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Scenario simulation of Taiwan's semiconductor industry in the next five years

Sirirat-Sae Lim[1*], Yu-Na Zhang[2], Wen-Chuan Ke[3], Pei-Hsuan Chen[4]

[1] Associate Professor, School of Technology Management, National Yang Ming Chiao Tung University.

[2] lecturer, College of Economics and Management, Yantai Nanshan University, Yantai, China; PhD Candidate in Financial Technology, INTI International University, Malaysia

[3] PhD Researcher Fellow, School of Technology Management, National Yang Ming Chiao Tung University; Adjunct Associate Professor, Department of Industrial Engineering and Management, National Taipei University of Technology; Adjunct Associate Professor, Department of Public Administration, National Open University; Visiting Professor, School of Intelligent Construction, Wuchang University of Technology.

[4] Master's Thesis, School of Technology Management, National Yang Ming Chiao Tung University.

Corresponding Author: Sirirat-Sae Lim

ABSTRACT

With globalization, the semiconductor industry has become a cornerstone of modern technology and plays a crucial role in Industry 5.0. From smartphones and computers to automobiles and medical devices, almost all modern equipment relies on semiconductor technology. However, in recent years, the formation of international geopolitical situations and the US-China trade war have had a certain impact on the semiconductor industry. Taiwan, due to its key position in the global semiconductor supply chain, is likely to be significantly affected. The geopolitical risks and challenges brought about by the US-China trade war will force companies to reconsider their supply chain strategies and market layouts; furthermore, how companies should respond to these challenges has become an urgent issue to be addressed.

This paper aims to explore the impact of geopolitics and the US-China trade war on the supply chain of Taiwan's semiconductor companies through scenario simulation , and to analyze the companies ' coping strategies in this context. The main objective of this study is to understand the specific impacts of geopolitics and the US-China trade war on the supply chain of Taiwan's semiconductor companies through scenario simulation, including issues such as rising costs, supply chain disruptions, and market uncertainty. Simultaneously, the research process also explores the strategies adopted by companies to address these challenges, such as supply chain diversification, localized production, and partnerships with other countries.

The study employed scenario analysis, interviewing semiconductor and related technology management experts to simulate potential scenarios for Taiwan's semiconductor industry over the next five years. This allowed the Taiwanese government and businesses to prepare in advance and formulate corresponding strategies. The study compiled expert meeting data to identify three scenarios: the most optimistic scenario of further growth; a neutral scenario of mixed strengths and weaknesses; and the most pessimistic scenario of technological stagnation. After simulating each scenario, a SWOT analysis was conducted to provide relevant strategic recommendations for the government and businesses.

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Research has identified the most significant influencing factors for Taiwan's semiconductor industry as: its strategic location as a key hub; process technology; R&D talent; and policy support. Therefore, scenario simulations predict a mixed picture for the next five years, with breakthroughs in wafer fabrication technology, a widening talent gap, integration of the upstream, midstream, and downstream supply chains, and geopolitical influences. Strategic recommendations are as follows: For the government, efforts should be made to address the talent shortage and actively seek product export licenses; for businesses, continuous R&D and innovation are crucial, along with actively recruiting R&D talent, diversifying supply chain risks, and proactively managing operations to mitigate geopolitical impacts.

Understanding the impact of geopolitics and the US-China trade war on the semiconductor industry is crucial for companies to develop effective response strategies. With continuous technological advancements and changes in global markets, semiconductor companies need the ability to flexibly respond to external risks. This research not only provides valuable insights for semiconductor companies but also offers theoretical and practical support to policymakers and academia.

KEY WORDS: Taiwan semiconductor industry, scenario analysis, semiconductor, US-China trade, geopolitics.

1. Introduction

In modern society, semiconductors play an indispensable role, appearing ubiquitous, leading major industrialized nations worldwide to prioritize the development of their semiconductor industries (Chen, Shih, Chang, and Jin, 2021) . Since the 1960s, Taiwan has been developing its high-tech industry. With strong government support and assistance, it has established a globally unique science park model and gradually formed a complete semiconductor industry cluster, encompassing upstream wafer materials and IC design, as well as midstream and downstream IC manufacturing, IC packaging, and IC testing—a remarkably comprehensive industrial structure. According to IC Insights, Taiwan's IC-related industry output has reached a global market share of 19.8%, making it the world's second-largest IC market after the United States. Its market share in wafer foundry and IC packaging and testing exceeds 50%, making it number one globally.

Taiwan's semiconductor industry boasts a highly complete upstream, midstream, and downstream supply chain with specialized division of labor, making it extremely competitive globally. This has resulted in semiconductor-related industries accounting for 15% of Taiwan's overall GDP (Chen, Shih, Chang, and Jin, 2021) . However, in a rapidly changing society, Taiwan's semiconductor industry may not be able to maintain its growth trend indefinitely. How to maintain its competitive advantage in the face of an uncertain future is a primary challenge for Taiwan's semiconductor industry.

On August 9, 2022, US President Biden signed the CHIPS Act, which aimed to encourage major wafer foundries to establish operations in the United States and expand domestic wafer manufacturing capacity. The goal was to increase domestic chip production and reduce reliance on foreign suppliers, while also aiming to prevent China's rise in semiconductor technology. Similarly, the Japanese government actively promoted local chip manufacturing, subsidizing TSMC with 19 billion yen to encourage TSMC to set up a factory in Japan. The aim was to ensure a stable semiconductor supply for Japan, promote chip research and development, and revitalize the Japanese semiconductor industry. These events have had a significant impact on Taiwan's semiconductor industry.

