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Artificial Intelligence Development: Implications for China*

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ABSTRACT

The Chinese government has developed ambitious policies for global leadership in the field of AI and economic growth. While China has made progress in several areas, it is lagging in developing its microelectronics sector. The purpose of the article is to advance the understanding of the relationship between technologies to manufacture integrated circuits (ICs) and the production capabilities of the Chinese AI industry. To this end, using the latest data on high-tech chip manufacturing in China from 2010 to 2019, this study examined the influence of import restrictions on the manufacture of high-tech equipment and the current state of IC production, and analyzed the opportunity to overcome dependence on foreign equipment and technologies. The results of the research show that (a) China has enough resources for production, especially in comparison with the leading chip-making countries; (b) since 2016, there has, indeed, been a decline in the actual value of the chip market in China, which confirms the difficulties in connection with the imposed restrictive measures; and (c) there is a gap in the production chain in China precisely at the stage of creating the latest-generation chips. To fully harness and scale the power of AI to achieve sustainable economic growth, Chinese policymakers should align import substitution strategies with appropriate business models and incentive structures.

INTRODUCTION

The consistent implementation of reforms and industrial policies has made China a global player in a historically insignificant period. Foreign investment has played an important role, for which China has become the largest destination.

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The end of the initial economic boom led by cheap manufacturing, worsened by the 2008 crisis, triggered a change in direction towards a domestic-consumer orientation for the Chinese economy. This process required higher wages for ordinary workers, and "Chinese screwdriver" has risen in price. The export-oriented economy based on the large-scale production of cheap and low-quality consumer goods is no longer growing. The time has come for innovative industry and modern technologies that produce goods with high added value.

The indicated necessity to reorient the Chinese economy coincided with the development of the global AI sector. By the mid-2010s, AI had become an innovative trigger that boosted the growth rates of leading economies (Furman and Seamans, 2019).

Experts in Chinese studies often define July 2017 as a "Sputnik Moment" (Lee, 2018) for developing the AI sector (Ding, 2018). We suggest that this moment, following the Chinese specifics, took a whole decade. Sections in government-innovation strategies have been devoted to national AI, smart sensors, robots, and augmented-reality technologies since the mid-2010s.

In 2015, the "Made-in-China 2025" program started, with USD 300 billion allocated to developing the high-tech sector (Zenglein and Holzmann, 2019). The program's goal was to intensify R&D in the creation of new materials, 5G telecommunications, and the expansion of robotics. Special attention was paid to the development of AI technologies. In 2016, the Government initiated the “Internet Plus” Artificial Intelligence Initiative to foster AI development to be in line with global AI technology and industries. Finally, in July 2017, the State Council launched the "New Generation Artificial Intelligence Development Plan”. We believe that this document is extremely ambitious. Today, this is a defining point in conceptualizing China's approach in the competition for global AI leadership. Like a plan for military combat, the program defines everything necessary for victory: strategic goals and the timing of their achievement, the detailed bureaucratic mechanisms, approved volumes, and sources of finance (Gill, 2020). Perhaps only the consequences for state and local officials for disrupting its implementation are not indicated. In terms of speed, we believe that the development of Chinese innovations has not been so rapid since Deng Xiaoping.

It may seem that China's goal of becoming a global center for AI by 2030 has every chance of becoming a reality. However, there is one very significant obstacle. There is a considerable lag in developing the microelectronics sector, namely, in producing semiconductors. The situation worsened after the US imposed prohibitive measures on technological, industrial, and trade cooperation with China in this area (Bown, 2020). The Chinese government responded by changes in industrial policy in technological innovation, which began in 2019 (Allen, 2019). Its main goal is to overcome the dependence of semiconductor production on foreign technologies. To solve this problem, Beijing allocated an additional USD 1.2 billion and created an unprecedented level of government preference for companies involved in their production (Roberts et al., 2021).

However, the situation has not yet been reversed. The question of creating a Chinese prototype of the American microcircuit (chip) Nvidia Tesla M40 GPU is not even on the agenda. Furthermore, without the production of national high-speed and highly energy-efficient chips, the path to the AI Olympus will remain closed. Therefore, what prevents China, with its experience in developing the high-tech sector, from overcoming the backwardness in developing semiconductor-based products?

This study aimed to determine the reasons that led to this lag. The paper focuses on assessing Beijing's actions towards implementing the plan for AI global leadership and identifying problems that block it. The paper focuses on the reasons that led to the backwardness and technological dependence in IC manufacturing as well as assessing the prospects for revitalizing this sector.

The methodological approach of this study employed the econometrics modeling method. It involved the formulation of two basic models combined into a system of recursive equations based on an available dataset covering the performance of high-tech chip manufacturing in China from 2010 to 2019.

1. LITERATURE REVIEW

Technology is considered the driving force for national economic development (Autio, 1998; Malecki, 1991), and the role of innovation is emphasized by many economists, from Schumpeter (1954) to Romer (1994). The growth theory and endogenous growth theory (Grossman and Helpman, 1994; Romer, 1994) have highlighted the strategic role of technological advances in economic development. Industrial innovation plays a crucial role in a country's national innovation system (NIS) and can come from different sources, such as in-house R&D, and domestic and international technology transfer (Sun, 2002).

