How to Improve the Resilience of Supply Chain of China's Semiconductor Industry Under Trade War

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Abstract. Semiconductor industry is one of the most important indicators to gauge a nation's scientific and technological strength and economic development. Under the context of China-US trade war, the China's semiconductor supply chain is facing with severe disruption risks. This paper analyses the internal and external environment where China's semiconductor supply chain is situated, and studies the relevant important influential factors for supply chain resilience. A new systematic evaluation method is proposed to quantitatively analyze the resilience of China's semiconductor supply chain by establishing an index evaluation system using the degree of exposure, sensitivity, and ability to recovery as the three main measurements. Through the improved grey correlation method, the correlation degree is employed as the index to express the influence of these three factors on the resilience of semiconductor's supply chain. As a result, the overall resilience of China's semiconductor supply chain is evaluated as relatively low degree, especially in the segments of key SME, EDA software and talent pool building. To deal with the foreign monopoly in these segments, some policy implications is raised like releasing government initiatives from downstream supply chain, fostering important technologies in a competitive market, and improving talent training system, innovative management system and mechanism.

Keywords: semiconductor · supply chain resilience · trade war · disruption risk · grey correlation method

1 Introduction

Semiconductor industry, as the basis of high-end electronic equipment manufacturing in China, is undoubtedly an important indicator for a country's scientific and technological strength and economic strength. The supply chain of China's semiconductor industry has been seriously disrupted due to the trade war with the US since 2018. China's semiconductor industry relies highly on the support of the global supply chain and lacks alertness for risks. As a result, at the micro level, China's semiconductor supply chain lags in segments including core intellectual property (IP), electronic design automation (EDA), key equipment fabrication and raw materials. Since China's semiconductor industry relies heavily on imports due to relatively weak capability for technology innovation, China's supply chain integration capability is poor in the semiconductor industry. All of these have created huge disruption risks in China's semiconductor industry's supply chain.

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Supply chain disruption is inevitable, with many causes, a wide range of consequences, and ongoing uncertainty regarding how and when supply chains can become more resilient [1, 2]. Theory and past research on supply chain resilience generally focuses on the development of resilience from unexpected shortages in supply or spikes in demand. For example, research has shown that experience with supply disruption can improve responses to future supply disruption, and that learning from demand disruption is also sometimes transferable [3–5]. Yet, when disruption involves high impact spikes in both supply and demand, theory and past research provide little insights for enabling resilience.

Given the likelihood of other high impact disruptions in the future, understanding supply chain resilience to disruption has academic and practical value. In building the conceptual foundation, we draw one stablished theory and literature regarding supply chain disruption management [1, 6, 7] and supply chain resilience [3, 4, 8, 9]. It is well established that supply chain disruptions can take many forms [10–12]. Yet, the past literature has not explicitly distinguished between turbulence involving the volume of supply or demand shocks, which we consider the scale of supply chain disruption, and turbulence involving the nature or breadth of supply or demand shocks, which we consider the scope of supply chain disruption.

To relieve the impact of disruption risks, one of the most effective measures is to build a resilient supply chain. China's semiconductor supply chain resilience refers to the extent to which the normal operation of the supply chain is hindered when the supply chain is affected by a combination of internal and external factors, and the ability of the supply chain to resume normal operation. We identify three characteristics of China's semiconductor supply chain resilience: degree of exposure, sensitivity, and ability to recovery, and analyze them separately. Then, a model to evaluate China's semiconductor supply chain resilience using the three characteristics will be established through empirical evidence, and finally the corresponding strategies will be proposed. The research aims to contributing to the theoretical foundation of supply chain resilience by examining the implications of scale and scope in high impact disruptions by employing the degree of exposure, sensitivity, and ability to recovery as the three main measurements. Through the improved grey correlation method, the paper uses the correlation degree as the index to calculate the influence of these three factors on the resilience of semiconductor's supply chain respectively as an attempt to identify the important influencing indexes. This research aims to contribute to improving the resilience of supply chain of China's semiconductor industry to confront with the challenge of trade war and other disruption risks.