The formation of geopolitical circumstances and the US-China trade war have already impacted the semiconductor industry to some extent. From an international relations perspective, geopolitical response strategies involve multiple aspects, encompassing different theoretical perspectives such as realism, liberalism, and constructivism. The United States primarily employs a realist "balance of power" strategy in the semiconductor industry, that is, balancing the power of its main rivals by establishing or joining alliances to prevent any single country or group from becoming a hegemon. In contrast, China primarily employs a strategic culture strategy, emphasizing its influence over neighboring countries based on its historical and geographical factors.

Numerous adjustments in the global supply chain, companies need to examine their globalization strategies, and governments also need to assist companies with relevant supporting measures and create a suitable environment for investment and R&D to cope with the impact of these changes and maintain Taiwan's competitive advantage in the semiconductor industry. This study uses scenario analysis to identify key factors affecting Taiwan's semiconductor industry and simulates three possible future scenarios to provide a reference for strategy formulation. The aim is to develop corresponding strategies under these simulated and predicted scenarios to maintain Taiwan's global competitive advantage in the semiconductor industry.

2. Characteristics of the Semiconductor Industry in Major Countries

The global semiconductor industry is highly dynamic in terms of technological innovation, supply chain management, and international competition. The current characteristics of the semiconductor industries in major countries and regions are described below:

2.1 USA

2.1.1 **Technological Advantages**: The United States is home to many of the world's leading semiconductor companies, such as Intel , Qualcomm, Nvidia and Texas Instruments . These companies have technological advantages in areas such as CPUs, GPUs, communication chips and embedded systems.

2.1.2 **R&D Investment: US companies invest** heavily in R&D, continuously driving technological innovation and process advancements. The US government also actively supports semiconductor R & D, promoting the development of related industries through various policies and funding.

2.1.3 **Supply Chain Management:** The United States has mastered the core technologies and design capabilities in the upstream of the semiconductor industry chain, but the manufacturing process relies more on outsourcing and the global supply chain.

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2.2 Taiwan

2.2.1 **Powerful Manufacturing Processes**: TSMC is the world's largest semiconductor foundry, possessing the world's most advanced manufacturing processes, covering 5nm, 3nm, and 2nm process nodes. In addition, UMC and PSMC also hold significant positions in the foundry industry.

2.2.2 **Complete supply chain**: Taiwan has a complete semiconductor supply chain, including design, manufacturing, packaging and testing, which has formed a strong industrial cluster effect.

2.2.3 **Innovation capability: Taiwanese companies continue to** invest in technological innovation and R&D to maintain their leading position in global semiconductor technology processes and other fields.

2.3 Japan

2.3.1 **Advanced Technology**: Japanese companies possess strong technological capabilities in fields such as microelectronics, lithography, and packaging technology, which enable them to continuously drive the development of semiconductor technology.

2.3.2 **Materials and Equipment**: Japan holds an important position in the field of semiconductor materials and equipment, with related companies such as Tokyo Electron, Shin-Etsu Chemical, and Sumco holding leading positions in the global market.

2.3.3 **Diversified Applications**: Japan's semiconductor industry covers multiple application areas such as consumer electronics, automotive electronics, and industrial control, and has formed a wide market demand.

2.4 South Korea

2.4.1 **Leading position in memory chips**: Samsung Electronics and SK Hynix hold leading positions in the global DRAM and NAND Flash markets, possessing strong technological and production capacity advantages.

2.4.2 **System-on-a-Chip (SoC)**: South Korean companies also perform well in system-on-a-chip (SoC) and application processor (AP). Samsung's Exynos series and Qualcomm's Snapdragon series are competitive in the global market.

2.4.3 **R&D Investment**: The South Korean government and enterprises continue to invest in semiconductor technology and process R&D to promote technological upgrades and market expansion.

2.5 Europe

2.5.1 **Expertise**: European companies such as Infineon, STMicroelectronics, and NXP possess expertise and market advantages in automotive electronics, industrial automation, and IoT chips.

2.5.2 **Government Support**: European governments support the development of the semiconductor industry and promote technological innovation and industrial upgrading. The EU also promotes the localization and self-sufficiency of semiconductor production.

2.5.3 **Research Resources**: Europe possesses abundant research resources and innovation capabilities, providing crucial support for the continued development of semiconductor technology.

2.6 China

2.6.1 **Technological catch-up**: Companies such as Huawei and SMIC have invested heavily in technological research and development, striving to narrow the technological gap with leading global companies.

2.6.2 **Strong market demand**: China is the world's largest semiconductor market, benefiting from huge demand from consumer electronics and industrial applications.

2.6.3 **Government Support**: The Chinese government strongly supports the development of the semiconductor industry, has introduced a number of policies and funds to support it, and actively promotes the localization and self-reliance of the semiconductor industry chain.

While countries have different policy goals and priorities due to their varying national circumstances, they can generally be categorized into four types based on their main policy visions: addressing future challenges, pursuing global leadership, promoting economic growth, and strengthening basic research to drive national development (Ministry of Science and Technology, 2019) . Countries with a vision focused on addressing future challenges are primarily Asian, including Japan, South Korea, Singapore, and mainland China; those aiming for global leadership are mainly European, including Germany, Switzerland, and Sweden; those prioritizing economic growth are primarily Denmark, Finland, and Australia; and those emphasizing strengthening basic research are mainly the Netherlands and the European Union.