For emerging economies, technology transfers from advanced countries (Young and Lam, 1997) and benefits from foreign investment (Hu and Jefferson, 2002; Du et al., 2020; Rutkauskas et al., 2021) have been regarded the most appropriate sources of innovation, as these economies lack the capital and scientific talent required to perform advanced studies.

Nevertheless, the importance of in-house R&D is critical for developing countries if they do not want to fall behind the innovation leaders and want to sustain evolutional growth. First of all, the ability to perform in-house R&D can enhance absorptive capabilities (Malerba, 1992; Nelson, 1959; Rosenberg, 2009) for monitoring up-to-date external technologies and scientific opportunities. By successfully implementing and converting them, domestic companies will finally be able to build their innovative capabilities. At the same time, it is natural for developing countries to transition away from technological dependency on other countries and, thus, promote domestic technological development (Katz, 2001; Lemoine and Ünal-Kesenci, 2004; Lema and Lema, 2012; Pasaribu et al., 2021; Wojciechowski & Korjonen-Kuusipuro, 2021).

Though technological innovations foster economic development, their complex structures and multi-level relationships do not guarantee that all in-house R&D results in breakthrough innovations or market success. In many countries, the path from in-house R&D to technological innovation and market success is hampered by institutional, regulatory, and organization failures (Sun, 2002).

The consistent implementation of reforms and industrial policies has made China a global player in a historically insignificant period. Foreign investment has played an important role, for which China has become the largest destination. Since 2005, many scientists have started questioning whether China has gone too far in using this strategy and have found mixed empirical evidence regarding the role of FDI on domestic firms and in-house R&D (Sun, 2012, Sułkowski et al., 2021).

Since the mid-1990s, China has tried to build an industry-oriented national innovation system with a decisive role played by government institutions. It has significantly increased the investment in science and technology (S&T) and launched "S&T take-off".

China's strategy allowed it to enter the race for global AI leadership at a speed unprecedented in the history of innovation (Lee, 2018) and even outperform its closest rival, the United States, in some areas. However, there is still a considerable lag in developing the microelectronics sector, namely, in producing semiconductors, which requires strong in-house R&D and breakthrough innovations (Li et al., 2019).

The Chinese government relied for too long on the technology-borrowing strategy. In the case of semiconductor-based products, borrowing meant unprecedented imports from flagship vendors.

Until 2018, the role of national technologies in this innovative gambit had not been decisive. The question of their nationality was certainly considered, but it was not critically essential. In addition, our attention is drawn to the fact that, despite the main strategic goals for developing national AI, the importance of modern national technologies, quality, and the technological level of the semiconductor base were not fully considered.

3. RESEARCH DESIGN

3.1 Data Sample

The study focused on confirming hypotheses based on data for the turnover of high-tech products and indirect indicators characterizing the conditions for the development and production of microchips. The production of semiconductors involves various stages related to different segments in terms of complexity and production technologies. As a result, it is necessary to consider the possibility of using resources, production capacities, and technologies, as a consequence of the development of scientific thought in specific areas. After the production and/or purchase of the various components, they are expected to be combined into the final product. This is followed by an analysis of the production possibilities regarding the quantity of products produced and the market needs for these products.

Thus, to realize the maximum possible coverage of this cycle, data for the country under study were collected from statistical resources and aggregated into a single database. As a result, the sample was artificially limited by the time frame from 2010 to 2019. Additionally, due to Gauss–Markov limitations, most of the data had to be discarded regarding their significance in the process of correlation analysis.

3.2 Methodology

We assumed that the development of technologies to produce chips and semiconductors directly depended on the demand and production capabilities of the Chinese high-tech industry. This is due to the following. A) The restriction of import opportunities severely limits and restrains the production of high-tech equipment in the absence of a sufficiently developed production of high-end products. B) The need to meet consumer demand must be accompanied by an increase in scientific activity in the region. As a leading country in high technologies, China must achieve a high level of scientific and technological progress and be able to set market trends. Therefore, we posit the following research hypothesis:

Hypothesis 1 (H1). *There should be a decrease in activity at one of the stages of chip production in China, before, after, or at the stage of semiconductor production.*

Hypothesis 2 (H2). *In the case that all resources and capacities are available, the volume of chip and semiconductor production depends on industrial demand.*

3.3 Data Description and Variables

The dataset covers China's high-tech IC manufacturing records from 2010 to 2019. We gathered data from sources including the OECD database and statistical reports of different agencies such as the Semiconductor Industry Association. All the data included in the database were considered and analyzed. To test these assumptions, we formulated two basic models and then combined them into a system of recursive equations based on data availability.

$$\begin{cases} Y_{1i} = \beta_1 + \beta_2 X_{1i} + \beta_3 X_{2i} + \varepsilon \\ Y_{2i} = \beta_1 + \beta_2 Y_{1i} + \beta_3 X_{3i} + u \end{cases}$$, where:

Y_{1i} – SCp_i, Y_{2i} – ICp_i, X_{1i} – $PATi/RDpers_i$, X_{2i} – SCc_i, X_{3i} – $ICgm_i$.

