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Overcoming fragility factors in the development of Taiwan's semiconductor industry through resilience construction

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Abstract

Advanced semiconductors have so far been the foundation for the development of applied technologies such as artificial intelligence, 6G communications and electric vehicles, as well as national defense security. Many countries regard the development of the semiconductor industry as the focus of national interests and national security. According to a report from the British newspaper "The Guardian", Taiwan already dominates almost 100% of the global chip industry. However, due to the existence of fragile factors such as geopolitical influence, dependence on imports of certain key raw materials and equipment, gaps in technical information between upstream and downstream industries, and concerns about information leakage, in addition to intensifying multilateral tensions, Taiwan's semiconductor industry is also faced with technological challenges, market and resource allocation and other pressures. For Taiwan's semiconductor industry, which dominates the chip market, to maintain leading competitiveness in a turbulent situation, it needs to effectively deal with fragile factors and formulate industrial development policies for the next stage.

This study extensively collects information related to Taiwan's semiconductor industry, trying to analyze the vulnerability factors of industry development through a deep understanding of the semiconductor industry, and combines the vertical macro, meso and micro levels with the horizontal socio-ecological resilience, ecological resilience and engineering Derivation of the concept of

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resilience, and then systematically constructing pattern, using policy expertise to analyze coping strategies for vulnerability factors. The research results will provide important insights and strategic direction suggestions for Taiwan's semiconductor industry in its continued global operations, to stabilize Taiwan's semiconductor industry's key position in the global semiconductor industry value chain.

Keywords: *Taiwan semiconductor industry, geopolitics, vulnerability factors, resilience, global value chain.*

1. Introduction

The current international situation is in a state of tension and has not yet stabilized from the chaos caused by the COVID-19 epidemic, that is, the Russian Ukrainian war that broke out in February 2022 and the Israeli-Palestinian conflict that began to worsen in November 2023. With the global situation full of uncertainty due to epidemics and wars, governments and companies around the world have begun to increase their requirements for supply chains. Strategic industries such as semiconductors are the focus of industry focus (Yao Shengxiong, 2024). When the international situation continues to be tense , in order to maintain a survival advantage, countries often use international sanctions as an important tool of foreign policy (Lenway, 1988; Selden, 1999) . International sanctions are a widely used tough diplomatic technique (Gutmann, Neuenkirch & Neumeier, 2023) to induce foreign countries, companies or individuals to change their behavior (Meyer et al., 2023).

In recent years, with the tense relations between China and the United States and the escalation of mutual sanctions (Witt, 2019a), the two sides have adopted a number of sanctions tools to restrict each other's economic development, and the scope of countries to which these sanctions tools are limited is not limited to the United States and China. , also includes third-party countries and companies (Meyer et al., 2023). In the context of geopolitical tensions and global technology competition, the United States and China have increasingly regarded semiconductors as national strategic resources, highlighting the importance of the semiconductor value chain to industrial development. The country's grasp of the advanced process technology, product innovation, and supply chain core of the sales market for semiconductors will have a critical impact on the global economic system, political strategy, trade relations, and industrial layout.

However, past literature has mainly focused on the impact of geopolitical tensions on global supply chains and the adjustment strategies of multinational companies, but there is a lack of relevant research on Taiwan's semiconductor upstream, midstream, and downstream companies to respond to geopolitical risks and adopt effective supply chain management strategies. , such as identifying key influencing factors, balancing supplier strategies for regional diversification, and establishing risk prevention mechanisms, still require in-depth research.

Overall, the semiconductor industry has been impacted by the Sino-US technology cold war. Semiconductor development has become a national defense and security issue that all countries attach great importance to. The country's mastery of semiconductor advanced process technology, product innovation and the supply chain center of the sales market can influence the global economic system, political strategy, and trade. Relationships and industry and supply chain layout have a key impact (Tao et al., 2023; Gao et al., 2023). Therefore, in the context of the treacherous and ever-changing international policies of the United States and China, studying the impact factors of mutual sanctions between the United States and China on the supply chain of Taiwanese semiconductor companies is of great importance and special significance to corporate operations and national development.

2. Exploration of existing data

2.1 Definition of terms

2.1.1 Geopolitics

The geopolitics mentioned in this article refers to the influence of a country's geographical location, terrain, climate, resource distribution and other factors on international politics, inter-state relations and power structure. Geopolitics will affect a country's economic behavior, diplomacy and security strategy, and the country's economic development and position in the global market will affect its role in geopolitics.

2.1.2 US-China international sanctions

The U.S.-China international sanctions mentioned in this article refer to the economic, trade, political or other forms of punitive measures implemented by one country against another country to prompt it to change its behavior or achieve specific goals. This is an important tool of foreign policy. Sanctions typically include economic restrictions, financial sanctions, trade embargoes and assets froze.

2.2 Proposition of research questions

Witt (2019a) and Witt (2023) and others pointed out that the US-China technological cold war has led to a pattern of deglobalization and decoupling. Weber, Schneider (2020), Gutmann (2023) and Meyer (2023) and others pointed out that the two sides-imposed sanctions on each other. Policy details also affect the company's operational decisions. This study aims to explore the impact of geopolitical tensions caused by mutual sanctions in the U.S.-China trade war on the supply chain management of Taiwan's semiconductor companies, and then explore the factors and response strategies that affect Taiwan's semiconductor supply chain management. Based on this, we propose the following research questions for discussion:

2.2.1 What factors influence the geopolitical situation on Taiwan's semiconductor supply chain? Are there vulnerabilities in the supply chain of Taiwanese semiconductor companies? If so, what internal and external risks may it face? Will the U.S.-China international sanctions exacerbate the vulnerability of Taiwan's semiconductor companies' supply chains? What impact will it have on the supply chain management of Taiwan's upstream, midstream and downstream enterprises?

2.2.2 What are Taiwan's semiconductor companies' response strategies under the geopolitical situation? How should Taiwan's semiconductor upstream, midstream and downstream companies respond to internal and external

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risks? Faced with the impact of US-China international sanctions on the supply chains of Taiwan's upstream, midstream and downstream semiconductor companies, what strategies should companies adopt to deal with it?