From the foregoing, we can understand that the policy directions of various countries are generally similar, aiming at the development of talent, regulations and innovation ecosystems, and the resolution of socio-economic issues. While countries and economies may have slightly different visions after considering their own unique characteristics, leading to variations in development strategies, implementation measures, and key areas, the overall direction remains largely the same.

3. Research Design

3.1 Research Questions

A nation's control over the core of the semiconductor supply chain—including advanced manufacturing processes, product innovation, and sales markets—has a crucial impact on the global economic system, political strategies, trade relations, and industrial layout. However, past literature has primarily focused on the impact of geopolitical tensions on global supply chains and the adjustment strategies of multinational corporations, lacking research on effective supply chain management strategies for upstream, midstream, and downstream semiconductor companies in Taiwan. This includes aspects such as identifying key influencing factors and balancing regionally diversified supplier strategies. Therefore, this paper explores the following question: Given Taiwan 's crucial position, what are the response strategies for semiconductor companies in a climate of escalating geopolitical tensions?

3.2 Selection of Research Methods

Because numerous factors influence the future development of

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Taiwan's semiconductor industry, predictions cannot be made based on a few quantitative data points. Furthermore, the past and present contexts differ; the globalized production practices of the past have reversed in recent years, making it impossible to predict future trends using past data. In addition, the future development of Taiwan's semiconductor industry is currently under high uncertainty, making it difficult to pinpoint the direction of international political events, such as the end date of the Russia-Ukraine war or the future development of the US-China trade war. This study aims to explore the key factors influencing Taiwan's semiconductor industry to deduce the potential future challenges the industry may face.

Forward-looking research methods must be aligned with target setting, and the choice of research methods is also influenced by resources, such as budget, expert feasibility, policy support, implementation timeline, and technological foundation. Contextual analysis is suitable for long-term environments with highly uncertain future conditions and complex external factors. It covers various possible future development scenarios and describes each scenario, greatly reducing the probability of unexpected events and extending the scope of strategic thinking, enabling governments or enterprises to have more flexible and adaptable strategies. Therefore, this paper selects contextual analysis from the field of forward-looking technology research to address different situations and predict future development trends.

"Scenario" refers to the possible script, outline, or story content of a dramatic plot development (Porter et al., 1991) ; while scenario analysis is essentially an analysis of how a dramatic event occurs and evolves. Therefore, the essence of scenario analysis is to construct various possible future situations based on a narrative style, then discuss the uncertainties and impacts, and formulate contingency plans. Thus , Yu Xujiang (1998) argues that scenario analysis is about providing an integrated description of future scenarios and using it as a basis for decision-making.

However, given the complexity of the real-world environment and the scarcity of objective data, scenario analysis requires collaborative judgment from multiple experts across different fields. This collaborative process synthesizes usable information and simulates several scenario scenarios. Through these simulations, decision-makers gain a clearer understanding of potential future situations. Sufficient background knowledge enhances their ability to make informed judgments, leading to more successful decisions. Only by combining the experience and wisdom of experts from various fields and utilizing all available objective information, employing a systems thinking approach to make judgments, can the predicted future scenarios serve as a reliable basis for decision-making. The focus of this method should be on fully revealing its inherent uncertainty, not only in prediction and forecasting but also in exploring various possible future scenarios.

3.3 Scenario Analysis Process

This paper adopts the most common SRI scenario analysis method , based on Wack (1985) , Porter (1991) , Schwartz The views of (1996) et al . can be mainly divided into the following six steps:

3.3.1 Determining the "Decision Focus" of Scenario Simulation: The decision focus plays a crucial role. If the focus is too broad, it will be difficult to concentrate, making it hard for experts to reach a consensus during the discussion. Conversely, if the issue is set too narrowly, the corresponding external environmental influences will be relatively simple, making it difficult for the scenario simulation to extend and develop.

3.3.2 Identify "Key Decision Factors": Decision factors refer to factors that influence the development of a decision issue. In practice, experts are usually asked to brainstorm possible decision factors for the originally set decision issue. However, the initial decision factors are often diverse and may be very similar. Therefore, it is necessary to discuss and remove unnecessary decision factors, and merge similar decision factors, redefining them as key decision factors to form the basis for subsequent scenario deduction.

3.3.3 Exploring "External Drivers": In addition to focusing on discussions of key internal decision-making factors, it is also necessary to consider the forces in the external environment that will influence the outcome of future events. These complex external influences interact with each other to shape the future situation. Therefore, it is necessary to clarify the external influences that will impact the originally intended decision-making issues.

3.3.4 Select “Contextual Logic”: Next, classify the external drives discussed in step 3 according to their impact and uncertainty, and present them in the matrix.

3.3.5 Writing the Context Content and Context Story: After constructing the context logic, combine all possible context combinations and describe each aspect of the context through text.

3.3.6 Decision-Making Implications: After writing the scenarios, analyze the content of each scenario story to understand the implications of the decision-making issues under the same circumstances, including opportunities and threats. At the same time, examine the correlation between the plot's content and key decision-making factors to facilitate further in-depth analysis.