Table 1 lists the definitions of the variables used in the empirical procedure, while above, we discuss why we chose these variables.

Table 1. Description of variables.

Variable	Description
ICp	Integrated circuit (IC) production, US dollars, billions, current prices
RDexp	Research and development expenditure (% of GDP)
Manuf	Manufacturing, value added (% of GDP)
GDPp	GDP per person employed (US dollars, PPPs)
RDpers	Quantity of researchers in R&D per million people
AIf	Quantity of AI startups
ICm	Integrated circuit market, US dollars, billions, current prices
SILIp	Silicon production volume, metric tons
ICgm	Integrated circuit market, global, US dollars, billions, current prices
Pat	Patents statistics in China
EXP	Semiconductors' (SC) export from China, US dollars, billions, current prices (2014-2019)
IMP	Semiconductors' import in China, US dollars, billions, current prices (2014-2019).
SCp	Semiconductors' production, US dollars, billions, current prices
SCc	Semiconductors' consumption, US dollars, billions, current prices
VCinv	Venture capital (VC) investments, US dollars, billions, current prices (2014-2019)
VCd	Quantity of VC deals (2014-2019)
Funds	Venture capital funds raised, US dollars, billions, current prices
SCf	Quantity of semiconductors' firms

Table 2 and Table 3 present the means and standard deviations, while Table 3 presents the Pearson correlation coefficients for our variables.

Table 2. Descriptive statistics.

	Mean	*Median*	*Std. Dev.*	*Skewness*	*Kurtosis*
ICp	13.36	12.35	5.812668	0.530178	2.129457
ICm	89.3	80	30.37927	0.665621	2.064804
ICgm	349.9	335.5	60.4565	0.857776	2.397819
Manuf	29.60194	29.67406	1.876458	-0.05878	1.521493
Pat	880,660.4	884,693.5	388580	-0.16783	1.606504
RDexp	1.96132	2.013745	0.185605	-0.44738	1.767663
RDpers	1098.029	1089.098	127.2669	-0.04712	2.252631
SCc	153.66	159.1	40.58522	-0.30868	2.00315
SCp	49.34	44.95	26.04958	0.4514	2.088538
Silip	4995	5000	456.6849	-0.63313	3.682924
AIf	86	59.5	74.82869	0.865227	2.366798
GDPp	22,703.97	22452	4668.108	0.14019	1.827895

Table 3. Correlation matrix.

	ICP	*ICM*	*ICMGL*	*MAN-NUF*	*PAT*	*RDEXP*	*RDPERS*	*SCC*	*SCP*	*SILIP*	*AIF*	*GDPP*
ICp	1.00											
ICm	0.99	1.00										
ICgm	0.98	0.99	1.00									
Manuf	-0.88	-0.90	-0.83	1.00								
Pat	0.93	0.93	0.87	-0.96	1.00							
RDexp	0.90	0.88	0.82	-0.95	0.97	1.00						
RDpers	0.86	0.83	0.79	-0.79	0.93	0.87	1.00					
SCc	0.91	0.90	0.83	-0.96	0.97	0.98	0.85	1.00				
SCp	0.93	0.94	0.89	-0.96	0.93	0.93	0.75	0.96	1.00			
SILIP	-0.15	-0.14	-0.18	-0.02	-0.10	0.05	-0.27	0.04	0.08	1.00		
AIf	0.86	0.87	0.86	-0.77	0.86	0.77	0.86	0.76	0.75	-0.52	1.00	
GDPp	0.94	0.94	0.89	-0.97	0.96	0.97	0.81	0.98	0.99	0.04	0.78	1.00

Table 3 shows a high correlation between the chip production and all the other factors, except for silicon mining, which partly confirms our assumption that there are more than enough resources for production in China, especially in comparison with the leading chip and IC manufacturers.

4. RESULTS

4.1 Dependency on IC Imports

Despite all the efforts, the dependence of the Chinese high-tech sector on foreign, primarily American, technologies remains very high. The "leader" is the microelectronics sector (Chen and Dong 2020). This dependency is especially severe for national IC production. The realities of the current scene for Chinese innovation are technological backwardness and a reliance on licensed obsolescent hardware. This is happening amid the growing consumption by Chinese companies of microelectronic products, primarily chips and microprocessors (chipsets) made on their basis. Moreover, this growth is becoming ever more widespread from year to year. According to The General Administration of Customs of the People's Republic of China (GACC), in 2020, the IC import value in China was USD 350 billion, a 14.6 percent increase compared to the previous year. As of February 2021, the import value was already 34.3 percent higher in a year-on-year comparison (Figure 1).