In order to have a specific understanding of the research questions raised above, this study attempts to find answers to the questions through existing data exploration, that is, relevant literature discussion, and expert interviews. Therefore, the following data collection and analysis are conducted on the questions raised.

2.3 Semiconductor supply chain

The semiconductor industry has industrial characteristics such as capital and technology intensiveness, high entry barriers, and high volatility due to economic fluctuations (Wang Shufen et al., 2010). The technical development of the design and manufacturing of integrated circuit (IC) design affects not only the R&D capabilities of one's own enterprises, but also requires the logistics support and technological upgrades of supply chain manufacturers in the professional technical field, making the semiconductor value chain form a It is an extremely huge industry. The supply chain is highly specialized and consists of multiple key links, including upstream silicon intellectual property (IP), electronic design automation software (EDA), and semiconductor design (Fabless Design); midstream wafer manufacturing (Foundris) and downstream packaging and testing (Assembly, Testing and Packaging), semiconductor equipment (Equipment) and raw material (Raw Material) manufacturers also play an important role. Among them, IC design companies themselves do not produce semiconductors, but focus on chip design, such as Nvidia, Qualcomm, etc.; wafer foundries produce semiconductor components designed by other manufacturers, focusing on In the manufacturing field, such as TSMC, UMC, etc.; packaging and testing factories package and test semiconductor components produced by wafer factories, such as ASE, Amkor and other companies (semiconductor Investment Wars, 2022).

In addition, vertically integrated device manufacturers (IDMs) handle chip design and production and have their own wafer factories. They can control the chip production process from design to manufacturing, better control quality and supply chain dynamics, and accelerate Iteration speed and potential cost savings enable innovation and production to be more synchronized, such as for major memory manufacturers such as Samsung and Micron. Furthermore, judging from the distribution of major manufacturers in the division of labor, the semiconductor supply chain has gradually formed an ecology of regional specialization over the past few decades. Khan et al. pointed out that there are nine main processes in the production process of an IC, which are divided into R&D, circuit design (including silicon IP design, integrated circuit IC design), wafer manufacturing, packaging and testing, IDM manufacturers and terminals Users (including IC modules and IC channels), etc. (Khan et al., 2021), the upstream of Europe and the United States has a relatively high market share in the fields of silicon intellectual property (IP), electronic design automation software (EDA), and chip design (Design) , although the field of semiconductor equipment (Equipment) is not far behind, but raw materials (Material), wafer manufacturing and packaging testing are concentrated in Asia, such as Japanese raw material companies Shin-Etsu Chemical (Shin-Etsu), Tokyo Yika Industrial (TOK), Taiwan's wafer foundries TSMC, United Microelectronics (UMC) and packaging and testing factory ASE (ASE), South Korea's IDM manufacturer Samsung, packaging and testing factory Amkor and other major production bases are all Located in Asia, many European and American IDM companies have factories also located in Southeast Asia. In such a supply chain ecosystem, semiconductor chips can be said to be highly dependent on Asia for production.

However, it is difficult for advanced semiconductor development and production to be carried out by the same country. The main reason is that semiconductor manufacturing and development involves highly complex supply chains and technical expertise, and different countries may have specific professional advantages in different fields (Ren et al., 2023; Grimes & Du, 2022). The results of producing advanced process chips need to be achieved by integrating resources and expertise from different sources (Ren et al., 2023).

2.4 The impact of international sanctions on the decision-making of semiconductor companies

According to the international sanctions model constructed by Meyer et al. (2023), which compiled past sanctions events, the goal of sanctions is to change the behavior of the target government. Companies in the sanctioned country are the first line to be directly affected, and the prohibition of the sanctioning country or restricting exports and imports, prohibiting or restricting financial investment, prohibiting or restricting technology transfer, and prohibiting or restricting the activities of overseas subsidiaries, these will become factors affecting the business strategies of companies in sanctioned countries and companies in third-party countries.

At the beginning of the U.S.-China trade war, the U.S. government increased trade tariffs on specific goods from China through industrial investigations and background checks on overseas companies under Article 301 of the U.S. Trade Code, and banned U.S. businesses, federal agencies, and contractors from purchasing from China. Chips, components and services from specific companies forced the Chinese government to enter the trade negotiation stage ; then, the Export Control Act (ERA) and the Entity List were used to restrict U.S. technology exports, and companies in Europe, Japan, Taiwan and South Korea were included in export controls scope, making it impossible for mainland China to effectively obtain key commodities such as semiconductor equipment, materials, chips and technologies from other countries.

However, the import and export controls announced by the U.S. government can only prevent the inflow and outflow of specific semiconductor commodities. Mainland China can still use international financial instruments to conduct IPOs, corporate mergers and acquisitions, and shareholdings in the United States and other related international financial means to further obtain benefits from the U.S. Prohibited services, technologies and specific goods. Therefore, during 2019 and 2020, the U.S. government passed the Foreign Investment Risk Review Modernization Act and the Foreign Company Accountability Act to tighten the review and prevent blockage of international financial instruments. The Chinese government also follows the U.S. government’s lead in imposing punitive high tariffs on specific goods, prohibiting or restricting export controls and unreliable entity lists, the Anti-Foreign Sanctions Law of the People’s Republic of China, and measures to block inappropriate extraterritorial application of foreign laws and measures. Respond to the international sanctions policy formulated by the United States.

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2.5 Application of PESTLE architecture

PEST analysis is a management tool used by enterprises to evaluate the impact of the external macro environment on it, including political, economic, social and technological levels. It was proposed by Francis Aguilar, a professor from Harvard University in 1967; later, Walsh (2005) integrated the arguments of many scholars and added two new elements: L (Legal) and E (Environmental) to the original theory and expanded it into the PESTLE framework. To analyze and interpret the external environment from a more comprehensive and accurate perspective (Hien et al., 2014). Since the PESTLE framework covers political, economic, social, technological, legal, environmental and other aspects, it can analyze the external macro-environment of this research topic.

3. stages of expert interviews

From the perspective of Taiwan's semiconductor companies, this article not only explores existing data, but also conducts three stages of in-depth interviews with 23 experts. Through a three-stage thematic analysis method, it gradually derives and constructs a pattern (pattern) to explore Influencing factors and coping strategies of the supply chain of Taiwan semiconductor companies.