4. Research Process and Data Collection

4.1 Research Process

Due to the difficulty in coordinating the schedules of experts, this study adopted a two-stage expert meeting approach. The first stage involved a 3-hour meeting with 8 experts, while the second stage involved a 2-hour meeting with 4 experts. Since the experts were located in different regions, the meeting was conducted online, allowing each expert to participate in a familiar and comfortable environment. Due to the short meeting time, the expert meeting process could not follow the aforementioned scenario analysis steps. Therefore, the process was simplified to: 1. Discussion of key factors and external drivers; 2. Scenario simulation; and 3. Strategic recommendations for the proposed scenario.

The first phase primarily discussed the key factors and external drivers influencing Taiwan's semiconductor industry, inviting experts to share their perspectives on these factors that may impact the industry's future. The second phase involved experts simulating potential scenarios for Taiwan's semiconductor industry over the next five years, using optimistic, neutral, and pessimistic viewpoints. To ensure focus, the PEST model was applied to each scenario, and experts explored the political, economic, social, and technological factors representing optimism and pessimism. Finally, experts proposed countermeasures and suggestions for each of the three scenarios. Following the meeting, the content from both phases was organized using the aforementioned steps, including quadrant

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selection for external drivers and scenario descriptions.

4.2 Data Collection

The data in this paper mainly comes from expert opinions. According to Chen Zeyi (2011) , situational analysis and prediction are usually conducted through expert meetings, with the expert group consisting of elite representatives from various fields. The number of participants in the meeting is generally 8 to 12, and the participants should include experts from various different fields. In this study, a total of 25 invitations were sent out, 12 experts agreed to attend, 2 did not respond, and 11 declined. The qualifications of the experts who agreed to attend the expert meeting are shown in Table 1.

Table 1 List of experts

Serial Number	category	Employer	job title	Work experience
1	government agencies	Executive Yuan Level 1 agencies	Vice Chairman	42 years
2	Market research institutions	legal entity	researcher	18 years
3	Market research institutions	legal entity	manager	22 years
4	Schools and Institutions, Polytechnics	Colleges and Universities	Vice Dean	7 years
5	Schools and Institutions, Polytechnics	Colleges and Universities	professor	16 years
6	School of Institutional Management	Colleges and Universities	professor	25 years
7	School of Institutional Management	Colleges and Universities	professor	25 years
8	School of Institutional Management	Colleges and Universities	Associate Professor	20 years
9	Industry professionals	IC design company	manager	23 years
10	Industry professionals	IC design company	manager	10 years
11	Industry professionals	IDM Factory	Section Chief	27 years
12	Industry professionals	Management Consulting Co., Ltd.	CEO	18 years

Source: This article is compiled from various sources.

5. Research found

This article organizes the content of the expert meeting using the SRI scenario analysis method. After initially determining the decision-making issues, the PEST framework is used to identify key decision factors and external drivers. Then, each external driver is categorized on the uncertainty axis to determine its impact and uncertainty quadrant. The next step involves story writing, selecting three scenarios: optimistic, most likely, and pessimistic, representing icing on the cake, a mixed bag, and technological stagnation, respectively. Finally, based on these three scenarios, the opportunities, threats, and strategic needs of the government and the semiconductor industry are identified.

5.1 Scenario Deduction Steps

5.1.1 Determining the "Decision Focus " in Scenario Simulation Strategic planning for Taiwan's semiconductor industry over the next five years. It requires first identifying development opportunities for Taiwan's semiconductor industry between 2020 and 2030, and then formulating corresponding strategic plans. Under this premise, this article sets the decision-making issue as: "What external factors and trends will influence the development of Taiwan's semiconductor industry over the next five years?"

5.1.2 Identify the "key decision factors" and " external drives ". Identifying key decision factors (KDF) involves finding all the critical factors that will influence decision-making. In addition to key factors, it's essential to consider the external forces that might affect the outcome of future events. This stage allows experts to speak freely, aiming to list all factors relevant to the decision-making process. At the meeting, experts presented key factors and external influences affecting Taiwan's semiconductor industry. To better summarize expert opinions, Table 2 categorizes the key decision factors and external influences proposed by experts using the PEST model.

Table 2 Key Factors and External Influences Affecting Taiwan's Semiconductor Industry

Surface	Key factors	External influence
technology	Process technology	Other countries are developing non-EUV technologies
		Breakthrough in manufacturing process technology to 1 nanometer
		GAA, Quantum Bit advanced process technology development
	compound semiconductors	Development of compound semiconductors

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	Changes in end-user demand	5G, AI, electric vehicles, IoT, industrial automation
	semiconductor materials	Superconductor industry development
	Semiconductor equipment	Development of semiconductor equipment
	Instruction set architecture	RiscV architecture development
politics	Geopolitics	US-China trade war
		Cross-Strait Relations
		US talent restriction policy
	Government subsidies	Taiwan government subsidies for the semiconductor industry
		Taiwan government subsidies for semiconductor equipment
		Taiwanese government subsidies for the IC design industry
		The Chinese government's substantial subsidies to the semiconductor industry
	Environmental sustainability	Net zero carbon emissions
economy	Market demand	The impact of inflation on the speed of economic recovery
	Investment Environment	Industry investment in semiconductor technology
		Industry investment in semiconductor production capacity
society	Talent	talent shortage
		Talent siphon effect
		The semiconductor industry needs visionaries to lead it.
		Semiconductor industry companies have well-established management systems.
	Energy shortage	Water and electricity shortage
		clean energy supply

Source: This article is compiled from various sources.

5.1.3 Select "Contextual Logic"

Next, the external driving forces discussed in step 2 are classified according to "impact" and "uncertainty" and presented in the "impact" and "uncertainty" matrices.