2 Supply Chain Resilience Literature

The concept of resilience was derived from the study of natural environments, where all systems may have varying degrees of resilience, and it has become an integral part of the field of system security. The concept of resilience is so universal that it has been gradually applied to the study of social and economic systems, such as tourism systems, financial systems, and supply chain systems. In the study of supply chain resilience, it was widely accepted that a complex supply chain, the single source of supply and over-dependence on suppliers and customers of an enterprise directly affect the business activities of the enterprise, especially when the competitors of the supply chain vertically integrate it, the enterprise will face the risk of supply chain disruption [3, 13, 14]; they also proposed that the existence of high resilience in the supply chain is due to the complexity and uncertainty inherent in supply chains, and it is these characteristics that affect the probability and the degree of supply chain disruptions. Ho pointed out that external factors driving supply chain resilience include major changes in areas such as ecological, economic, and political environments; sudden catastrophic events, such as earthquakes and tsunamis can also lead to high supply chain resilience and increase the risk of supply chain disruptions [13]. Rajesh and Kamalahmadi et al. suggested that when infrastructure cannot support the development of advanced technologies and other operational activities, the resilience of the supply chain can be adversely affected; they pointed out that the transparency, flexibility, and visibility of the supply chain can be effective indicators to detect the degree of the supply chain resilience [8, 15].

Supply chain resilience has been examined in multiple business contexts. Since several systematic literature reviews show that supply chain resilience has been defined and measured in many ways, a starting point for theory development is definitional clarity [4, 12, 16, 17]. Resilience can be defined as a firm's capacity to survive, adapt, and grow in the face of turbulent change [18]. Supply chain resilience is about balancing exposure to risk while not overly eroding profits, regardless of small scale or catastrophic disruption, by focusing on improving the adaptability of global supply chains, collaborating with stakeholders, and leveraging information technology to assure continuity [19].

When supply chain risks are known and recurring, this is associated with low impact disruptions, and cost efficiency becomes the focus. With low impact disruptions, there is a value of building supplier flexibility [20], as building redundancy in the supply chain is costly. In contrast, when supply chain risks are unknown, unpredictable, and are potentially long term in nature, these are high impact disruptions. Natural disasters, trade wars and global pandemics involve substantial risks. With a risk of high impact disruptions to supply chains, incrementally improving cost efficiency is no longer the focus. High impact disruptions require firms to invest significant resources to build supply chain redundancy and resilience.

Costly high impact disruptions can justify the investments needed to develop supply chain resilience [1, 10]. This involves understanding points of vulnerability, the adaptive reconfigurations of global value chains and broader thinking on building supply chain resilience [3, 6, 11]. The reality of risks from high disruption due to natural disasters, trade wars and global pandemics drive managerial and academic attention to supply chain resilience.

Building resilience is necessary to avoid dire operational and financial consequences of high impact disruptions. High impact disruptions can devastate unprepared businesses and their stakeholders [12, 21]. In addition, building resilience can also lead to positive consequences and new opportunities). The dynamic capabilities of supply chain resilience can lead to innovation. If partners in the supply chain can collaborate to co-create supply chain resilience, the potential payoffs are high for suppliers and customers. Innovation can be involved in the co-created capability of anticipating disruption, in the agility of response, and in the capability to recover and learn [4, 16].

3 Current Situation of Supply Chain of China's Semiconductor Industry

3.1 External Environment

Under the influence of intensifying trade tensions and the COVID pandemic, the global semiconductor market has been hitting rock bottom. Moreover, the uncertainty of industrial development has also increased despite the continuous advancement of technology. In 2020 global semiconductor industry revenue was $412.1 billion, down by 12.1% compared that to the last year. With the global economic slowdown and rapid market changes brought by international trade tensions, the global semiconductor market has been weakened ever since, which has a great impact on China's semiconductor industry, which lacks advanced technologies and depends on imports to acquire those core semiconductor-related technologies (such as those used in EDA and lithography) [22]. According to the 2020 semiconductor market data released by the Global Semiconductor Industry Association (SIA), the sales of global top ten semiconductor companies is $ 229.133 billion, accounting for nearly 55% of the overall sales of the entire industry [23]. The top four companies are Intel, Samsung Electronics, SK Hynix and Micron Technology. According to the distribution of the enterprises (Table 1), the U.S. companies maintain its leading role in the industry [24]. Among the top ten companies, five come from the U.S., two from Korean companies, two from European companies, and one from Japanese companies. From these data, we can see that in the semiconductor supply chain, the key segments are concentrated in semiconductor companies from the United States, South Korea, Japan, and other advanced countries. Those companies enjoy significant advantages in segments China lags, resulting in China's resilience problems in the semiconductor supply chain.

