

The Dilemma and Countermeasures of The Value Chain of China's Semiconductor Industry

Huirong Bao ^a, Zhixin Cai ^{b,*}

School of economics and trade, Foshan University, Foshan, China

^a abigailbao9490@163.com, ^b jjkk0901@163.com

Abstract: Semiconductors are the core components of the digital economy, the hub of all digital products and future technologies, and the basic technical support for defense, communications, big data, artificial intelligence (AI) and other industries. As the most thorough and comprehensive industry in globalization, the semiconductor industry contains all the attributes and elements in the global value chain. The close division and cooperation of its global industrial chain is a typical case of the global specialization cooperation division mode. This paper systematically examines the dilemma of China's semiconductor value chain, and puts forward specific policy suggestions for China. China should further promote the transformation of technology application achievements, smooth the domestic and international trade cycle, and expand international semiconductor coordination and cooperation, to enhance the competitiveness of its semiconductor industry and gradually enhance the toughness of the supply chain of the semiconductor industry.

Keywords: Semiconductor industry; Value chain; Global supply chain.

1. Introduction

Chip industry is an important foundation of digital economy, and its development level has become an important basis to measure a country's technology and industrial level. The R&D and production of the semiconductor industry have significant characteristics of economies of scale, so the production of the semiconductor industry has obvious characteristics of vertical specialization. The integrated circuit industry is one of the industries with the highest degree of transnational specialization in the supply chain of the manufacturing sector. The active iteration of chip technology and the innovation drive at the application end have deepened the transnational vertical specialization and division of labor in the integrated circuit industry (Huang Yejing et al., 2022) [1]. Since the outbreak of the new crown epidemic, the global supply chain and supply system have suffered serious impact. The East Asian regional supply chain developed from the traditional "East Asian production network" has experienced serious external impact, and the "new triangle trade model" developed from the traditional "wild geese array model" has also faced a more severe test of the internal and external situation. According to the statistics of the Chinese customs, integrated circuits (HS4:8542) and machines and devices for manufacturing semiconductor single crystal columns or wafers, semiconductor devices, integrated circuits or flat panel displays (HS4:8486) are the two largest categories of goods imported by China from Japan in 2021. Among them, the import of integrated circuit commodities from Japan increased by 21.7% year-on-year; The import of machines and devices for manufacturing semiconductor single crystal columns or wafers, semiconductor devices, integrated circuits or flat panel displays increased by 33.9% year on year. The trade volume of integrated circuits between China and South Korea increased from US \$24.6 billion in 2007 to US \$108.9 billion in 2021, with an average annual growth rate of 11%, 5% higher than the growth rate of bilateral trade between China and South Korea. The trade volume of bilateral integrated circuits between China and South Korea accounted

for 30% of the trade volume between China and South Korea. The import of integrated circuits from South Korea accounted for 20% of China's global imports of integrated circuits. The export to China accounted for 44% of South Korea's global exports of integrated circuits. China has basically formed an integrated circuit industry development pattern of benign interaction with Japan and South Korea, and has basically integrated into the integrated circuit industry system of China, Japan and South Korea. The regional comprehensive economic partnership (RCEP) has officially entered into force since January 2022, bringing significant opportunities for the deepening of economic and trade cooperation and the release of economic and trade potential among China, Japan, South Korea and the entire East Asia region. The official entry into force of RCEP marks the launch and operation of the world's largest free trade area, as well as the establishment of a bilateral free trade relationship between China and Japan for the first time. The development and changes of the integrated circuit supply chain in China, Japan, South Korea and even the whole East Asia region have also ushered in unprecedented new opportunities.