5.1.4 Writing Contextual Content and Contextual Stories

Based on the results summarized in step three, this study selects the most important factors from politics, economy, society, and technology to simulate the situation.

In terms of politics, there are two situations: stability and conflict. The most frequently mentioned issues in expert interviews are the US-China trade war and cross-strait relations. Therefore, political stability means that the US-China trade war is easing and cross-strait relations are peaceful; political conflict means that the US-China trade war is intensifying and cross-strait relations are deteriorating.

In terms of the economy, the current situation is characterized by inflationary effects from COVID-19 and the Russia-Ukraine conflict, resulting in poor economic conditions, slowing consumption, and a decline in demand for semiconductors. Therefore, the economic situation can be divided into two scenarios: rapid economic recovery and slow economic recovery.

In terms of the social aspect, the experts repeatedly discussed the current shortage of semiconductor talent, thus the social aspect can be divided into the reduction of the talent gap and the increase of the talent gap.

Finally, in terms of technology, there are two scenarios: breakthroughs and stagnation. Taiwan's most important semiconductor industry focuses on IC manufacturing, and the process technology of wafer manufacturing is the most discussed topic at expert meetings. Therefore, a technological breakthrough means that Taiwan has broken through the 1-nanometer limitation in wafer manufacturing and is leading other countries in technology. Stagnation, on the other hand, means that Taiwan has been unable to break through the 1-nanometer limitation in wafer manufacturing, while other countries have successfully developed other non-EUV process technologies, and Taiwan no longer maintains its leading position in wafer manufacturing technology.

The scenarios are shown in Table 3. This paper selects the three most optimistic, most likely, and most pessimistic scenarios, namely, adding to the good, having both advantages and disadvantages, and technological stagnation.

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Table 3 Context Selection

politics	economy	society	science and technology	Context Name	Remark
Stablize	Rapid economic recovery	Reduced talent gap	Breakthrough	Adding flowers to brocade	Most optimistic
conflict	Slow economic recovery	Increased talent shortage	Breakthrough	Half good and half bad	Most likely
conflict	Slow economic recovery	Increased talent shortage	Stagnation	Technological stagnation	Most pessimistic

Source: This article is compiled from various sources.

5.1.4.1 **Adding icing on the cake:** In an optimistic scenario, the US-China trade war eases, and the US relaxes its sanctions against China. This allows Taiwanese semiconductor manufacturers to continue shipping to China, leading to soaring profits. The supply chain returns to a globalized model, with production occurring in the lowest-cost locations. Inflation thus slows, economic recovery accelerates, and consumer demand for 3C electronic products increases. The booming development of emerging technologies such as self-driving cars, 5G, and AI also significantly boosts semiconductor demand. Furthermore, Taiwan's wafer fabs have broken through the 1-nanometer process technology barrier, attracting many international talents to Taiwan to research semiconductor-related technologies, thus reducing the talent shortage. Technological leadership coupled with stable cross-strait relations also attracts substantial investment to Taiwan's semiconductor industry.

Table 4. Analysis of the Situational Connotation of " Adding Flowers to Brocade"

Context Name	Adding flowers to brocade
Advantages	● Wafer fabs achieve breakthrough in 1-nanometer process technology ● It boasts the world's most complete semiconductor industry cluster and professional division of labor.
Disadvantages	● Domestic market demand is small, and specifications are usually set by European and American countries . ● IC design IP, key semiconductor equipment, and materials are controlled by foreign companies.
Chance	● Emerging applications such as IoT , self-driving cars, and 5G ● Increased international talent and investment are accelerating the development of advanced manufacturing processes .
threaten	● Korea and China continue to develop semiconductors. ● Development of superconductors and other advanced process technologies
Government strategy	● for emerging applications such as IoT , self-driving cars, and 5G. ● Relax international talent immigration policies to encourage talent from all countries to come to Taiwan to research semiconductors . ● Formulate policies to support domestic semiconductor equipment and materials suppliers, such as requiring joint ventures to be established if a certain percentage of equipment and materials are imported from abroad.
Industry Strategy	● Strengthen the deployment of emerging applications ● Expand the hiring of foreign nationals

Source: This article is compiled from various sources.

5.1.4.2 **A Mixed Bag:** The most likely scenario is a continuation of the current situation. The US-China trade conflict intensifies, and the US imposes more and more bans on China's semiconductor industry. China urgently needs to find alternative solutions and develop another set of technologies to avoid being strangled by the US. Although China's technology cannot catch up with the US in the short term, the US and Chinese semiconductor industries have clearly formed two different ecosystems. Due to Taiwan's leading technology in advanced wafer manufacturing processes, both the US and China are actively courting Taiwan. Taiwanese semiconductor companies have no choice but to cooperate, developing two supply chains—one for China and one outside of China—leading to a significant increase in demand for talent. Tariffs and the two production models have caused costs to rise, and inflation is worsening, thus reducing semiconductor demand.