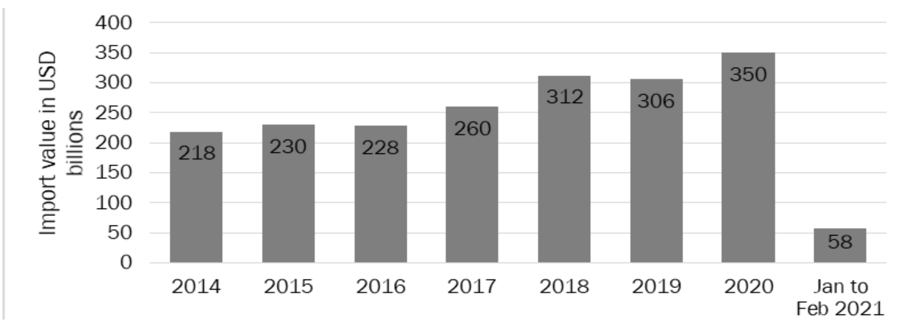

Figure 1. IC import value in China from 2014 to Feb 2021 (in USD billions). *Source:* Trading economics, China customs.

The reason for such rapid growth in IC imports is the fact that, without them, it would be impossible to produce household appliances or smartphones and tablets, develop the AI sector, and explore the surface of the Moon. The production scale has moved ICs from single-piece electronic products to the category of industrial raw materials, with a very contrasting price gradation. The price is influenced by the dimensions of the chip (nanometer (nm)), which are determined by their production technology. The smaller the size and the higher the speed and energy efficiency of the chip, the higher its cost.

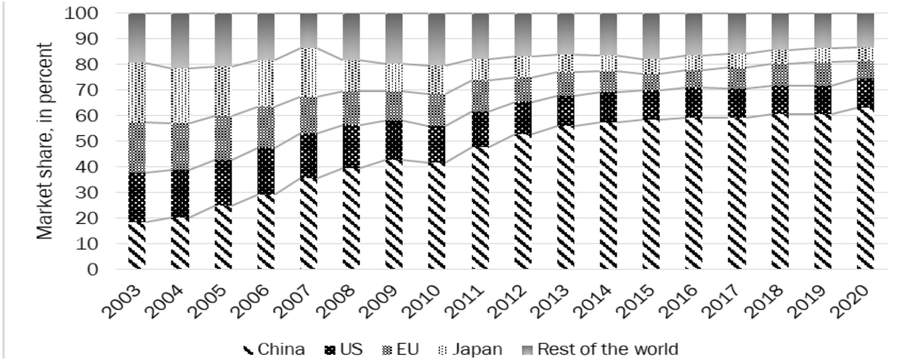

Figure 2. IC consumption market share worldwide, from 2003 to 2020, by region. *Sources:* PwC; SIA; IC Insights, Gartner; CCID Consulting.

Today, for high-tech products, both for the domestic market and for export production, China consumes approximately 61% of the world's ICs (Figure 2). At the same time, by the end of 2020, Chinese chipmakers mainly produced chips in low and medium price ranges. These were 130 and 100 nm microcircuits—widely used in the auto industry, household appliances, and smartphones. The IT and AI industry need chips with 65 nm and below. Moreover, their production in China today does not exceed 20% of that required. Fewer than 2% of national chipmakers produce 43 nm medium-speed and energy-efficient microcircuits. Their quality does not satisfy even national vendors (primarily ZTE and Huawei) that work on IT and AI solutions. National chipmakers produce flagship (5 nm technologies) microchips crucial for AI development as experimental single-part samples.

Figure 3 depicts the dynamics of chip production depending on all the indicators that cover the same time range from our dataset.