The widely spreading of digitalization and information technology in China makes China a major consumer of semiconductors, but the global semiconductor market share

Table 1. Top ten Semiconductor Companies by Global Market Share, 2020.

Ranking	Supplier	Sales (USD billion)	Market Share (%)	Country of origin
1	Intel	657.93	15.7	United States
2	Samsung Electronics	522.14	12.5	Korea
3	SK Hynix	224.78	5.4	Korea
4	Micron Technology	200.56	4.8	United States
5	Broadcom	152.93	3.7	United States
6	Qualcomm	135.37	3.2	United States
7	Texas Instruments	132.03	3.2	United States
8	STMicroelectronics	90.17	2.2	United States
9	Kioxia	87.97	2.1	Japan
10	NXP	87.45	2.1	Netherlands

occupied by China's semiconductor companies is only about 3%. China's semiconductor industry not only lacks competitiveness but also faces the danger of being isolated out of the global semiconductor supply chain at any time.

3.2 Internal Environment

The upstream semiconductor manufacturing supply chain provide various materials and manufacturing equipment, in the midstream is semiconductor design companies, and the downstream is semiconductor manufacturing and packaging companies. Materials segment has the most market segments than other segments of semiconductor industry. Various materials are used throughout the process of semiconductor manufacturing (wafer manufacturing, chip manufacturing) and chip packaging and testing. According to Semiconductor Equipment and Materials International (SEMI), the 2020 global semiconductor materials industry has reached $46.9 billion, and the market volume in China has been growing rapidly since 2019 (a 12% year-on-year growth in 2020), indicating the potential demand of a huge market [25].

In recent years, with the adjustment of national policies and changes in domestic market demand, China's semiconductor industry has developed rapidly in the material segment and its production has become more independent from foreign supply. Many internationally competitive enterprises have been developed in China [23, 26]. However, according to the data released by the Ministry of Industry and Information Technology, on the supply side, given the current huge demand for semiconductor materials in China, the production and R&D capabilities in key materials are still weak. For most large enterprises, 32% of the key materials cannot be obtained domestically and 52% relying on imports (Table 2). This situation of being 'stuck' has seriously restricted the healthy development of China's semiconductor industry.

Semiconductor manufacturing equipment integrated technologies used in the whole semiconductor manufacturing process. With these equipments, anyone can produce the products that meet the technological requirements in the industry. That is, 'a generation of products should be produced by the corresponding generation of equipment'. For a new product to be manufactured, there should be a new equipment introduced. Therefore, the fabrication of semiconductor equipment is also a decisive in the entire semiconductor manufacturing supply chain.

4 Methodology of Measuring Supply Chain Resilience in China's Semiconductor Industry

4.1 Influential Factors

The degree of exposure is the extent to which the semiconductor manufacturing supply chain is exposed to the pressure and risk brought by external environment. The degree of exposure of semiconductor manufacturing supply chain is negatively related to the resilience. That is to say, the greater the exposure, the lower the resilience is, and the more vulnerable the semiconductor manufacturing supply chain is to the external factors.

Table 2. Comparison of production levels of major materials and key equipment between China and foreign countries.