3.1 Macro level: Phase 1 expert interviews

Through the expert interviews in the first stage, it was found that the experts interviewed in this stage analyzed and interpreted the external environment from a more comprehensive and accurate perspective. Therefore, this article uses the PESTLE structure as a blueprint, and the analysis of the interview results is as follows:

3.1.1 List of interviewed experts

A total of 7 experts were interviewed in the first phase. Their corporate fields are supplying chain management, procurement strategy and market research departments. Most of them look at problems at a macro level.

Table 1 List of experts interviewed in the first stage

Respondent code	Position	Position	Semiconductor experience	Company field
01	operations	manager	20	market research
02	purchase	Director	twenty-three	Procurement strategy
03	purchase	manager	twenty-three	supply chain management
04	operations	manager	17	supply chain management
05	operations	manager	15	supply chain management
06	operations	manager	14	supply chain management
07	purchase	Section Chief	11	Procurement strategy

Source: Compiled by this article.

3.1.2 Opinions of experts interviewed in the first stage

Based on the results of the interviews provided by the experts interviewed in the first stage, it is shown that it has most of the connotations of the PESTLE structure, which are listed in Table 2.

Table 2 Opinions of experts interviewed in the first stage

Impact factor level	Impact factor category	Impact factor description	coping strategies
politics	national industrial policy	Semiconductor subsidy policies in various countries	Appropriate adjustments to semiconductor subsidy policies in various countries
	geopolitical regionalism	U.S. controls and bans on Chinese semiconductors	The improvement of interactive relations between the United States and China
economy	Cost structure changes	Tariff wars lead to rising upstream costs. Supply chain transfer costs increase	Coordinated tariff reductions among countries. Reduce supply chain diversion
	Anti-globalization and regionalization	Countries pursue independent chip supply	Increase the degree of independence of chip supply in each country
society	culture	Differences in workplace culture. invisible social class influence	Adaptation and adjustment of workplace culture. Reduce the influence of social class
	Human Resources	changes in manpower supply and demand. High-tech talents are in short supply	Adjust in response to changes in manpower supply and demand. Strengthen the cultivation of high-tech talents
technolog y	advanced manufacturing	Development of wafer manufacturing process and oligopoly problem	Strategies to improve the water process development and oligopoly

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	technological independence	Reliance on imports of certain key raw materials and equipment	Strengthen independent production capacity of key raw materials and equipment
industry	market trends	The gap in technical information between upstream and downstream industries	Reduce the technological information gap between upstream and downstream industries
	strategic thinking	Shift of supply chain production focus	Weakening the shift in supply chain production focus
Safety	information security	Concerns about information leakage	Strengthen information security to avoid leakage
	law and order	Security issues at supply chain locations	Strengthening security at supply chain locations

Source: Compiled by this study.

3.2 Meso level: Phase 2 expert interviews

3.2.1 List of interviewed experts

Continuing the first phase, a total of 12 experts were interviewed in the second phase. Their corporate fields are IC design, wafer packaging and equipment testing, and IC system application and integration departments. Most of them look at the problem from a meso level.

Table 3 List of experts interviewed in stage 2

Respondent code	Position	Position	Semiconductor experience	Company field
01	product project	manager	12	Wafer packaging and testing
02	resource planning	Department manager	twenty-three	Wafer packaging and testing
03	Industrial Engineering	Senior engineer	10	Wafer packaging and testing
04	Health management	Senior engineer	16	Wafer packaging and test equipment
05	Health management	Department manager	6	Wafer packaging and testing
06	project	Deputy Director	twenty-two	IC system application and integration
07	project	Department manager	9	Wafer packaging and testing
08	Factory project	deputy manager	10	IC design
09	business	Associate	25	Wafer packaging and test equipment
10	product project	Assistant manager	13	IC design
11	business	business representative	2	IC design

Source: Compiled by this study.

3.2.2 Opinions of experts interviewed in the second stage

Based on the results of the interview-related information provided by the experts interviewed in the second stage, it is shown that it has the connotation of the four categories of supply chain vulnerability factors provided by Sharma et al. (2021). Here is an introduction to the categories of supply chain vulnerability factors provided by Sharma et al. connotation, and the opinions of the interviewed experts are summarized in Table 4.

3.2.2.1 Vulnerability factors of enterprise supply chain

Sharma et al. (2021) roughly divided supply chain vulnerability factors into four categories: complexity of supply chain design, complexity of production and organization operations, complexity of supplier management, and complexity of customer information management. First, the complexity of supply chain design is to explore the series connection between each supply chain node of the product. The greater the number of production node connections that exist in the upstream or downstream, it will increase the difficulty of coordination between supply chain manufacturers and easily lead to production processes. Errors, the complexity of supply chain management will be higher (Aelker et al., 2013; Wilding et al., 2012). However, in order to reduce the complexity of supply chain management and stabilize the source of procurement quality, enterprises reduce the number of suppliers, which may lead to too close contact or even dependence between the enterprise and the suppliers. At this time, the vulnerability of the supply chain will also increase. (TY Choi & Krause, 2006).

Secondly, the complexity of production and organizational operations is considered to exist in every node of the supply chain. The higher the diversity of objects, structures, processes and organizational operations of products designed by enterprises; the more critical nodes must exist in the supply chain. The more there are, the more difficult management will be (Sharma et al., 2021). The complexity of a product is defined by the number of components required to produce the product (Clark & Fujimoto, 1991). The greater the number of components, the more complex the structure and process design of the product will be, and the

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possibility of production failure will increase. (Inman & Blumenfeld, 2014).

Furthermore, to illustrate the complexity of supplier management, each supply chain member will try to maximize their personal operating performance and operating efficiency. Therefore, how to maintain the relationship between supply chain members and make the supply chain execution smoother has become very important (Fisher, 1997; Zeng & Yen, 2017). Buyer companies will establish strong collaborative relationships with suppliers to gain maximum competitive advantages in terms of business flexibility, supply efficiency and sustainability (Liao et al., 2010). However, behavioral uncertainty between buyers or suppliers will affect bilateral trust in business cooperation, making it impossible to effectively transform supply efficiency (Sharma et al., 2021).