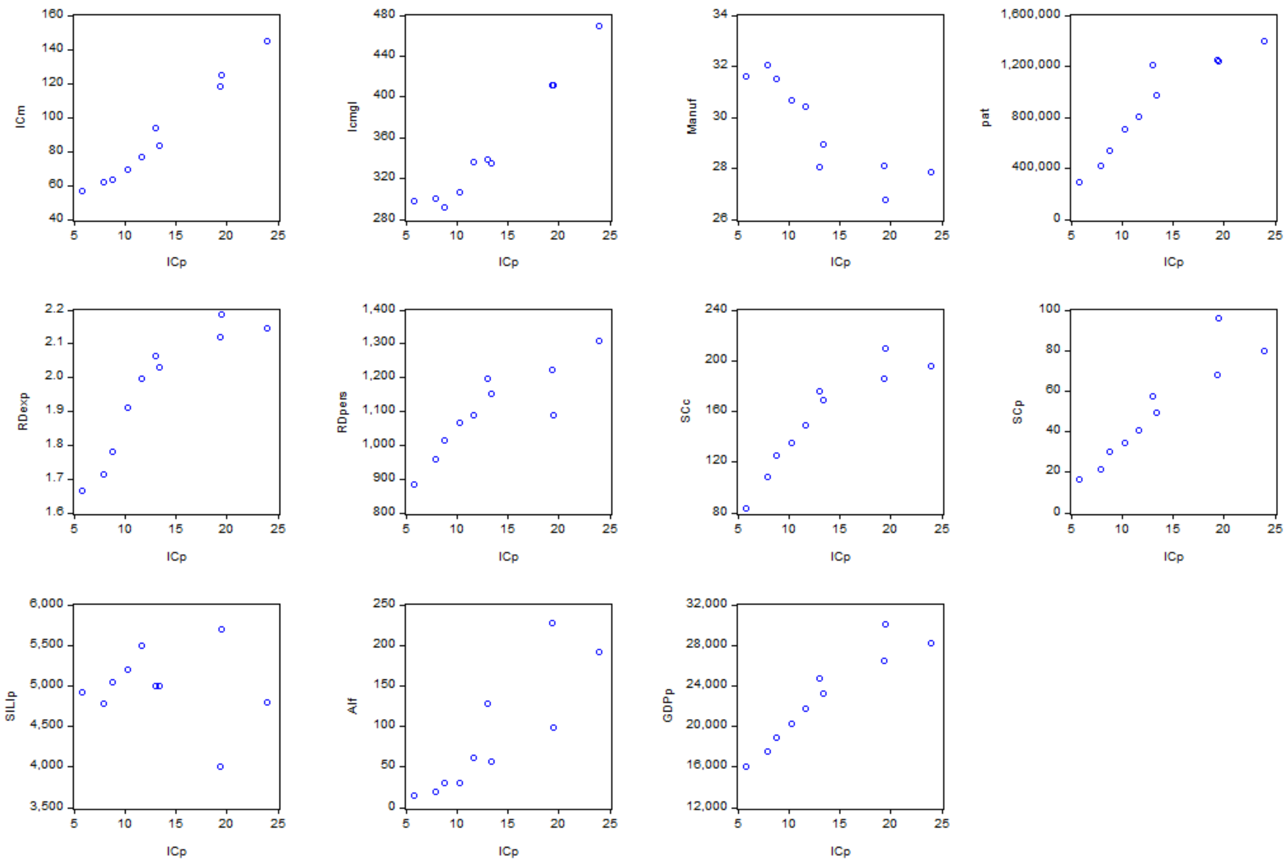

Figure 3. Scatter graphs of chip production vs. all other indicators.

As we can observe, almost all the factors have a strong dependence on chip production. Only manufacturing has reverse dependence, which can hint at the lag of technological development with respect to world trends. However, it should be noted that the Chinese government attempted to overcome the lag in the national semiconductor industry. We considered Chinese innovation strategies and can conclude that there is a clear understanding of the drastic situation at the government level.

To overcome the lag in microelectronics and the dependence on IC imports, in 2014, the government set up the China Integrated Circuit Industry Investment Fund (CICF) and issued the «Guidelines to Promote National Integrated Circuit Industry Development”. This was, perhaps, the first attempt to determine the prospects for national flagship microchip manufacturing. In May 2015, the «Made-in-China 2025» program came into effect. In this document, the national semiconductor industry was assigned quantitative tasks to overcome the dependence on IC imports for the first time. The share of national chips was supposed to, by 2020, be 40% of that required and, by 2025, reach 70%. We noted that the program's priority is, again, scaling up production with no attention paid to the quality issue. The model, traditional for China, has been preserved—quantity prevails over quality. In total, China planned to spend USD 1.980 billion on developing the semiconductor base in 2015. A primary role was given to venture capital, and in 2016 alone, about USD 2.6 billion in private investment was attracted. By 2018, the government accepted more than 70 investment programs intended for IC factories' construction and the acquisition of foreign companies and startups.

In addition to direct financial investments, the Chinese government also uses indirect methods, such as income tax incentives—the traditional scheme of supporting manufacturers in China. The government began to reduce taxes for chipmakers in 2012. However, the list of companies eligible for the deduction was insignificant until recently and included only 12 companies. By 2020, the list of beneficiaries included more than 1300 enterprises. The tax preferences have a gradation that depends on the quality of the products. Companies producing chips based on the non-modern 130 nm technology are exempt from taxes for two years. Chipmakers producing microcircuits using 65 nm technology and below are exempt for five years. As a result of these actions, China improved its position in IC manufacturing, increasing its share in global production to 9%. In 2018 alone, the profit of Chinese chipmakers amounted to USD 26.1 billion. The presented figures may look optimistic for the external market. The situation in the domestic IC market has practically not changed. In 2020, chipmakers were able to meet internal needs for only 20.1% of the required microcircuits. If the growth rates for chip productivity continue, then, by 2025, national chipmakers will be able to meet only 25% of the domestic market demand. This situation is rather unfortunate. Despite all the government efforts, the targets of the "Made in China 2025" program for national microelectronics will not be met. Our investigation also shows that this growth covers the lowest price segment of semiconductor-based products. The results of evaluating the system of recursive equations are presented in Table 4. The r-squared is 0.097 in the full model, suggesting that our findings are reliable.