2. Analysis of Supply Chain Vulnerability of China's Chip Industry

2.1. Analysis Based on The Perspective of Global Trade Chain

The semiconductor industry sprouted from the needs of American military industry in the middle of the 20th century, and began to spread to East Asia in the 1980s. Now it has the characteristics of high globalization. According to the American Semiconductor Association, the global sales of semiconductor products reached US \$55.59 billion in 2021, an increase of 26.2% year on year. As the world's major production base of electronic communication equipment and its components, three quarters of the world's wafer production capacity is concentrated in East Asia, where international

trade in integrated circuits is developing vigorously.

At present, the Asian chip trade network composed of mainland China, Taiwan, South Korea, Japan and ASEAN has begun to take shape. East Asia, represented by TSMC, Samsung, SK Hynix and other manufacturers, has more than three-quarters of the world's wafer production capacity. According to the statistics of DIGITIMES, Taiwan's TSMC's market share in the specialized OEM field was 59.5% in 2021. By contrast, the revenue scale of SMIC, the largest wafer foundry in mainland China, is only one tenth of that of TSMC.

Because the design, R&D and production of integrated circuits require a lot of investment, the major integrated circuit manufacturers focus their main division of labor on a specific subdivision of the integrated circuit industry system. Samsung and SK Hynix of South Korea both have strong competitiveness in the field of DRAM and NAND memory. The integrated circuit enterprises in Taiwan, China, led by TSMC, focus on the development of semiconductor contract manufacturing and OEM projects. Japanese enterprises have a strong monopoly in the production of semiconductor silicon wafers and photoresist products. Shinyue chemical industry and sumco, two Japanese enterprises, have a global share of more than 60% of silicon wafers. According to IC insights, a semiconductor industry research organization, in 2020, American integrated circuit enterprises accounted for 55% of the total market sales, while Korean companies accounted for 21%. Taiwan companies accounted for 7% of the total sales, 1% higher than European and Japanese companies, and mainland companies accounted for only 5% of the global market.

From the perspective of the global chip trade chain, it is found that among the top ten semiconductor companies in the world in terms of total revenue in 2021, the United States accounted for 7, South Korea for 2, and Taiwan for 1. Among them, the top ten American enterprises have branches or production bases in East Asia or Southeast Asia, which to some extent reflects the industrial hegemony of the United States in the semiconductor industry and East Asia's efforts to actively participate in the cycle of the semiconductor global value chain.

2.2. Analysis Based on The Perspective of Global Supply Chain

Today, the world has basically formed three supply chain network systems with China as the center in East Asia, the United States as the center in North America, and Germany as the center in Europe. At present, China is the only country in the world that has all the industrial categories in the United Nations Industrial Classification. Among the world's more than 500 major industrial products, the output of more than 220 industrial products ranks first in the world. China almost has the development mode and development needs of the whole industrial cycle of industrial products, so it should have high industrial control. However, the two characteristics of the chip supply chain, namely, the deep degree of interdependence and the high technological threshold, have given birth to the huge power and vulnerability of the chip industry's technological control. The supply chain of the chip industry can be roughly divided into three major links: the upstream "raw materials and production equipment", the midstream "chip design, manufacturing and testing" and the downstream "chip application". The upstream, midstream and downstream enterprises cooperate closely with each other to form a part of the chip industry chain (Li Wei, 2022).

The "tug of war" of the global supply chain system has become the main feature of the current national industrial chain supply chain competition (Wang Bing, 2022). The raw materials and production equipment upstream of the chip supply chain usually have a high technological threshold, and the absolute advantage of relevant production technology is almost occupied by American and Japanese enterprises. Among them, lithography, the core equipment to produce large-scale integrated circuits, has a very high technical threshold because its manufacturing and maintenance require a high degree of optical and electronic industry foundation. At present, only ASML in the Netherlands can produce the most advanced extreme ultraviolet lithography machine in the world.