Table 5. Analysis of the Contextual Implications of a Balanced Situation (Equal Advantages and Disadvantages

Context Name	Half good and half bad
Advantages	● Wafer fabs achieve breakthrough in 1-nanometer process technology

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	● It boasts the world's most complete semiconductor industry cluster and professional division of labor. ● Taiwan's semiconductor industry has a complete multinational supply chain.
Disadvantages	● Domestic market demand is small, and specifications are usually set by European and American countries. ● Foreign companies control IC design IP, key semiconductor equipment, and materials. ● Semiconductor talent shortage
Chance	● Operating in both the US and Chinese markets
threaten	● China poaching talent from Taiwan's semiconductor industry ● China is copying Taiwan's semiconductor technology. ● Countries are actively developing their domestic semiconductor industry chains.
Government strategy	● Restricting Taiwanese semiconductor industry talent from developing in China ● To cultivate a large number of semiconductor talents, increase scholarships and subsidies, and attract foreign students to study semiconductor- related majors in Taiwan.
Industry Strategy	● Supply chain diversification risk ● Avoid customer over-concentration ● Promote industry-academia collaboration and strengthen practical training in semiconductors. ● Tuition fees will be subsidized for students majoring in semiconductor-related fields, and the tuition will be repaid as a fixed percentage of their salary after employment.

Source: This article is compiled from various sources.

5.1.4.3 **Technological Stagnation:** In the most pessimistic scenario, the US-China trade conflict deepens, and the US imposes increasing restrictions on China. Taiwanese semiconductor companies suffer declining performance due to their inability to export to China. To counter the US, China invests heavily in its domestic semiconductor industry, building numerous wafer fabs, leading to an oversupply of mature process wafers, further reducing profits for Taiwanese semiconductor companies. Increased export restrictions also raise costs, accelerate inflation, slow economic recovery, and decrease market demand for semiconductors. Meanwhile, other countries have developed advanced non-EUV process technologies, and Taiwanese semiconductor companies are actively researching and developing advanced processes, leading to a surge in demand for talent. However, due to tense cross-strait relations, declining semiconductor demand, and reduced investment in Taiwan's semiconductor industry, insufficient R&D funding results in stagnation of advanced semiconductor process technology.

Table 6. Analysis of the Contextual Implications of Technological Stagnation

Context Name	**Technological stagnation**
Advantages	● It boasts the world's most complete semiconductor industry cluster and professional division of labor. ● Taiwan's semiconductor industry already has a complete multinational supply chain.
Disadvantages	● Wafer fabs lag behind other countries in process technology. ● Domestic market demand is small, and specifications are usually set by Europe, America, and mainland China. ● Foreign companies control IC design IP, key semiconductor equipment, and materials. ● Semiconductor talent shortage
Chance	● Developing in the field of non -silicon-based semiconductors
threaten	● China poaching talent from Taiwan's semiconductor industry ● China steals Taiwan's semiconductor technology ● Countries are actively developing their domestic semiconductor industry chains. ● China's semiconductor industry is characterized by low-price competition.
Government strategy	● Increase subsidies for Taiwan's semiconductor industry ● Increase subsidies for the compound semiconductor industry ● Leveraging the advantages of Taiwan's supply chain to strengthen Taiwan's semiconductor industry ● Help semiconductor companies obtain export licenses for their products (non-military, non-defense).
Industry Strategy	● Strengthen the layout and investment in IC design and other semiconductor industry chains. ● Strengthen the layout of the compound semiconductor industry ● Cost control needs to be strengthened

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	● Supply chain diversification risk ● Avoid customer over-concentration

Source: This article is compiled from various sources.

5.1.5Decision-making implications

After completing all the scenario revisions, this paper analyzes the decision implications based on the three scenarios mentioned above. For each scenario, a SWOT analysis is conducted, and corresponding strategic recommendations are provided for the government and industry. The paper summarizes how Taiwan's semiconductor industry can properly manage its resources to seize opportunities and avoid threats in order to achieve success.

SWOT analysis, proposed by Ken Adrew in 1971, is considered the best method for determining niche strategies, enabling organizations to leverage their strengths to develop opportunities and defend against their weaknesses and environmental threats. Taiwan's semiconductor industry began development in 1976. In its early stages, it built a complete semiconductor supply chain through innovative business models of specialization and contract manufacturing, allowing Taiwan to secure a place among the top two global semiconductor companies. However, following the US-China trade war and the COVID-19 supply chain crisis, countries recognized the importance of self-sufficiency in semiconductors. The US, Europe, South Korea, Japan, and mainland China are actively building their domestic semiconductor production systems. This international trend has significantly impacted Taiwan's semiconductor industry. This paper analyzes the four dimensions of Taiwan's semiconductor industry—Strengths, Weaknesses, Opportunities, and Threats—based on newspapers, magazines, and research reports, to examine the current competitiveness of Taiwan's semiconductor industry, as shown in Table 7.

Table 7 SWOT Analysis of Taiwan's Semiconductor Industry

Strength	Weakness
1. Leading the world in wafer foundry technology and scale 2. It boasts the world's most complete semiconductor industry cluster and professional division of labor. 3. Taiwan's semiconductor industry has a complete multinational supply chain.	1. Domestic market demand is small, and specifications are usually set by Europe, America, and mainland China. 2. IC design IP, key semiconductor equipment, and materials are all controlled by foreign companies. 3. Semiconductor talent shortage
Opportunity	**Threat**
1. Countries are actively inviting Taiwanese businesses to set up factories in their local markets in pursuit of localized supply chains. 2. A complete semiconductor industry chain has attracted international manufacturers to establish R&D centers. 3. The US-China trade war and COVID-19 have led to a shift in orders.	1. The Chinese government provides substantial subsidies to support the semiconductor industry, resulting in lower manufacturing costs for manufacturers compared to Taiwan. 2. China poaching semiconductor talent from Taiwan 3. South Korea is strengthening its semiconductor industry with state power, and its advanced process technologies could become a competitor to Taiwan. 4. The invitations extended by various countries to TSMC to set up factories in their countries of origin may lead to an outflow of technology and talent.

