13th Five-Year Plan for Science and Technology Innovation in the Materials Sector under 13th Five-Year Plan [41]	To strengthen China's material system and vigorously develop high-performance carbon fibers and composite materials, high temperature alloys, new materials for military industry, third-generation semiconductor materials, new display technologies, special alloys and new rare earth materials, etc., so as to meet the material needs of China's major projects and national defense construction. One of the key developments: third generation semiconductor and LED materials.
2019-11	Ministry of Industry and Information Technology	Directory for Guiding the Exemplary Application of the First Batch of Key New Materials (2019)[42]	1. Gallium Nitride (GaN) single crystal substrates: 2-inch and above. 2. GaN epitaxial wafers for power components: 4-inch and above. 3. Silicon Carbide (SiC) epitaxial wafers: 4" and above. 4. SiC and N-type SiC single crystal substrates: 4" and above. 5. Aluminium-based SiC complexes. 6. SiC ceramic membrane filtering material. 7. β-SiC micropowder. 8. Key strategic material: high temperature continuous resistant SiC fiber.

Source: Compiled by the author from publicly available information.

[41] Notice of the Ministry of Science and Technology on the Issuance of the "13th Five-Year Plan for Science and Technology Innovation in the Materials Sector," *Chinese Academy of Sciences*, September 12, 2017, http://www.bdp.cas.cn/ztzl/sswgh/201709/t20170912_4614051.html.

[42] Notice of the Ministry of Industry and Information Technology on the Issuance of the 'Directory for Guiding the Exemplary Application of the First Batch of Key New Materials (2019 Edition)'," *Chinese Government Portal*, December. 3, 2019, https://reurl.cc/RbqAyz.

2. China's Third Generation Semiconductor Situation and Plight

With subsidies granted by the Chinese government, third generation semiconductors are springing up everywhere. According to a China Resources investment report, there were 2, 12 and 18 cases for newly-built SiC plants between 2018 and 2020, with investment amounts of 5 billion, 19.9 billion and 46.5 billion yuan respectively.[43] Under the "Third Generation Semiconductor Industry Technology Innovation Strategic Alliance," there were 14 SiC construction projects (including new construction and expansion) worth 22.08 billion yuan in 2019 and 17 projects worth 55 billion yuan in 2020; there were 3 GaN projects worth 4.5 billion yuan in 2019 and 7 projects worth 14.4 billion yuan in 2020 (as displayed in Figure 8-2).

In terms of output value, the total output value of power and RF third-generation semiconductors surpassed 10 billion yuan in 2020, up about 70 percent from 2018, with the scale of power components reaching 4.47 billion yuan. As a result of the increased investment, the value of output will also go up in the future. For instance, Hunan Sanan's third-generation semiconductor plant, which commenced production in June 2021, is the first in China and the third in the world in the vertically integrated silicon carbide (SiC) chain, with a capacity of up to 30,000 6-inch SiC wafers per month and its projected production value of 12 billion yuan.[44] In the same month, Innoscience (Suzhou) Semiconductor Co also started mass production at its 8-inch GaN on Si plant.[45] With a maximum annual production capacity of 780,000 wafers, this facility is expected to have an annual production value of 15 billion yuan. The market for SiC and GaN power components in China is forecast to be several times larger than the current size by 2023.

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[43] Chen-i Lin, "3rd Generation Semiconductor Era Begins: a Look at the Strategic Benefits of Semiconductors," *Sina.com*, August 11, 2021, https://finance.sina.com.cn/tech/2021-08-11/doc-ikqciyzm0748150.shtml.

[44] Chia-i Chang, "'Chinese Industry,' San'an Optoelectronics, Hunan Semiconductor Base Phase I Project Commences Production," *chinatimes.com*, August 11, 2021, https://wantrich.chinatimes.com/news/20210624S379223.

[45] Gallium Nitride (GaN) is used in low and medium frequency elements.