Key equipment and materials	International market	Domestic market
Mask Aligner	Asmac (ASML) 7nm/5nm with NA = 0.33 EUV technology	90nm Mask Aligner for the front-end semiconductor manufacturing manufactured by Shanghai Microelectronics (SMEE) IC has achieved mass production
Etching machine	Si-based etching is mainly monopolized by Lam and AMAT	SMIC and NWC with strong competitive strength
Film Equipment	CVD is monopolized by Hitachi, Lam, TEL, AMAT, PVD is monopolized by Lam and AMAT	North China and Shenyang Tuojing with competitive strength
Ion implanter	70% for AMAT and 18% for Axceils	CSC and Keston have entered the market
Cleaning equipment	Mainly from DNS, Lam, TEL, etc.	Shengmei Semiconductor, North China, to Zhichun Technology has a certain international competitiveness
Testing Equipment	Mainly monopolized by two companies, Teradyne and Edelman	Changchuan Technology and Precision Measurement Electronics can provide self-developed products
EDA	Mainly three companies: Cadence, Synopsys, Mentor (referred to as the EDA triumvirate)	Some of the tools are available from companies such as UW-JT and SMIC
Silicon Wafers	Mainly monopolized by Japan, Germany, South Korea and other semiconductor companies, occupying 95% of the global market share	The main silicon wafer products are 6–8 inches, high-end product development and production is in the initial stage
Photoresist	The market is basically monopolized by Japanese companies such as JSR, Tokyo Chemical, Sumitomo Chemical, and Rohm and Haas in the United States	The self-sufficiency rates of G and I line photoresist for 6-inch wafers are about 60% and 20% respectively, and the high-end products are completely dependent on imports.

(*continued*)

Table 2. (*continued*)

Key equipment and materials	International market	Domestic market
Key equipment and materials	International market	Domestic market
Mask	Companies from the United States, South Korea, China and Taiwan and other semiconductor account for more than 80% of the market share	Dominated by foreign companies such as Photronics of the United States and Toppan of Japan, the domestic market share is very low
Process Chemicals	Dominated by companies from Germany, the United States, Korea, Japan and other companies, accounting for more than 85% of the market share	Products with relatively low level of technology, only a few domestic products have reached the international SEMI G4 standard
Electronic Gases	Enterprises from the United States, Germany, France, Japan and other countries enjoy more than 90% of the global market share of electronic gases	85% of the materials need to be imported, domestic products are concentrated in the middle and low-end market
Polishing materials	Mainly monopolized by the United States, Japan and Europe. Among them, Dow Chemical accounts for 80% of the whole market share	Localization rate is about 5%, and 0 for high-end products
Target materials	The global target manufacturing is an oligopoly market, with a few Japanese and American chemical and manufacturing groups dominating the global target manufacturing	The industry is taking shape, but the high-end products and processes are still monopolized by foreign countries
Packaging materials	The main global suppliers of packaging materials are concentrated in Taiwan, Korea, and Japan	More in the low-end segment, with technology, cost and other aspects still lack competitive advantage

Sensitivity of semiconductor manufacturing supply chain refers to the sensitivity of the supply chain to external influences in its operation due to the imperfections, mismatches, and shortcomings within the supply chain. It reflects the degree of damage caused by adverse events to the semiconductor manufacturing supply chain. Resilience and sensitivity are also negatively related, that is, the stronger the sensitivity, the lower its resilience and the higher the degree of risk of meltdown of the semiconductor manufacturing supply chain due to external influences.

Recoverability of the semiconductor manufacturing supply chain refers to the ability of the supply chain to adapt to and recover from adverse events, which reflects the risk prevention ability of the semiconductor manufacturing supply chain against adverse impacts. Recoverability and resilience are negatively related, that is, when the supply chain is adversely affected by external environmental factors, if the intensity of the impact falls within the range of the supply chain's own recoverability, the supply chain can resume normal operation with relatively high performance.

According to relevant research, this paper proposed the characteristics of the industry and the characteristics of resilience, 3 indicators (the degree of exposure, sensitivity, and recoverability) are selected based on 18 criteria as shown in Table 3.