Source: This article is compiled from various sources.

6. Key Factors, Contexts, and Strategies

6.1 Key Influencing Factors

Aforementioned SWOT analysis of Taiwan's semiconductor industry identified the biggest threat as the aggressive development of semiconductor industries by countries like mainland China and South Korea, making them strong competitors. Furthermore, the future challenges facing Taiwan's semiconductor industry included geopolitical tensions, international competition, talent shortages, and technological breakthroughs. During the expert meeting, experts emphasized key factors influencing Taiwan's semiconductor industry, including its strategic geographical location, process technology, R&D talent, and policy support—qualities consistent with the data gathered in the industry background.

Based on scenario simulations, the possible scenarios for the next five years are roughly equal in terms of advantages and disadvantages: breakthroughs in wafer fabrication technology; increased talent shortage; integration of upstream, midstream, and downstream supply chains; and geopolitical influences. Strategic recommendations are as follows: For governments, efforts should be made to address the talent shortage and actively seek product export licenses; for enterprises, continuous R&D and innovation are crucial, along with actively recruiting R&D talent, diversifying supply chain risks, and proactively managing operations to mitigate geopolitical impacts.

6.2 Contextual Exploration

This paper proposes three scenarios: the optimistic scenario — adding icing on the cake, the most likely scenario — a mixed bag, and the pessimistic scenario — technological stagnation.

Political stability allows globalization to continue, enabling the semiconductor industry to choose the most economically efficient countries for production, maximizing profits for all nations and providing consumers with cheaper products. Political conflict, however, leads to trade barriers and increased tariffs, preventing companies from achieving maximum profits and forcing consumers to spend more. While the US-China trade war might politically benefit

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Taiwan, China's massive semiconductor demand and its status as a major export market for Taiwan's semiconductor industry mean that continued US sanctions against China will inevitably lead to a decline in Taiwan's semiconductor exports. In an optimistic scenario, global political stability is paramount. However, the ongoing Ukraine-Russia conflict and the US-China trade war are most likely to be linked to a pessimistic scenario: global political conflict and mutual checks and balances among nations.

Whether or not there are technological breakthroughs is a less significant variable. In the optimistic and most likely scenario, Taiwan's process technology continues to lead the world, maintaining its leading position in wafer foundry technology, and Taiwan's semiconductor industry continues to attract significant investment. In the pessimistic scenario, Taiwan's wafer foundry technology may stagnate or be surpassed by other countries. While the increase or decrease in the talent gap and the speed of economic recovery will affect Taiwan's semiconductor industry, their impact will be less significant than the first two factors. Regardless of the scenario, the talent gap in the semiconductor industry will persist, and attracting international talent while retaining Taiwanese talent will be a major challenge in all three scenarios. Although economic recovery will affect the size of semiconductor demand, in the long run, humanity will continue to develop new technologies, such as electric vehicles, IoT, 5G, and the metaverse; therefore, the future demand for the semiconductor industry will only increase.

6.3 Strategy

The speed of economic recovery and the atmosphere of international political situation are beyond the control of the Taiwanese government. Among the four variables of politics, economy, society and technology, the most controllable are technological breakthroughs and the improvement of the talent shortage problem. Therefore, strategies are being explored for these two major issues.

6.3.1 Technological Breakthrough

While TSMC currently leads the world in wafer fabrication technology, its process technology is nearing the physical limit of 1 nanometer. Therefore, it urgently needs to plan ahead to maintain its leading position in future process technologies. Technologies currently under development include FinFET, VTFET, and RibbonFET .

Besides breakthroughs in manufacturing processes, materials technology is another major battleground. In recent years, semiconductor materials have evolved from first-generation silicon, to second-generation gallium arsenide (GaAs)/indium phosphide (InP), and now to third-generation compound semiconductors primarily composed of gallium nitride (GaN) and silicon carbide (SiC). This material shift allows transistors to withstand higher voltages and achieve faster processing speeds, effectively improving the performance of individual transistors. Silicon carbide (SiC) materials help improve vehicle performance, and their application in electromechanical systems can reduce vehicle size and weight. With the increasing demand for electric vehicles in the future, the demand for third-generation semiconductors will also rise significantly.

In the semiconductor equipment sector, Taiwan relies heavily on imports from other countries, and the government has rarely implemented policies to strengthen this sector. Referring to South Korea's example, where foreign companies are required to establish joint ventures when their equipment imports reach a certain percentage, Taiwan could perhaps adopt a similar approach to enhance its national semiconductor equipment reserves.

6.3.2 Talent replenishment

Strengthening basic science is a major priority. Taiwan should cultivate more talent in basic sciences such as physics and mathematics. When Moore's Law is about to be broken and manufacturing processes need to break through the physical limit of 1 nanometer, more talent in basic science will be needed to develop new technologies.

Talent development and education are also very important. The government can promote simple semiconductor-related courses so that more people can learn relevant knowledge. For example, many wafer manufacturing plants lack equipment technicians, who usually only need to learn about the equipment.