Finally, there is the complexity of customer information management. The movement of product supply and demand information from end customers to upstream suppliers is often opaque due to the impact of inventory reserves and business models (Lee et al., 2004), resulting in supply chain relationships. Become complex and fragile. Information asymmetry caused by blurred information will prevent buyers and sellers from effectively resolving conflicts in production decisions related to inventory, transportation, delivery time, production capacity and quality (Levi et al, 2000; Abdel-Basset & Mohamed, 2020). The complexity of customer information management plays an important role in the supply chain, and its impact is directly reflected in production efficiency, production capacity allocation, and effective operations planning and management (Petersen et al, 2019).

3.2.2.2 Opinions of experts interviewed in the second stage

Table 4 Opinions of experts interviewed in the second stage

sanction factor	supply chain factors	category
Prohibitions or restrictions on exports and imports	Supply chain design complexity	➢ OEM production model ➢ Outsourced production model ➢ geopolitical risks ➢ political intervention ➢ Supplier location (origin) ➢ Supplier Enterprise Risk Assessment (ERM) ➢ Supplier Performance Metrics ➢ supplier concentration ➢ Process coordination between buyers and suppliers ➢ Dependence on target market ➢ Customer Relationship Management (CRM) ➢ Transparency of production information ➢ Product production cost ➢ Product category complexity ➢ Management convenience of semiconductor talents
	Complexity of production and organizational operations	➢ Enterprise Agile Capabilities ➢ Enterprise Risk Assessment (ERM) ➢ Supplier location (origin) ➢ Customer Relationship Management (CRM) ➢ Manufacturing is highly flexible ➢ technology dependence
	The complexity of supplier management	➢ Supplier Enterprise Risk Assessment (ERM) ➢ Supplier location (origin) ➢ Material inventory management ➢ Process coordination between buyers and suppliers ➢ Supplier Performance Metrics ➢ technology dependence ➢ Manufacturing is highly flexible
	The complexity of customer information management	➢ Enterprise agility capabilities ➢ Requirements data sharing
Prohibiting or restricting technology transfer	Supply chain design complexity	➢ Vertical and horizontal integration capabilities of the production chain ➢ Dependence on target market ➢ Product grade division ➢ Manufacturing is highly flexible
	Complexity of production and organizational operations	➢ Dependence on target market ➢ OEM production model ➢ technology dependence ➢ Product grade division ➢ Product production cost
Prohibition or restriction of overseas subsidiaries	Supply chain design complexity	➢ Enterprise operating cost control ➢ Supplier location (origin) ➢ Dependence on target market ➢ Adjustment of shareholding structure ➢ Vertical and horizontal integration capabilities of the production chain ➢ Resource integrity of the industrial chain ➢ Product technology complementarity

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		➢ Management convenience of semiconductor talents
Prohibitions or restrictions on financial investments	Supply chain design complexity	➢ Process coordination between buyers and suppliers

Source: Compiled by this study.

3.3 Macro-Meso-Micro Level: Phase 3 Expert Interviews

3.3.1 List of interviewed experts

Following the second stage, a total of 4 experts were interviewed in the third stage. Their corporate fields are wafer measurement, advanced packaging, semiconductor process and advanced innovation departments, and they mostly look at problems from the macro-meso-micro level.

Table 5 List of experts interviewed in phase 3

Respondent code	Position	Position	Semiconductor experience	Company field
01	innovation	director	10-20	Advanced Innovation Department
02	project	President		Wafer measurement
03	project	President		Semiconductor process
04	project	Director		Advanced packaging supply chain

Source: Compiled by this study.

3.3.2 Opinions of experts interviewed in the third stage

According to the results of the interviews provided by the experts interviewed in the third stage, it has most of the connotations of the PESTLE structure at the macro level, the upstream, middle and downstream connotations of industrial market trends at the meso level, the theoretical connotations of Porter's five forces plus complementors, and the connotations of POCD. At this point, this study has completed the 3-stage derivation process and attempted to construct a pattern. This is to introduce the theoretical connotation of Porter's five forces plus complementors and the connotation of POCD and summarize the opinions of the experts interviewed in the third stage in Table 6.

4. Vertical analysis: macro level, meso level, micro level

4.1 macro level

If we look at Taiwan's semiconductor development context, Mr. Chiang Ching-kuo instructed the National Science Council to create the first science park, the Hsinchu Science Park, with the purpose of cultivating Taiwan's modern industrial capabilities, attracting overseas talents to return to China to start businesses, and providing domestic university graduates with good employment and entrepreneurial environment. The establishment of the science park is a pioneering initiative that gives full play to the clustering effect of the industry. Upstream and downstream manufacturers are independent but have cooperative relationships, and industrial information circulates quickly, which can be said to include technology, industry, safety, law, political, economic, social and other factors.

4.1.1 inclusive factor analysis

In terms of the PESTLE framework, it was gradually developed from PEST analysis. It is a management tool used by enterprises to evaluate the impact of the external macro environment on it, including political, economic, and social and technology. The level was proposed by Francis Aguilar, a professor from Harvard University, in 1967; later, Walsh (2005) integrated the arguments of many scholars and added L (Legal) and E (Environmental) two elements and expanded it into the PESTLE structure to analyze and interpret the external environment from a more comprehensive and accurate perspective (Hien et al., 2014). Looking at the development of Taiwan's semiconductor industry, the factors involved can be analyzed from the technical, industrial, security, legal, political, economic, social and other levels, as described below.

4.1.1.1 Technical factors

Although Taiwan may not be ahead of other countries in IC design and technology research and development, it does have considerable standards and advantages in manufacturing. In terms of advanced manufacturing, the current problem is the continued development and oligopoly of the wafer process. It may be necessary to strategically maintain advantages and make improvements and adjustments; and in terms of technological independence, due to certain key raw materials and equipment systems If we rely on imports, we need to develop and strengthen independent production capacity in response.

4.1.1.2 Industrial factors

In terms of market trends, there is a gap in technical information between the upper, middle and lower reaches of the industry, which can be strategically reduced; and in terms of strategic thinking, there is a problem of shifting the focus of supply chain production, because Taiwan’s semiconductor industry is The form of ecological settlement exists, so the shift of the production focus of the supply chain needs to be weakened.