Table 1. Upstream of chip supply chain: raw materials and production equipment

	Representative category	Representative enterprises with absolute advantages	Country	
Raw material	Silicon wafer	Sumco Corp.	Japan	
	Photoresist	JSR Corp.	Japan	
	CMP polishing material	Dow Chemical Company	USA	
	Mask	Photronics, Inc	USA	
	Sputtering target	JX Nikko Metal	Japan	
	Wet chemicals		BASF SE	Germany
			Ashland	USA
			KANTO Chemical	Japan
	Electron gas		PRAXAIR	USA
			Air Liquide	France
		Taiyo Nippon Sanso (TNSC)	Japan	
Production equipment	Photolithography machine	ASML Holding N. V	Netherlands	
		Nikon	Japan	
		Canon	Japan	
	Etching machine	Lam Research	USA	
	Film deposition equipment	TOKYO ELECTRON LTD.	Japan	
		ASML Holding N. V	Netherlands	
Ion implanter	Applied Materials	USA		

Information source: collected and sorted by the author.

The midstream of the chip supply chain refers to the design, manufacturing and packaging of chips based on the upstream raw materials and production equipment. Among them, chip design has extremely high technical barriers. The United States, Britain and Germany have the absolute advantage of providing templates and logic for chip design. The United States and South Korea have the comparative advantage of chip design. The technological threshold of chip manufacturing is high, and Taiwan, the United States and South Korea have their comparative advantages. The technical threshold of chip sealing and testing is low, and Taiwan, the United States and Mainland China have their comparative advantages. In other words, at present, China's position in the international chip supply chain industry chain is at the middle and low-end level. Only because of logistics,

labor and economies of scale and other reasons, China has obtained comparative advantages in the chip sealing and testing link with low technological threshold, and does not have the horizontal ability to independently develop and produce high-end chips and the consumables required. At present, China's chip supply chain is heavily dependent on foreign countries and is fragile in nature.

The issue of supply chain has become a key issue in the U.S. global strategy and an important part of the "big power competition" strategy (Guan Chuanjing et al., 2022). With the continuous development of globalization, based on the comparative advantages of various countries (and regions), the current world chip supply chain has basically formed a clear industrial chain mode of highly specialized division of labor and global integration and cooperation. The extremely complex process characteristics of chip manufacturing determine that a country cannot monopolize all links of the chip technology chain. Different from the textile, toy and other industries, the chip industry is extremely difficult to replicate and use for reference due to its high technological threshold. Developing economies with "late mover advantage" actively undertake the backward production capacity transferred and eliminated by manufacturers and countries with first mover advantage through "outsourcing" based on development needs. With the help of "transfer" and "outsourcing", manufacturers and countries with first mover advantages further improve production and R&D efficiency, leading to the strengthening of the "oligopoly" pattern of first mover advantage manufacturers and economies in the chip industry and the "low-end lock-in" of late developing economies. The above links have further widened the technological gap between China and emerging economies in chip supply chain related industries.

At present, China is the largest country in chip consumption in the world, and should have a strong buyer's market control ability. However, the unequal control power of the chip industry weakens the actual industrial control power of the Chinese buyer's market, and achieves a seemingly "hegemonic stability" system of the international chip industry. On the other hand, as the world's largest rare earth producer, exporter and applicator, China should have the ability to balance the supply chain of the chip industry by controlling rare earth exports and obtain more bargaining chips. However, the rare earth purification technology involved in chip production still has a "neck sticking" problem, resulting in the reduction of China's actual control over the chip industry. From the perspective of industrial control based on technological power, China is at the middle and low end of the chip supply chain technology chain, so it has chip technology vulnerability; From the perspective of industrial control based on market power, Sino US trade and technological frictions and some overseas sales and service sanctions against Chinese enterprises initiated by some western countries based on ideological issues are also the embodiment of China's low control over the chip industry and the fragility of the chip market; From the perspective of "supply chain resilience", due to the restrictions of western countries' industrial hegemony in the field of technology and sales channels, China's chip supply chain has the characteristics of strong exposure, strong sensitivity and poor recovery.