4.2 Model Construction

According to the three indicators of the semiconductor manufacturing supply chain resilience index system, that is the degree of exposure, sensitivity and recoverability, an evaluation model of semiconductor manufacturing supply chain resilience was established.

$$\mathrm{Resilience(T)} = \mathrm{Recoverability\ (T3)} - \mathrm{Exposure\ (T1)} - \mathrm{Sensitivity\ (T2)} \tag{1}$$

where the evaluation formula for each indicator is expressed as:

$$\mathrm{T_k} = \mathrm{W_k^*(X_k)} \quad \mathrm{k} = 1, 2, 3 \tag{2}$$

where $\mathrm{T_k}$ is the value of overall evaluation for the indicator k;

$\mathrm{W_k^*}$ is the value of the normalized weight of each indicator for the indicator k;

X_k is the average value of the scores of each indicator for the indicator k.

The grey correlation analysis can measure the degree of closeness between the factors and judge the overall degree of strengths and weaknesses described by a multi-level integrated index system. Since the semiconductor supply chain is a rapidly developing and constantly changing system, therefore, in the multi-factor analysis system, the dynamic development trend should be emphasized, and the influence of each factor on the development trend of the system should be explored. The grey relational analysis method can intuitively reflect this dynamic through geometric curves.

After obtaining the decision matrix, a modified grey correlation analysis is used to find the numerical relationships among the subsystems (or elements) of the system by determining the reference series that reflect the characteristics of the system behavior and the comparison series that affect the system behavior. The specific steps are as follows:

The decision matrix for m indicators and n experts is $\mathrm{X} = (\mathrm{X_{ij}})_{\mathrm{m}\times\mathrm{n}}$. Applying the improved gray correlation method to determine the weights of each indicator, and the specific calculation steps are as follows:

1. The highest scores of the experts for each indicator are used to form a comparison series X_0 as the comparison sequence for the gray correlation method:

$$X_0 = (X_0(1), X_0(2), \cdots, X_0(m)) \tag{3}$$

Table 3. Evaluation index system for supply chain resilience of China's semiconductor manufacturing.

Target & Indicators		Criteria
China Semiconductor Manufacturing Supply Chain Resilience	Exposure R	Ratio of foreign suppliers for key equipment R1 Ratio of foreign suppliers for key materials R2 EDA software self-development capability R3 International market share of semiconductor products R4
	Sensitivity S	Domestic market share of semiconductor products S1 Revenue of new products S2 Number of related patents yearly S3 Spatial aggregation degree of supply chain S4 R&D spending in semiconductor industry S5
	Recoverability E	Growth rate of R&D facilities E1 Growth rate of semiconductor manufacturing companies E2 Growth rate of semiconductor packaging and testing companies E3 Growth rate of semiconductor design companies E4 Training system for talents in semiconductor industryE5 Government funding E6 Tax incentives E7 Intellectual Property Protection E8 Market growth potential E9

2. Find the average value $\mathrm{X_i}$ of the scores of n experts on each indicator where Y_i is the sum of n experts' scores for the i-th index.

$$X_i = Y_i/n \tag{4}$$

3. Calculate the square of the difference between $\mathrm{X_i}$ and the comparison sequence $\mathrm{X_0}$ to find the indicator distance $\mathrm{B_k}$:

$$\mathrm{B_k} = \frac{1}{\mathrm{q}}\sum (\mathrm{X_0(i)} - \mathrm{X_i})^2 \quad \mathrm{k} = 1, 2, 3 \tag{5}$$

where k denotes the subscripts of the three indicators; q denotes the number of indicators.

1. Calculate the weight W_k of each indicator:

$$W_k = \frac{1}{1 + B_k} \quad k = 1, 2, 3 \tag{6}$$

2. Calculate the normalized weights of each indicator:

$$W_k^* = \frac{W_k}{\sum W_k} \quad k = 1, 2, 3 \tag{7}$$

4.3 Data Collection

We provided experts with qualitative indicators selected from the literature from Li (2020) as well as quantitative indicators with specific values, such as some industrial data. Then the experts evaluated the indicators based on a 5-point Likert scale method. Consequently, the results of resilience degree are divided into 3 levels, namely 'low resilience', 'moderate resilience' and 'high resilience'. According to the hierarchical division of resilience, each resilience level was given the same weight. Once the range of resilience indicator is obtained, the resilience level can be calculated based on that, as shown in Table 4.