4.1.1.3 Safety factor

In terms of information security, there are concerns about information leakage (including business secrets), and information security measures need to be strengthened; and in terms of public security, it is necessary to maintain or strengthen security and defense at supply chain locations.

4.1.1.4 Legal factors

As far as patent protection is concerned, it may still not be rigorous enough at present, and patent protection can be further strengthened to cope with this.

4.1.1.5 Political factors

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In terms of national industrial policies, major countries in the world have introduced semiconductor subsidy policies. In the face of changes in the world situation, they only need to make appropriate adjustments; and in terms of geopolitical regionalism, the United States has introduced many controls and bans on Chinese semiconductors. In response, it is necessary to improve the interactive relationship between the United States and China.

4.1.1.6 Economic factors

As far as cost structure changes are concerned, rising upstream costs due to tariff wars require coordination among countries to reduce the impact of tariffs on costs; and when costs increase due to supply chain shifts, ways can be found to reduce supply chain disruptions. transfer. In addition, in terms of anti-globalization and regionalization, as countries pursue independent chip supply, their degree of chip autonomy can be appropriately increased.

4.1.1.7 Social factors

In terms of culture, Taiwanese have the flexibility of the Chinese and the precision required by the Japanese, which creates differences between Eastern and Western workplace cultures. For the transfer of the supply chain, workplace culture needs to be adapted and adjusted. As for human resources, adjustments need to be made in response to changes in manpower supply and demand.

4.2 Meso level

4.2.1 Market Analysis

The meso level can be analyzed from the upstream, midstream and downstream of the market. The upstream is IP design and IC design industry. Foreign manufacturers have benefited, such as Global Wafer, etc.; patent protection may still be insufficient, and efforts need to be strengthened; the midstream includes IC manufacturing, wafer manufacturing, related production process testing equipment, photomasks, chemicals, etc., where competition is fiercest and also causes surprise. increase, which in turn causes prices to fall. Although mainland China does not have opportunities in advanced manufacturing processes, it can develop mature processes; the downstream includes IC packaging and testing, related production process testing equipment, components (such as substrates, lead frames), IC modules, IC pathways, etc. The market affects the interests of certain countries, such as electric vehicles.

4.2.2 Support of Potter's Five Forces and Complementors Theory

The earliest framework of five forces analysis was proposed by Harvard Business School professor Michael Porter in 1979. The competitive state of the industry cannot be measured only between the enterprise and its existing competitors, but rather through the intensity of the five competitive forces. To decide. These forces center on "the competitive intensity of existing competitors" and develop competitiveness such as "risk of entry of potential competitors", "bargaining power of suppliers", "bargaining power of buyers" and "threat of substitutes". Through the intensity analysis of these five forces, it can help companies judge the degree of industrial competition in their own market and formulate appropriate competitive strategies (Porter, ME, 2008). In addition, former Intel CEO Andy Grove (1996) believed that the five forces model ignored the role of "complementors", so in order to conduct a more comprehensive analysis, he added the role of complementors analysis.

Based on the current development status of Taiwan's semiconductor industry, if analyzed in accordance with Potter's five forces and complementor theory, it can be found that because existing competitors are strong, it is necessary to continuously increase annual output value to maintain and strengthen competitiveness; if potential competitors enter In terms of risks, due to the high entry barriers to the industry, it is often difficult for existing companies that decide to enter the market to seize the current market; in terms of the bargaining power of suppliers, low differentiation and many suppliers reduce the cost of switching. , can decide whether to continue the partnership based on the effectiveness of the cooperation ; in terms of the buyer's bargaining power, because the industry has characteristics that are not easily replaced, the price can be adjusted by the seller; in terms of the threat of substitutes, because Taiwanese manufacturers have strong advanced manufacturing capabilities Under strong circumstances, in addition to fixed specifications, customized products can also be customized according to consumer needs, thereby reducing the risk of being replaced. In terms of the power provided by complementors, Taiwan's semiconductor supply chain forms an ecosystem of its own, and each other interacts with each other. Support virtually enhances stress resistance and gradually enhances resilience.

4.3 Micro level

As far as entrepreneurial management is concerned, we can analyze the fitness and interaction of the four major elements in the POCD structure. Sahlman (1996) believes that examining people, opportunity, context and deal the degree of fit between the four dynamic elements. Because many semiconductor companies in science parks started as new start-ups, the development conditions and potential of new semiconductor companies in science parks were analyzed and evaluated (Austin et al., 2006; Chaulagain M., 2020), can better understand the company's existing advantages and adjustments that should be made in the future. Therefore, the micro level can be observed by people, opportunities, context, and agreements. In terms of personnel, the culture of cooperation and mutual support cultivated between organizations in the past affects the personnel established by the enterprise, including any important stakeholders, to jointly support the company's development; in terms of opportunities, Taiwan's semiconductor supply chain has established its market positioning , and create products that meet the needs of the target customer group; in terms of context, it is an environmental factor, including legal, political, economic, etc. that affects the operation and development of the enterprise, as mentioned above; in terms of the agreement, it includes the enterprise and the supplier business interactions with resource providers such as suppliers, customers, partners, and investors.

In addition to analyzing the degree of fit and interaction of the four elements of POCD , since the entrepreneurial process of new ventures begins with the initiation of opportunities, and can only develop smoothly after the formation of an entrepreneurial team and the acquisition of resources, it can also be analyzed by T i mmons The dynamic balance of the three elements of opportunity, team and resources in the model helps it solve various problems encountered in the changing external environment. The opportunity elements have been analyzed previously. Therefore, looking at teams and resources, semiconductor start-ups can focus on the formation of multi-faceted teams in a highly competitive environment, and as the business develops, they can further clarify the company's need for resources. needs.