3. China's Response to The Vulnerability of Chip Supply Chain

3.1. Promote the Transformation of Technology Application Achievements

We should continue to strengthen the protection of intellectual property rights, create a new mechanism and platform for enterprises, universities, scientific research institutes and enterprises involved in the chip industry to promote the high-quality development of factor income trade, guide China's chip industry to the high-end of the global value chain, speed up the research of key core technologies and major technical equipment, create more products and technologies with a voice, and further promote the transformation of technological application achievements. Government departments should give more support to R&D institutions in terms of tax concessions for R&D in the chip and semiconductor industry and talent system training, pay attention to following the objective law of the iterative development of the chip industry, formulate more chip subsidy policies in line with international rules, and gradually promote the import substitution of domestic chip production equipment. Continue to adhere to innovation driven, simultaneously strengthen and promote basic and applied research, and guide the industrial chain to become bigger and stronger. We should continue to encourage enterprises to increase R&D investment, and promote innovation to lead technological progress and economic development. We will continue to promote the development of new infrastructure such as 5g and cloud computing, give play to the "mature role" of effective investment in economic and social development, and better serve the transformation of chip technology applications.

3.2. Smooth the Circulation of Domestic and International Trade

China has become the world's largest chip consumer and exporter. It should make good use of its comparative advantages, smooth the domestic and international chip trade cycle, and strive for more active advantages in the international chip trade market. We should continue to create a market-oriented, legal and international business environment, facilitate convenient business exchanges, build an efficient and coordinated modern logistics industry system, strengthen the policy guidance to support advanced manufacturing industries such as the chip industry, establish and improve the chip supply chain security system with better services, actively guide the flow of more resource elements to the chip industry, and build a good ecological system conducive to the development of China's chip industry. Marketization is still the only way to upgrade China's chip industry (Xu Bo, 2022). Government departments should actively play a guiding role in the upgrading and iteration of the chip industry, build a mechanism platform for more chip enterprises' technical exchange and cooperation, promote more chip multinational companies to realize technology spillovers in China, enhance the toughness of the domestic semiconductor industry chain system, and consolidate and enhance the dominant position of China's chip market.

Chip industry goods usually have the characteristics of high transportation accuracy requirements, high value of goods and fast customs clearance efficiency guarantee, which puts forward higher requirements for breaking through the

bottleneck of transportation and unblocking the upstream and downstream logistics circulation of the chip industry. We can take advantage of China's advantages in infrastructure, market scale and industrial clusters to explore a new mechanism for adding "chip free trade zone" in the existing domestic free trade zone, constantly innovate the multimodal transport mode, and give more trade facilitation measures to chip industry enterprises in investment activities, business negotiations, industrial cooperation, entrepot trade, offshore trade and other fields, so as to reduce the indirect trade costs of intra-regional trade caused by efficiency loss and time delay.

3.3. Expand International Chip Coordination and Cooperation

Further promote the high-level opening-up of the chip industry, and calmly respond to various risks and challenges of the international chip industry with a more open and inclusive attitude. Nowadays, the world economic globalization is threatened by more and more deep geopolitical conflicts, and the game between China and the United States and even the eastern and Western camps in the economic, political, cultural and other fields is increasingly fierce. At the current stage, maintaining concentration and expanding opening-up are the most fundamental and effective solutions for China to deal with "anti-globalization", and the need to practice multilateralism and maintain world stability. We should actively strive for and steadily expand international chip coordination and cooperation with Europe, East Asia and other regions, and actively carry out business activities between enterprises and private chips. The "rules of origin accumulation" reached by RCEP is conducive to reducing the threshold of tariff preference, promoting intra-regional trade cooperation, stabilizing and strengthening the regional industrial chain supply chain, and the original materials of all members in RCEP region can be accumulated. For example, when determining the "origin qualification" of China's exported chips, parts imported from Japan, South Korea and other RCEP member countries can be "accumulated" into the "ingredients in RCEP", bringing real tariff concessions to enterprises, which is greatly conducive to the optimization of the layout of the industrial chain within the entire RCEP. Similarly, RCEP's cumulative rules of regional origin and "direct transportation" provisions should be actively used to strengthen connectivity and mutually beneficial cooperation with RCEP countries in the chip industry, and build a "chip Silk Road". We should give better play to the important role of non-governmental cooperation and enterprise cooperation in China's "going global", continue to strengthen cooperation with Japan, South Korea, ASEAN, the European Union and other "swing countries and economies" in the chip industry chain, supply chain, value chain and innovation chain, play the role of "ballast stone" in economic and trade cooperation, jointly oppose trade protectionism and hegemonism, and actively practice multilateralism. Actively connect with high-level economic and trade rules to enhance the soft power of China's chip competition. Benchmarking table CPTPP, DEPA and other new international economic and trade rules continuously