The indicators in the supply chain resilience evaluation system designed in this paper for China's semiconductor manufacturing are selected qualitatively and quantitatively. The scope covered by the indicator system is large with relevant indicators being obtained from the literature of Semiconductor Industry Development Report (2020), Qian Zhang, Xiaochuan Wang and Ziying Leng, etc. The scored are obtained by a questionnaire using a five-level Likert scale. Relevant experts and scholars are also invited to rate on the quantitative indicators and qualitative indicators.

The professional scholars and industry experts make subjective judgments on each indicator and make corresponding scores. The improved grey correlation algorithm can calculate the weight value of each indicator and the weights obtained in this way can reflect both objective facts and subjective judgments of experts drawing from their experience.

Table 4. Classification of Semiconductor manufacturing supply chain resilience level.

Resilience Ranking range	[0,1)	[1,3)	[3,4)	[4,5)
Resilience Indicator range	< 0.33	0.33 ~ 1.33	1.33 ~ 2.33	2.33 ~ 3
Resilience level	Rare resilience	Low resilience	Moderate resilience	High resilience

5 Results

According to the decision matrix, calculate the comparison sequence X_0 and each average value of m-th indicators respectively, denoted as X_i, and then get the distance between the indicators B_k:

$$\begin{aligned} B_1 &= (0.803, 0.340, 0.230, 0.730) \\ B_2 &= (0.613, 1.250, 0.672, 0.613, 0.613) \\ B_3 &= (0, 0.264, 0.049, 0.043, 0.077, 0.340, \\ &\quad 0.038, 0.340, 0.033) \end{aligned} \tag{8}$$

The next step is to calculate and the weight of the first-level index and normalize it to get W_k^*:

$$\begin{aligned} W_1^* &= (0.206, 0.277, 0.302, 0.215) \\ W_2^* &= (0.214, 0.153, 0.206, 0.214, 0.214) \\ W_3^* &= (0.114, 0.098, 0.118, 0.119, 0.115, \\ &\quad 0.093, 0.120, 0.093, 0.120) \end{aligned} \tag{9}$$

Finally, it is to calculate the combined evaluation values of the three characteristics separately and obtain the final quantitative results of the semiconductor supply chain resilience T:

$$T_1 = 4.260\, T_2 = 1.477\, T_3 = 1.6834 \tag{10}$$

$$T = T_1 - T_2 - T_3 = 1.01 \tag{11}$$

From the empirical analysis, the current resilience of China’s semiconductor manufacturing supply chain is at a low level of resilience. Among the quantitative results of each index, R1, R3 and S5 have the highest level. Through the empirical analysis of the semiconductor supply chain, combined with the ranking interval given in Table 3, it can be concluded that the current supply chain resilience of China’s semiconductor industry belongs to the section of ‘low resilience’.

The evaluation values of exposure and sensitivity show that there is a large room for improvement in segments of equipment, materials, product market share and technology research and development of China’s semiconductor industry, which means China is still at the risk of being cut out of global supply chain and suffers from ‘supply blockage’. The risks in specific segments of the supply chain are not entirely distributed equally, with intellectual property-intensive segments (including Mask equipment, EDA, etc.) being most vulnerable to this technological blockage.

The recovery index value reveals the importance the country attaches to the semiconductor industry. Through years of efforts, the resilience of China’s semiconductor supply chain has remained safe and sound, but as the global supply chain is affected by the ‘anti-globalization’ trend, relying solely on the market and government policies is no longer a best choice. It is necessary to re-identify the risks from the perspective of the supply chain to map out the driving mechanism of each segment through upstream and downstream supply chain, invest more in key segments to enhance the overall resilience of the entire supply chain.

6 Conclusion and Insights

6.1 Conclusion

In this study, the resilience in the supply chain of semiconductor industry has been evaluated. The influential factors for the resilience were explored in the supply chain of semiconductor industry. The resilience degree depends both on proactive and reactive actions. Several factors like single sourcing, low inventory, inflexible and non-reconfigurable production systems, as well as lack of contingency plans declined the resilience. Enhancement of the resilience becomes possible with the help of backup or dual sourcing policies, flexible and reconfigurable production and logistics systems, risk mitigation inventory, coordinated contingency policies, and physical security technologies. Generally, leanness and complexity of the supply chain of semiconductor industry predominantly influence the resilience control framework.