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Furthermore, we can also pay attention to the resources or capabilities of the enterprise by applying the VRIO framework proposed by Barney in 1991. They must be valuable, scarce, inimitable and organizationally supportive at the same time in order to have sustainable competitive advantages. First, examine whether resources or institutions can help companies take advantage of opportunities or resist threats based on their value. From the perspective of Taiwan's semiconductor industry, they are valuable resources, so they can enhance the efficiency and effectiveness of companies, thereby improving their market position and financial performance; In terms of scarcity, examine whether the resources or capabilities are relatively scarce in current or potential competition? Considering the situation of Taiwan's semiconductor industry in the global context, it is still relatively scarce, with only a few competitors possessing this resource. Therefore, enterprises can still obtain competitive advantages from it; furthermore, from the perspective of whether the resources or capabilities are difficult to be imitated, obtained or copied by competitors, Taiwan's semiconductor industry still has unique and complex resources, thus increasing the number of similar industries in other countries. The difficulty of imitation can then protect the company's competitive advantage; finally, it is necessary to examine whether it has the corresponding internal capabilities to form a sustainable competitive advantage. As far as Taiwan's semiconductor industry is concerned, it can be said that most relevant companies already have the corresponding capabilities.

4.4 Longitudinal analysis and integration

The longitudinal analysis includes three levels of analysis: macro, meso and micro. Table 6 presents the integrated results of the longitudinal analysis.

Table 6 Longitudinal analysis and integration

Macro level			
Impact factor level	Impact factor category	Impact factor description	Coping strategies
technology	advanced manufacturing	Development and oligopoly of the water manufacturing process	Strategically improve the water process development and oligopoly
	technological independence	Reliance on imports of certain key raw materials and equipment	Strengthen independent production capacity of key raw materials and equipment
industry	market trends	The gap in technical information between the upper, middle and lower reaches of the industry	Reduce the technological information gap between the upper, middle and lower reaches of the industry
	strategic thinking	Shift of supply chain production focus	Weakening the shift in supply chain production focus
Safety	information security	Concerns about information leakage	Strengthen information security to avoid leakage
	law and order	Security issues at supply chain locations	Strengthening security at supply chain locations
law	Patent protection	Patent protection may still be insufficient	Strengthen patent protection
politics	national industrial policy	Semiconductor subsidy policies in various countries	Appropriate adjustments to semiconductor subsidy policies in various countries
	geopolitical regionalism	U.S. controls and bans on Chinese semiconductors	The improvement of interactive relations between the United States and China
economy	Cost structure changes	Tariff wars lead to rising upstream costs. Supply chain transfer costs increase	Coordinated tariff reductions among countries. Reduce supply chain diversion
	Anti-globalization and regionalization	Countries pursue independent chip supply	Increase the degree of independence of chip supply in each country
society	culture	Differences in workplace culture. invisible social class influence	Adaptation and adjustment of workplace culture. Reduce the influence of social class
	human Resources	changes in manpower supply and demand. High-tech talents are in short supply	Make adjustments in response to changes in manpower supply and demand. Strengthen the cultivation of high-tech talents

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Meso level		
Market analysis	upstream	IP design and IC design industry. Manufacturers in many countries have benefited, such as Global Wafer. The main problem in upstream wafer manufacturing is that patent protection may still be insufficient and needs to be strengthened.
	midstream	IC manufacturing, wafer manufacturing, related production process testing equipment, photomasks, chemicals, etc. Competition in the midstream is the most intense, causing surprises to increase and prices to fall. Taiwan Tech continues to develop advanced manufacturing processes and strategically overcomes vulnerability factors to maintain its advantage. Although there is less opportunity for advanced processes in mainland China, it can still develop mature processes.
	downstream	IC packaging and testing, related production process testing equipment, components (such as substrates, lead frames), IC modules, IC pathways, etc. Downstream often affects the interests of certain countries, such as electric vehicles.
Project	Strength	Current Situation Analysis
existing competitors competitive intensity	powerful	Continuously increase annual output value, maintain and strengthen competitiveness.
Risk of entry by potential competitors	middle	High barriers to entry make it difficult for existing companies that decide to venture into the current market.
Bargaining power of suppliers	middle	The differences are low and there are many suppliers, which reduce switching costs and can decide whether to continue the partnership based on the effectiveness of the cooperation.
Buyer's bargaining power	middle	It has the characteristics of being difficult to replace and the price can be adjusted by the seller.
Threat of substitutes	weak	It has strong advanced manufacturing capabilities and can customize products according to consumer needs, thereby reducing the risk of being replaced.
Strength provided by complementors	powerful	It forms an ecosystem of its own and supports each other.
Micro level		
Elements	Describe	
Personnel (P)	The culture of cooperation and mutual support fostered between organizations in the past has influenced the people established in the business, including any important stakeholders, to work together to support the company's development.	
Chance (O)	Create the cornerstone of differentiation, establish market positioning, and create products that meet the needs of target customer groups.	
context (C)	Environmental factors, including legal, political, economic, etc., affect the operation and development of enterprises.	
protocol (D)	Including business interactions between enterprises and resource providers such as suppliers, customers, partners, investors, etc.	
Team (T)	Focus on multi-faceted team composition in a highly competitive environment.	
Resources (R)	As the business develops, the company's demand for resources will be further clarified.	
VRIO	Pay attention to the enterprise's resources or capabilities. They must be valuable, scarce, inimitable and organizationally supportive at the same time in order to have a sustainable competitive advantage.	

Source: Compiled by this study.

5. Horizontal analysis: engineering resilience, ecological resilience, social ecological resilience

"Resilience" is the ability of a social system (such as an organization, city or society) to take proactive measures and recover from disturbances when it senses that it is beyond the normal and expected range of disturbances. The design to strengthen crisis resilience can be implemented into specific steps, plans and resource integration and allocation. Even if the crisis cannot be prevented, the ability to deal with it after it occurs will be more effective due to the preparation process. measure. The term resilience can be extended to the system's ability to resolve hazard threats and the force behind changes in system vulnerability. Here is a hierarchical analysis of the application of

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the concept of resilience in the development of Taiwan's semiconductor industry as follows:

5.1.1 Engineering toughness

Engineering resilience is defined as "the ability of people or things to return to their original state after suffering an impact or disturbance." This resilience can be used as a measure of system stability (Holling, 1996; Walker and Salt, 2006; Gunderson, 2003). Stability refers to "the ability of a system to return to equilibrium after a brief disturbance" (Holling, 1973). The faster the reply is, the more stable the system is. Compared with this traditional definition of resilience (Pimm, 1984), Holling and his supporters are interested in the magnitude of disturbance that the system can tolerate, arguing that although the time required for recovery (reply Speed) is important, and resilience focuses on the ability to recover (Berkes et al. , 2003 ; Gunderson , 2003).