connect the "Corridor Initiative" along the "belt and road" with the production network in East Asia, create a more fair, inclusive, inclusive and complete East Asian chip industry chain, and strive to resist the negative impact of the "decoupling" of science and technology between China and the United States through economic and trade policy tools, so as to continuously improve the international competitiveness of Chinese chips.

Acknowledgements

Key projects of social investigation reports and academic papers in Social Sciences (xsjj202414zsa01) "Digital trade rules and value chain position of semiconductor enterprises"

References

- [1] Huang Ye-jing, Sun Mei-lu, Dou qian-bin. Cross-board Supply Chain risk of IC industry under Perspective of Trade Networks Analysis, *Asia-pacific Economic Review* [J], 2022, 3:119.
- [2] Milberg,W.,D. Winkler. "Trade Crisis and Recovery- Restructuring of Global Value Chains", Policy Research Working Paper [J], No 5294, The World Bank, 2010.
- [3] Sheng Bin, Chenxin Jin, "The Evaluation of RCEP Agreement: Market Access and Trading Rules", *China & World Economy*, Vol. 30, No. 5, pp. 49–74.
- [4] Tang Yihong, Zhang Pengyang, Enhancing the Controlling Capability of the Industrial Chain and Supply Chain Transfer— Research on the Transfer of China's Manufacturing Industry Chain, *China Opening Journal* [J], 2022, 4:7.
- [5] Li Wei, Li Yuyi, Decoding the U.S. Hegemony in the Semiconductor Industry: Conceptualizing the Political Economy of Industrial Power, *Foreign Affairs Review* [J], 2022, 39(01):22.
- [6] White G F., *Natural Hazards, Local, National, Global*, London: Oxford University Press, 1974, p.33.
- [7] Wang ling, Zhu Zheyuan, Literature Review on Vulnerability in Supply Chain, *Soft Science* [J], 2011, 25(09):136.
- [8] Svensson G., "A Conceptual Framework for the Analysis of Vulnerability in Supply Chain", *International Journal of Physical Distribution & Logistics Management*, 2000, 30(9): 731-749.
- [9] Christopher M., "Managing Risk in the Supply Chain", *Logistics & Supply Chain Management*, Prentice-Hall, 2005.
- [10] Henry Farrell, Abraham L. Newman, "Weaponized Interdependence: How Global Economic Networks Shape State Coercion", *International Security*, Vol.44, No.1, 2019, pp.42-79.
- [11] Xue Lan, Wei Shaojun, Li Yan, He Jun, Luo Changyuan, Yu Zhen, Yang Rongzhen, The CHIPS and Science Act of US and Analysis of Its Impacts, *International Economic Review* [J], 2022(06):9.
- [12] Zhi Wang et al., "Re-examining the Effects of Trading with China on Local Labor Markets: A Supply Chain Perspective", NBER Working Paper no.24886, August 2018, revised on October 2018, https://www.nber.org/system/files/working_papers/w24886/w24886.pdf.