The resilience of supply chain of China's semiconductor manufacturing was evaluated using the improved grey correlation analysis method. First, key qualitative and quantitative evaluation indicators were validated by industry experts. Then, the correlation degree of indicators is used as the weight to describe the quantitative aspect of the supply chain resilience. Finally, a comprehensive evaluation of supply chain resilience is obtained. The overall resilience of China's semiconductor supply chain is evaluated as relatively low degree, especially in the segments of key semiconductor manufacturing equipment (SME), electronic design automation (EDA) software and talent pool building.

6.2 Insights for Enhancement Strategies for Supply Chain Resilience of Semiconductor Industry

Releasing government initiatives from downstream supply chain.

Semiconductors are not only the basis for the development of information and communication technologies, but also the cornerstone to the development of new infrastructure and national defence. Government efforts has been made to the semiconductor industry through various major special projects to build a supply chain system of more advanced technologies and is safer, reliable, independent, and controllable. However, as the supply chain is affected by complex market environment and technological development, downstream companies usually choose semiconductor products of both leading-edge technology and reasonable price, and those products usually come from a perfect ecological production system. For example, although the domestic central processing unit (CPU) has reached a high level of technology, however, domestic CPU has relatively high cost and insufficient ecological production environment. Although the domestic CPU developers had obtained relevant government funding, the technology selection risks the domestic downstream enterprises is still high. Thus, the end products are difficult to find it to the enter the new market. It is difficult to achieve the transformation from 'blood transfusion to blood creation', and even more difficult to form a benign technology and market ecology for semiconductor manufacturing.

It is recommended to change the investment areas targeted by national policies to: supply chain strengthening and ecosystem building; core technology breakthroughs led by key enterprises of the semiconductor supply chain; let national mega-projects for core national interests take the lead role in supporting the product users to choose the domestic semiconductor products, promote the process of localization of semiconductor manufacturing, and achieve the independent control of the supply chain.

Fostering important technologies in a competitive market.

As can be seen from the previous data analysis, the weaknesses in the China's semiconductor supply chain are mainly EDA software and key semiconductor manufacturing equipment (SME), while packaging, testing and other segments are already relatively mature. The strong support for R&D in developing key technologies is in line with the national strategy. According to general market laws, companies are usually driven to innovate by competitive pressures. However, direct support aimed directly at a few core enterprises may affect the development of SMEs and is not conducive to fostering an environment in which disruptive technologies emerge. Therefore, competition and innovation should be encouraged in the more mature industries such as packaging and testing, and special arrangements should be made for 'backup' enterprises and technologies to avoid 'monopoly' and the formation of technical rent-seeking in the market.

Improving talent training system and innovative management system.

According to statistics, Chinas' current semiconductor industry has less than 400,000 employees. If the semiconductor industry reached 1 trillion in total revenue in 2020, at least 300,000 workers should enter the industry. So, there is a huge demand for talents in China's semiconductor professionals. Colleges and universities should break dominant pattern for graduates in which most of whom end up pursuing academic career rather than becoming in engineers. Moreover, universities should pay attention to cooperation with enterprises in cultivating talents in the specific fields, to meet the immediate need of society for high-skill workers in the semiconductor industry. At the same time, independent innovation through R&D and entrepreneurship in the field should also be encouraged in the universities.

When firms are located around the core end products, the leading enterprises can form industrial clusters, and should drive the synergistic development of small and medium-sized enterprises, as well as making efforts in industrializing the technological innovations. At the same time, enterprises should also strengthen the cooperation with advanced technology enterprises outside the cluster to achieve higher level of informatization. As for the management system and mechanisms building, the government should take the leading role in the process and encourage relevant enterprises to participate in the decision-making process, establishing semiconductor industry, demonstration zone for technological innovations, forming supply chain alliance among leading semiconductor enterprises, effectively mobilizing multiple production factors, creating conducive production conditions and sustainable innovation cluster ecosystem, and improving the independent learning and innovative capability of the entire industry through knowledge sharing and technological guidance.

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