Under the thinking logic of engineering, in order to design and maintain efficient and stable operation of the system, engineers are committed to optimizing the system, that is, trying to improve the efficiency of system operation by anticipating and controlling the consumption of system resources. Optimization results can enable the system to maintain efficient and stable operation under a given situation, but it is often vulnerable to unexpected impacts. A better approach would be to develop system diversity, adaptability and cohesion to enhance the system 's inherent resilience.

5.1.2 Ecological resilience

Ecological resilience means "the amount of disturbance necessary to transform the system from a set of structurally stable equilibrium states to another set of equilibrium states" (Bennett et al. , 2005). This resilience can be used as a measure of system robustness. This definition assumes that the structure and function of the system continue to change over time (Walker and Salt, 2006), and the concept of returning to a stable equilibrium state is no longer applicable, because ecologists believe that there is no established equilibrium in complex systems . Therefore, the focus of ecological resilience consideration is not on the stability of the system or the speed of change and recovery, but on the system disturbance itself and the phenomenon when it is at the critical point of equilibrium.

Holling and most ecologists argue that resilient systems will be more stable during disturbances, that is, the emphasis is not on reaching a goal and staying in that state, but on the system being able to "maintain the state of competition" (staying in the game) (Pickett et al., 2004). The management of ecosystems should also be adjusted to enhance system adaptability and make the system more flexible to respond to emergencies and an uncertain future, and through the establishment of system tolerance, for example: continuous monitoring of environmental changes and continuous learning and learning by doing to absorb the impact of change.

Holling makes a clear distinction between resilience (i.e., the ability of a system to absorb change and maintain operation) and stability (i.e., the ability of a system to return to normal). Therefore, an extremely stable system will not cause too much disturbance and can quickly return to normal during the disturbance process, while a highly resilient system may be unstable but can continue to operate steadily despite great disturbances (Klein et al., 2003). From another perspective, engineering resilience focuses on maintaining efficiency of function and assumes that the system tends to be stable, while ecological resilience does not consider stability as a normal state and focuses on ensuring the system function during changes. Maintaining existence of function (Holling, 1973).

5.1.3 Social ecological resilience

2007, following Holling's interpretation of engineering resilience and ecological resilience, ecologist Brand and conservation biologist Jax further tried to clarify the concept of resilience and proposed the concept of social-ecological resilience covering the social aspect. Emphasize the interrelationship between social disruption and reorganization, and explore organizational transformation capabilities (transformability), learning and innovation capabilities (Brand and Jax, 2007). This development has shifted the concept of resilience to higher-level organizational systems and governance structures.

Surprises in the ecosystem into large, medium and small scales based on the scale of the event and correspond to the three different concepts of resilience mentioned above. They believe that disturbances caused by events at different scales require Through the response of different concepts of resilience. Minor disturbances caused by small-scale emergencies to the system usually do not exceed the system's tolerance and can be absorbed and restored to the original state through individual actions (engineering resilience - relying on the improvement of efficiency to reduce the time required for recovery); Disturbance caused by medium-scale emergencies requires organizations to coordinate with each other under the original structure and effectively use resources to achieve a new balance (ecological resilience -- relying on the improvement of system tolerance); unprecedented emergencies have The impact caused by the system is usually beyond the ability of the original organizational structure to cope with it. The system organization is bound to suffer serious damage and must undergo restructuring and regeneration (social ecological resilience --- relies on the cultivation of organizational learning, diversity and creativity) (Hunt and Berkes, 2003).

5.2 Horizontal analysis and integration

The horizontal analysis includes three levels of engineering resilience, ecological resilience and social acoustic resilience. Table 7 presents the integrated results of the horizontal analysis.

Table 7 Horizontal analysis and integration

macro level
Engineering Resilience
To design and maintain efficient and stable operation of the system, engineers are committed to system optimization, that is, trying to improve the efficiency of system operation by anticipating and controlling the consumption of system resources. Optimization results can enable the system to maintain efficient and stable operation under a given situation, but it is often vulnerable to unexpected impacts. The minor disturbances caused by small-scale emergencies to the system usually do not exceed the system's tolerance and can be absorbed and restored to the original state through individual actions (relying on the improvement of efficiency to reduce the time required for recovery).
ecological resilience
Focus on the system disturbance itself and the phenomenon when it is at the critical point of equilibrium; the management of ecosystems should be adjusted to enhance the system's adaptability and make the system more flexible in response to

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emergencies and uncertain futures. Disturbances caused by medium-scale emergencies require organizations to coordinate with each other under the original structure and effectively use resources to achieve a new balance (relying on the improvement of system tolerance).
socio-ecological resilience
The impact of unprecedented emergencies on the system is usually beyond the ability of the original organizational structure to cope with it. The system organization is bound to suffer serious damage and must undergo restructuring and regeneration (relying on the cultivation of organizational learning, diversity and creativity).

Source: Compiled by this study.

6. Integration: Pattern construction

6.1 The construction connotation of Pattern

This study attempts to construct a model at the vertical macro, meso and micro levels, combined with the horizontal concept of resilience, and uses this framework to analyze, clarify problems and think about and analyze response strategies. The construction connotations of Pattern are listed in Table 8.