Table 4. The basic model’s estimation using LS methods

Regressors	*Least squares*
PAT/RDpers	0.001136**
	(0.000381)
LOG(SCc)	0.869141***
	(0.371269)
R2	0.988147
Obs.	10
Regressors	*Least squares*
LOG(SCp)	0.459919*
	(0.08433)
LOG(ICgm)	1.179912**
	(0.29393)
R2	0.975861
Obs.	10

Standard errors in parentheses. *** p < 0.1, ** p < 0.05, * p < 0.01

The situation is aggravated by the quality of Chinese chips and chipsets. The situation in the domestic chip market for the IT and AI industry is very worrisome. Despite an additional USD 29 billion allocated in 2019 by the government as a subsidy to companies involved in the production of CPUs, GPUs, network cards, and modems, the production growth was only 3% (Zenglein and Holzmann, 2019). Furthermore, this is happening amid the rapid growth of China's AI sector in connection with the COVID-19 pandemic. By the beginning of 2021, Chinese chipmakers were only planning to comprehensively master 45 nm technologies. For even such a non-modern technological level, the cost of the equipment, technology, and training of specialists is USD 2.39 billion per production line (McClean, 2021). Additionally, it is believed that the main problems with IC production began with the introduction of prohibitive measures by the United States on technological, industrial, and trade cooperation with China (Shattuck, 2021).

The technological confrontation only lasted two years, and the Chinese IC problem is a systemic issue. We suppose that the Chinese leadership hoped to continue to use the achievements of innovative leaders in semiconductor production despite certain efforts. The actions of the White House government dealt a severe blow to the prospects of Chinese IT vendors, leaving them without modern components. Traditional importers, leading American semiconductor giants, notably, Intel, Qualcomm, Xilinx, and Broadcom, were banned from technological interaction and the supply of high-performance chips. However, the apogee of the problems was the introduction in May 2020 of changes to the Foreign Direct Product Rule. It practically deprived China of the opportunity to cooperate with Taiwan Semiconductor Manufacturing Co (TSMC). The estimates support our hypothesis that the industrial demand and the development of science are contributing to the increase in chip production in China. To confirm this and identify the impact of the restrictive measures, we estimated the growth rates for supply and demand in China's chip and semiconductor markets by evaluating trend patterns. The results are presented in Figure 4 and Table 5.

Table 5. Trend model estimation output

SCp	0.188752* (0.007772)	ICp	0.141957* (0.009746)
SCc	0.092926* (0.008745)	ICm	0.103969* (0.012999)

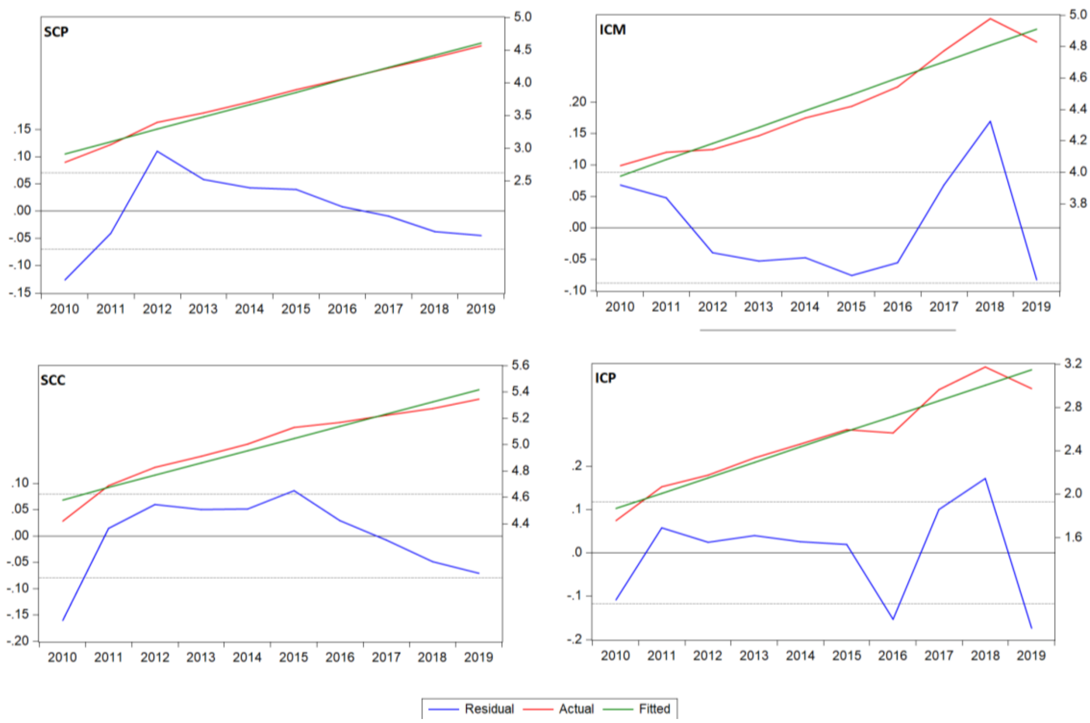

Figure 4. Chinese semiconductor market indicators: graphs

Standard errors in parentheses. * p = 0.0000

As we can see from the graphs in 2016 and 2018, indeed, there has been a decline in the actual values of the Chinese chip market indicators, which confirms the difficulties in connection with the imposed restrictive measures. Nevertheless, the obtained coefficients reflecting the calculated growth rates show that, in the reviewed period, the production of semiconductors had twice the growth rate compared to the demand for them. The growth rates for chip production were 1.5 times higher than their consumption. Thus, it can be assumed that, in China, there is a gap in the production chain precisely at the stage of creating the latest-generation chips.