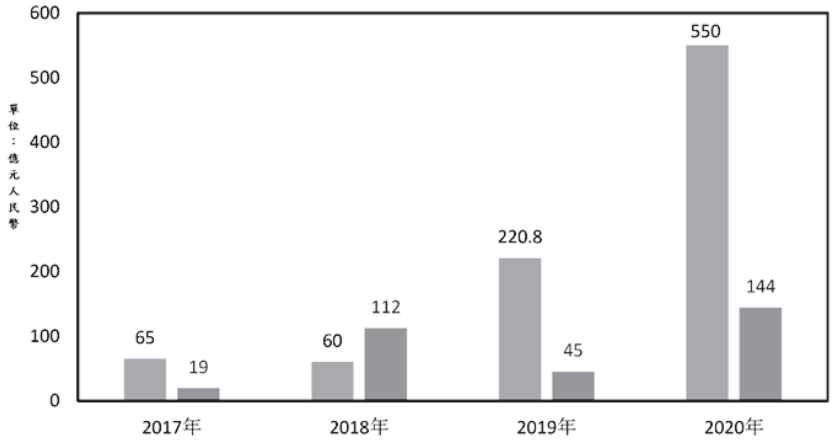

Figure 8-2 China's Third Generation Semiconductor Investment and Expansion from 2017 to 2020

Source: Third Generation Semiconductor Industry Technology Innovation Strategic Alliance, "Third Generation Semiconductor Industry Development Report 2020," *Third Generation Semiconductor Industry Technology Innovation Strategic Alliance*, April 2020, http://www.casa-china.cn/ uploads/ soft/210927/6_1522096971.pdf, p. 47.

Despite a surge in Chinese investment in third-generation semiconductors in the past few years, European and U.S. manufacturers have the first-mover advantage over China in terms of technology and products, e.g. 80 percent of SiCs come from the U.S. Since the design of third-generation semiconductors is not as difficult as that of logic ICs,[46] the majority of third-generation semiconductors are still produced in the form of integrated device manufacturers (IDMs) and original equipment manufacturers (OEMs) are not common. As such, China must surmount difficulties in process equipment and chip production (substrate → epitaxy → design → fabrication → packaging) if it is to overtake in technology. In epitaxial technology, for example, SiC requires stable control of material matching at high temperatures (2,600 degrees Celsius) to produce usable single-crystal SiC. Furthermore, due to the slow growth rate of third-generation semiconductor crystals, the high cost resulting from low process yields, the long-term downward

[46] The majority of third generation semiconductors are manufactured in micrometer or sub-micrometer processes.

trend in the IC prices,[47] and the leading market players strategically waging price wars to drive potential Chinese competitors out of the market, all these factors will impede the development of China's third-generation semiconductor industry.

V. Conclusion

Amidst the lingering COVID-19 outbreak and U.S.-China tensions, China's economic performance are barely satisfactory, thanks to a low base period last year. Xi Jinping intends to take advantage of the internal circulation economy to counteract the effects of the global economy hovering at a low level and to build domestic technological autonomy to prevent the U.S. government from restraining China's economic and high-tech progress by clutching at the throat of technology. Judging from the economic growth figures, the Chinese government's efforts are not in vain, but the results may not have emanated from the policies it has pushed, highlighting its policy mistakes or shortcomings. For example, the internal circulation policy, which relies on consumption to drive domestic economic growth, has seen a decline in the already sluggish domestic demand in August, due to the required rectification and reform of Ant Group and Tencent and other platforms since last year, as well as the Evergrande incident in September this year and power rationing, among other restrictive policies. As a result, the hope that domestic consumption would lead to economic growth did not materialize. Instead, the external circulation of exports continued to do well, as foreign buyers were unable to find alternative sources of goods.

When it comes to technological autonomy, China is still following the past path of developing consumer products, starting with the low-end market, then gradually upgrading products through research and development, and finally penetrating the high-end market. Nevertheless, the manufacture of chips involves large-scale capital, process experience and the coordination of upstream and downstream

[47] The price of third-generation semiconductors has risen rather than fallen in the past two years amid the COVID-19 pandemic and U.S.-China tensions, which is an exceptional case.

patents from various countries. Although China's policies have mostly backed up its semiconductor industry and hit some of its policy targets, excessive subsidies have led to a fierce race for government resources rather than focus on their own businesses, resulting in a plethora of failures, and despite some adjustments to the 14th Five-Year Plan's IC funding program, its effectiveness has yet to be tested over time. Moreover, China's technological progress has also been disrupted by the lack of access to advanced foreign equipment and materials following the U.S. technology embargo. Despite the fact that its development of traditional silicon-based chips has been hampered, China is now focusing its hope on third-generation semiconductors and is looking to overtake its rivals, but the technical difficulties and pricing practices of foreign manufacturers may not be overcome overnight. However, while China can count on its large domestic market, abundant and inexpensive technological talent, and substantial government subsidies to develop, it remains to be seen whether China's third-generation semiconductor industry can grow as rapidly as its silicon-based products in the past, given the constraints imposed by the U.S.