Table 8 the construction connotation of Pattern

levels of resilience PESTLE hierarchy	Engineering Resilience	ecological resilience	socio-ecological resilience
macro level	Breakthroughs in semiconductor process and packaging research and development, including impacts on technology, law, and security, are small-scale events.	Affected by geopolitics, the U.S.-China trade conflict has triggered mutual sanctions, involving the economic interests of both parties. It has also had a profound impact on companies in the semiconductor value chain and ecosystem, and has also caused political, economic, social, and political consequences to semiconductor companies. Impact on industry and other levels. Therefore, the impact of the US-China trade conflict is relatively deep and broad, and we can regard it as an event above a medium scale.	
meso level	This part includes the upstream IP design and IC design industry, where foreign manufacturers benefit but patent protection may still be insufficient; and midstream IC manufacturing, wafer manufacturing, related production process testing equipment, photomasks, chemicals, etc., where competition is the most intense. We can think of it as an event between mesoscale and small scale.	It mainly occurs in the downstream markets of IC packaging and testing, related production process testing equipment, components (such as substrates, lead frames), IC modules, IC channels, etc., affecting the interests of certain countries. Also, from the perspective of the impact of the US-China trade conflict, it can still be regarded as an event above a medium scale.	
micro level	If people, opportunities, connections and agreements are considered from an overall planning perspective, in terms of people, the culture of cooperation and mutual support cultivated between organizations will affect the people established by the enterprise, including any important stakeholders, who need to work together. Support the company's development; in terms of opportunities, Taiwan's semiconductor supply chain has established its market positioning and created products that meet the needs of target customer groups, occupying a place in the global market; in terms of context, it is an environmental factor, including legal , political, Economics, etc. affect the operation and development of enterprises; in terms of agreements, it includes business interactions between enterprises and resource providers such as suppliers, customers, partners, investors, etc.	If we consider people, opportunities, connections and agreements from an innovative system perspective, A transnational strategy can simultaneously achieve low costs; differentiate products according to local needs in different geographical markets; and promote the flow of skills between different subsidiaries. It is a good strategy, but care must be taken to avoid conflicting goals. Circumstances that lead to difficulties in implementation.	If we consider personnel, opportunities, connections and agreements from the perspective of resource contribution, we can see that the global standardization strategy pursues a low-cost strategy based on global scale and sells standardized products to maximize profits from economies of scale, which is in line with the current situation of Taiwan's semiconductor industry. The situation is quite consistent, and we can also see that the global standardization strategy has indeed been implemented in many semiconductor industries in Taiwan .

Source: Compiled by this study.

6.2 Conclusion

6.2.1 Discussion of resilience at the macro level

6.2.1.1 Engineering resilience

Breakthroughs in semiconductor process and packaging research and development, including impacts on technology, law, and security, are small-scale events.

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6.2.1.2 Ecological vs socio-ecological resilience

Due to the impact of geopolitics, the U.S.-China trade conflict has triggered mutual sanctions, involving the economic interests of both parties. It has also had a profound impact on companies in the semiconductor value chain and ecosystem, and has also caused political, economic, social, and political consequences to semiconductor companies. Impact on industry and other levels. Therefore, the impact of the US-China trade conflict is relatively deep and broad, and we can regard it as an event above a medium scale.

6.2.2 Meso- Level Resilience Discussion

6.2.2.1 Engineering resilience

Including the upstream IP design and IC design industries, foreign manufacturers have benefited but patent protection may still be insufficient; and midstream IC manufacturing, wafer manufacturing, related production process testing equipment, photo masks, chemicals, etc., the competition is the fiercest. We can think of it as an event between meso scale and small scale.

6.2.2.2 Ecological vs socio-ecological resilience

It mainly occurs in the downstream markets of IC packaging and testing, related production process testing equipment, components (such as substrates, lead frames), IC modules, IC channels, etc., affecting the interests of certain countries. Also, from the perspective of the impact of the US-China trade conflict, it can still be regarded as an event above a medium scale.

6.2.3 Discussion of toughness at micro level

6.2.3.1 Engineering resilience

If people, opportunities, connections and agreements are considered from an overall planning perspective, in terms of people, the culture of cooperation and mutual support cultivated between organizations will affect the people established by the enterprise, including any important stakeholders, who need to work together. Support the company's development; in terms of opportunities, Taiwan's semiconductor supply chain has established its market positioning and created products that meet the needs of target customer groups, occupying a place in the global market; in terms of context, it is an environmental factor, including legal, political, Economics, etc. affect the operation and development of enterprises; in terms of agreements, it includes business interactions between enterprises and resource providers such as suppliers, customers, partners, investors, etc.

6.2.3.2 Ecological resilience

If people, opportunities, connections and agreements are considered from an innovation system perspective, a transnational strategy can simultaneously achieve goals such as low costs; differentiate products according to local needs in different geographical markets; and promote the flow of skills between different subsidiaries. , it is a good strategy, but care needs to be taken to avoid conflicting goals that may lead to difficulties in implementation.

6.2.3.3 Social ecological resilience

If we consider personnel, opportunities, connections and agreements from the perspective of resource contribution, we can see that the global standardization strategy pursues a low-cost strategy based on global scale and sells standardized products to maximize profits from economies of scale, which is in line with the current situation of Taiwan's semiconductor industry. The situation is quite consistent, and we can also see that the global standardization strategy has indeed been implemented in many semiconductor industries in Taiwan.

6.3 Extended discussion: Thinking about possible strategies and adjustments

In addition to the aforementioned strategies for responding to many vulnerabilities in Taiwan's semiconductor supply chain under international sanctions, we can still think from a strategic perspective and consider whether strategies in the global environment, especially strategies that change over time, are appropriate. Here are some thoughts on the strategies Taiwan semiconductor companies may adopt and adjust under complex circumstances:

6.3.1 Abandon international strategy and localization strategy

When competitors appear, international strategies and localization strategies become less feasible.

6.3.1.1 Abandon international strategy

Since Taiwan has not established production and marketing functions in every major country and geographical area with which it does business, nor has it carried out some localization and customization of products and marketing strategies, but the scope is very limited. International strategies do not apply.

6.3.1.2 Abandon localization strategy

The localization strategy focuses on customizing the company's products or services to improve profitability, which is obviously not in line with Taiwan's current situation.

6.3.2 Implementation of global standardization strategy

Since the global standardization strategy pursues a low-cost strategy based on global scale and sells standardized products to maximize profits from economies of scale, it is quite consistent with the current situation of Taiwan's semiconductor industry. We can also see that the global standardization strategy has indeed Implemented in many semiconductor industries in Taiwan.

6.3.3 Consider cross-border strategies

A transnational strategy can simultaneously achieve low costs, differentiate products according to local needs in different geographical markets, and promote the flow of skills between different subsidiaries, which is a good strategy. However, it should be noted that if the goals conflict, implementation may be difficult.

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