The pessimistic situation looks more complicated, as these percentages are not represented by national companies. Chipmakers, headquartered in China, produced only 6.1% (USD 7.6 billion) of all the sales in the local market. Branches of foreign firms located in the country (TSMC, SK Hynix, Samsung, and Intel) made a decisive contribution.

Under pressure, the Chinese government and vendors in the IT and AI sectors are forced to pay. However, we assume that this amount may simply not be increasing, even for them. Moreover, it may not only be a matter of finances. To meet modern AI requirements, the Chinese semiconductor industry must catch up with the flagships that have proceeded for 13 years. The question of whether it will be able to make this leap forward remains open.

4.2 Current Trends in Chip Production in China. SMIC Case Study

The only way to overcome the catastrophic situation in China's semiconductor sector is to implement rapid and large-scale import substitution.

Import substitution should cover the entire production chain: equipment, technologies, and the scientific and business competencies of personnel. The situation is complicated because it is a race against time. Introduced by the Biden administration, more arduous trade restrictions for high-tech goods did not allow China much time to act.

To overcome the mentioned problems, it is practically impossible to use the strategy of innovative borrowing. Beijing needs to develop new innovative strategies to rescue the national microelectronics sector. We suppose that one of them could be the financial and legal support of national companies with economic and industrial success in AI. We define this form of interaction as the BAT strategy derived from Baidu, Alibaba, and Tencent, the leading players in this field.

We must pay tribute to the fact that the first steps for implementing this strategy have already been taken. In 2019, amendments to the "AI Program" were adopted at a State Council of China meeting. First, it was planned to allocate an additional USD 1.4 trillion, adding new members such as Huawei, Xiaomi, and SMIC and 87 other high-tech national unicorns. Now, the primary goal is to solve the problem of IC import substitution.

However, as always, the coin has two sides. The positive one is, ultimately, national production. The equipment is supplied by the national giant Semiconductor Manufacturing International (SMIC). The technology is overseen by the research company Shanghai IC R&D Center, the leader in the Chinese processor architecture market. The negative side is that chips of this size were relevant 13 years ago, indicating significant backwardness in Chinese specialists' technological competence.

In addition, SMIC, under the auspices of the government, in 2020, began the construction of a semiconductor plant in Shanghai implementing 28 nm technology. State support is even more ambitious. The Chinese Association of the Semiconductor Industry alone allocated USD 48 billion for the construction and technological launch. Another USD 40 billion for construction will be allocated by the National Investment Fund of China. The first products are expected to roll off the chipmaker's conveyor belt at the end of 2022.

The Chinese government, implementing the BAT strategy, hopes to close the gap in the microelectronics sector to fit the “Made-in-China 2025” program. However, Huawei's entry into the team of chipmakers "from scratch" will take several years. Complicating the situation is the absence, even in the plans, of mastering the fifth flagship technology, without which the further development of the national AI sector may stop.

We cannot provide a comforting forecast regarding Huawei's ability to exit without losses, even considering the colossal government assistance. There may simply not be enough time left for the BAT strategy to succeed. However, there is still the question of AI talents and their scientific and practical competencies necessary to implement these breakthrough technologies. The preparation and training of such specialists will also take a long time.

The only way for Beijing to rapidly overcome the backlog in IC production is not to create new unicorns but to strengthen the existing ones. However, today in China, there is only one successful example: SMIC.

SMIC was a successful company producing reliable mid-range chips primarily for the domestic market. The quality of its 14 nm chips left much to be desired and did not satisfy even domestic consumers. The incipient race for technological superiority certainly gave the chipmaker a chance to get into the top league of IC manufacturers. However, the company could realize this chance only with the financial and legal support of the state. It came to the aid to rapidly grow SMIC to the level of a world-class semiconductor unicorn. Since 2018, more than USD 9.6 billion has been invested in SMIC through the China Integrated Circuit Investment Industry Fund and Yizhuang Guotou.

In addition, the company received government approval to issue an additional 1.69 million shares for sale through the Shanghai STAR Market (a kind of Nasdaq). Following the announcement of a relisting through the Big Fund, Beijing has invested more than USD 2 billion in SMIC. As a result, by the beginning of 2021, this operation brought the company an additional USD 7.8 billion. Following changes in its charter, adopted under pressure from government regulators, 60% of the investments newly received by SMIC are directed to internal R&D. In 2020 alone, this amount was USD 4.3 billion: 40% went to the improvement of the 14th technology; 55%, to developing 7 and 5 nm technologies. The remaining 5% is for accelerated personnel training to improve their scientific and practical competencies.