Taiwan is currently facing a declining birth rate, and the shortage of manpower can be addressed by recruiting from abroad. The government should relax its policies on international talent immigration to encourage talent from various countries to come to Taiwan and work in the semiconductor-related industry chain. Companies should also increase their hiring of foreign personnel. Improving scholarship subsidies is another area that deserves attention. Currently, international students from countries such as India and Vietnam primarily choose South Korea and Singapore as their study destinations in Asian countries. The government needs to increase scholarship subsidies to attract outstanding international students to study semiconductor-related disciplines in Taiwan.

As for businesses, they can collaborate with schools to promote industry-academia cooperation, strengthen practical semiconductor training, or subsidize tuition fees for students majoring in semiconductor-related fields, with a fixed percentage of their salary repaid after employment. These measures would all contribute to the cultivation of semiconductor talent. Ultimately, both the government and businesses must work together to create a favorable working environment and competitive salaries, encouraging semiconductor talent to stay in Taiwan and contribute to the development of Taiwan's semiconductor industry.

7. Conclusion

7.1 Summary of this article

The semiconductor industry is playing an increasingly important role internationally, and Taiwan's leading position in the global semiconductor industry underscores its undeniable global influence. A review of newspaper and magazine reports, as well as expert conference findings, indicates that the most significant factors influencing the current state of Taiwan's semiconductor industry are talent and technology. Semiconductors are a knowledge-intensive industry, and Taiwan's talent supply has consistently failed to meet industry demands. This talent shortage hinders the continuous development of new technologies. Furthermore, semiconductors are also a technology-intensive industry, requiring continuous innovation and research to maintain a competitive edge. Therefore, reducing the talent gap and continuously developing new technologies are the primary challenges for Taiwan's semiconductor industry.

With the booming development of Taiwan's semiconductor industry, the Ministry of Economic Affairs should provide subsidies for emerging applications such as IoT, self-driving cars, and 5G to proactively secure a competitive advantage. Furthermore, the development of new technologies and applications requires a large pool of talent. The National Development Council, the Ministry of Labor, and relevant ministries should relax policies on international talent recruitment to encourage researchers from around the world to come to Taiwan to study semiconductors. The Ministry of Economic Affairs should also formulate policies to support local semiconductor equipment and materials suppliers. If a certain percentage of

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equipment and materials are imported from abroad, joint ventures should be established to address the gaps in equipment and materials in Taiwan's semiconductor supply chain.

Based on the scenario simulation results in this paper, the most likely scenario for Taiwan's semiconductor industry in the next five years is a mixed bag, with international political conflicts, a growing talent gap, and a difficulty in achieving further technological breakthroughs. Given the turbulent international situation, including the outbreak of the Ukraine-Russia war in 2022 and the escalation of the US-China trade war, the previous model of globalized division of labor is no longer viable. Diversifying the supply chain and avoiding the concentration of revenue in a few customers will be a major focus.

If the US continues to tighten its restrictions on China, companies with supply chains and customers in China will face significant challenges. Businesses should diversify their supply chains to mitigate risk and avoid over-reliance on a single customer. Furthermore, due to increased demand for talent, companies can consider industry-academia collaboration to strengthen practical semiconductor training and subsidize tuition fees for students in semiconductor-related fields, thereby attracting more talent to the semiconductor industry. As China actively develops its domestic semiconductor industry to avoid US restrictions, it will require a large pool of talent. The Taiwanese government may need to legislate to restrict Taiwanese semiconductor industry talent from working in mainland China. The National Development Council, the Ministry of Labor, and other relevant ministries also need to cultivate a large number of semiconductor professionals, increase scholarships and subsidies, and attract foreign students to study semiconductor-related fields in Taiwan.

Furthermore, given the current global economic recession, cost control is also crucial, with many major US tech companies opting for layoffs to reduce costs. Therefore, for Taiwan's semiconductor industry facing the next five years, in addition to attracting talent and continuing to develop new technologies, it also needs to pay close attention to supply chain and customer diversification, as well as cost control.

7.2 Contributions of this paper

The semiconductor industry is Taiwan's most important industry, hence the abundance of research on it. While recent studies have explored the impact of US-China trade tensions, COVID-19, and the Russia-Ukraine conflict on Taiwan's semiconductor industry, this paper differs in that it presents three potential future scenarios for the Taiwanese semiconductor industry and conducts SWOT analyses for each, offering recommendations to the government and industry. Government departments such as the Ministry of Science and Technology, the Ministry of Economic Affairs, and the National Science Council can refer to the expert meeting's recommendations for policy planning. Businesses can also consult the expert meeting's suggestions for strategic planning.

7.3 Research Limitations

Taiwan's semiconductor industry has experienced many changes in recent years. The COVID-19 outbreak in 2020 caused a contraction in demand, but unexpectedly, demand surged in 2021, ushering in a peak for the semiconductor industry. Just as everyone was rushing to increase production capacity and build factories, the outbreak of the Russia-Ukraine conflict in 2022 and high inflation caused an economic recession, leaving many IC design companies with huge inventories. Scenario analysis cannot make accurate predictions about short-term changes within 1-2 years; it can only provide a description of scenarios that may occur in the medium to long term (5-10 years).

7.4 Recommendations for Future Research

Regarding the directions for future research, the following two points are proposed:

7.4.1 This study provides an overview of Taiwan's entire semiconductor industry, covering IC design, IC manufacturing, IC packaging, and testing. The scope is very broad, and future studies may focus on more in-depth scenarios for individual industry chains.

7.4.2 The technological layout of the semiconductor industry often takes more than 10 years. Therefore, it is recommended that subsequent related research may extend the time frame even further, so that companies can respond earlier and make technological layouts.

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