The result of such large-scale financial injections was the rapid growth of both the production and technological preferences of the company. Today, SMIC is the main hope of the Chinese AI sector. The company is the only one in the country with a productivity of 6000 300 mm wafers per month, and it produces 14 nm chips of world-renowned quality.

We examined how China raised a top unicorn in IC production from an average company little-known in the world market. The Chinese government has poured billions of dollars into helping SMIC to master advanced technology.

The considered trigger strategies for the recovery of the Chinese microelectronics sector could change the situation globally. However, another outcome may also develop. Technology does not stand still. China may not have enough time to catch up with the innovation leaders who have spent more than 13 years developing and commercializing their flagship chips. However, the AI market is changing so rapidly that, while China's chipmakers keep up, they can start using completely new principles to improve processors. Reductions in the sizes of elements cannot be infinite. Chinese microelectronics has every chance not to remain in the status of catch up but to leap to a new period of AI technological leadership.

DISCUSSION AND CONCLUSIONS

This study reveals that, amid the current innovative realities, Beijing has relied on AI as one of the most important triggers for stimulating national economic growth. In addition to unprecedented financial support, the government has developed a particular strategy to stimulate the AI business ecosystem (BAT strategy).

As a result of these actions, China was able to bring its AI sector on a par with the innovative leaders. Moreover, in terms of funding, the number of scientific and applied developments, and the scale of the business ecosystem, national chipmakers were able to increase their share of semiconductor production.

This study also confirms the findings from previous studies that the optimistic portrayal of China's AI sector is not entirely realistic. The United States has begun "reforming" the innovation field. The US' future actions may bury Chinese plans for the AI leadership and completely halt its development.

The analysis presented in this study confirms that China's problems were formed due to the erroneousness of the chosen strategy based on an original way of creating innovative products with "Chinese characteristics". From the outset, China's innovation strategies for creating its new technologies have defined the path of "borrowing, digesting, absorbing, refining and renovating".

Such results, on the one hand, confirm the observation that advanced technologies cannot really be imported from foreign countries but can only be developed internally. This raises concerns about the efficiency of China's R&D activity. It turned out that, without appropriate institutional reforms, tech talents, new management practices, and new business model resources that have been devoted to S&T development generated less significant scientific and economic contributions than expected.

The results of this study can be extrapolated to similar problems in the high-tech industries of developing countries. The study expands the understanding of how much industrial policy in innovation technology requires a diversified approach in the conditions of globalization, accelerating digitalization and the redistribution of knowledge, information, and labor.

The question of whether China can become an AI leader by 2030 is still open. The main reason is the ability to overcome the 13-year gap in producing advanced semiconductor-based products. The study shows that it has not been possible to date despite all the state and private business efforts. Moreover, without technological independence in advanced semiconductor production, AI leadership is impossible.

However, we will also discuss another option. The study has highlighted a particular specificity of the global IC market. Today, it is perhaps the most eventful. For its implementation, exclusively high-tech production is used. The most complex technological processes, the equipment that implements them, and the scientific and practical competence of the service specialists are costly. Government patronage is a decisive factor for its development. Naturally, in the current conditions, the price of an entrance ticket to such a market for a new player is prohibitively high. For those entering the market later, all the R&D costs must be paid. These are colossal funds that more than one company cannot provide on its own. At the present stage of technology development, it is possible to start from scratch, entering the world semiconductor space only with the support of the state.

Moreover, the state can provide it only for strategic reasons. The Chinese government and private investors have postponed these strategic decisions for an unacceptably long time. The prevailing opinion was that the R&D costs of national microelectronics should and could be avoided.

However, it must be said that the Chinese government postponed financial support for semiconductor R&D companies until "better times". This is evidenced by the approximately USD 218 trillion accumulated by the Big Fund and the Association of Semiconductor Manufacturers by 2018. Private investment funds, in pursuit of rapid commercialization, simply refused to invest in fundamental research. An analysis of investment flows shows that, up to 2019, it was easier to receive loans for companies that were engaged in implementation projects but not in fundamental research.

It becomes apparent that the way to the flagship semiconductor heights for China is hindered by its experience in the high-tech sector. The strategy of borrowing the incremental technological and hardware achievements of world leaders, which is the basis for China, simply does not work today.

Today, the Chinese government seems to be doing everything possible to make the national IC sector jump over its head. Will Chinese semiconductor flagships be able to seize this opportunity and overcome technological addiction? Furthermore, will the Chinese AI sector have enough time to remove this technological obstacle?

The time factor here may not be at all decisive. Do not forget about the national mental characteristics of innovators from China. The maxim put into upbringing and education plays a cruel joke with them (Lindtner, 2014). The absence of doubt about what those of superior age or status say and do is detrimental to the development of disruptive technologies. The Chinese AI talents lead in the improvement and modernization of borrowed incremental innovations, but there are practically no fundamental breakthroughs. It may so happen that this feature of China will become a stumbling block on the path to its AI world leadership. Breaking this national mentality may be necessary, and there is no such experience in innovation yet.

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