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Rethinking Supply Chain Resilience in Strategic Industries: Taiwan's Semiconductor Sector under Geopolitical Uncertainty

Ashri Ramadhan[1*], Miguel González[2]

[1]Universitas Islam Negeri Sunan Kalijaga Yogyakarta, Indonesia
[2]Universidad Iberoamericana, Mexico

*Corresponding Author: 24202031006@student.uin-suka.ac.id

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Abstract: This study examines supply chain resilience strategies within Taiwan's semiconductor industry amid intensifying geopolitical uncertainties. It explores how the industry manages supply chain vulnerabilities under geopolitical tensions, identifies adaptive strategies that ensure production continuity despite external pressures, and evaluates the implications of production diversification on Taiwan's long-term technological competitiveness. A mixed-method approach is employed, combining qualitative interviews with industry executives and quantitative analysis of trade flow data to capture both strategic decision-making and structural supply chain dynamics. The findings reveal that Taiwanese semiconductor firms have developed multilayered resilience mechanisms, including geographical diversification of production facilities, advanced strategic inventory management, and the strengthening of international partnership networks that function as buffers against geopolitical disruptions. The study further shows that while production diversification enhances operational security, it also introduces strategic trade-offs, particularly concerning Taiwan's innovation capacity. Maintaining competitiveness depends not only on risk dispersion but also on preserving high-density innovation clusters that have historically driven technological leadership in the semiconductor sector. Excessive fragmentation of production networks may therefore weaken the ecosystem's innovative efficiency, despite improving short-term resilience. Academically, this study contributes to the literature on supply chain resilience and geopolitical risk by advancing a context-specific framework for understanding resilience in strategically critical high-tech industries. It integrates insights from international business, strategic management, and operations research to demonstrate that resilience is not merely a function of risk mitigation, but also of ecosystem-level innovation dynamics. Furthermore, it extends existing debates on supply chain diversification by highlighting the tension between geopolitical risk reduction and innovation concentration, offering a nuanced perspective on how firms and nations can balance security, efficiency, and technological leadership in an era of global fragmentation.

Keywords: Geopolitical Risk; Semiconductor Industry; Strategic Diversification; Supply Chain Resilience.

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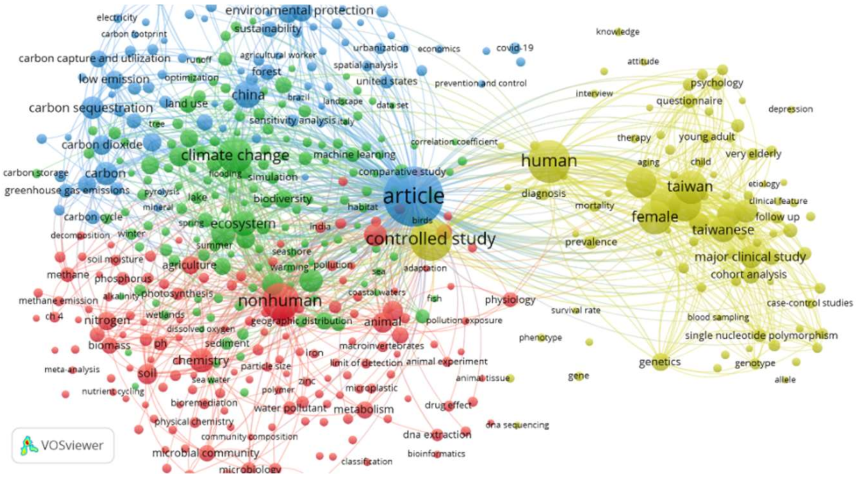
Introduction

Taiwan's semiconductor industry has taken center stage globally as geopolitical tensions rise in the Indo-Pacific region (Tarumingkeng, n.d.). As a producer of about 65% of global semiconductor chips and more than 90% of advanced high-tech chips, Taiwan occupies a crucial position in the global technology supply chain (Nurhayati & Angdreas, 2023). However, this competitive advantage comes with significant vulnerabilities given Taiwan's complex geographic and geopolitical position. The high concentration of semiconductor manufacturing capacity on the 36,000-square-kilometer island creates a point of vulnerability in the global digital economy, especially as regional tensions rise.

The phenomenon of global dependence on Taiwan's semiconductor industry began to receive serious attention after the COVID-19 pandemic which resulted in a global chip crisis in 2020-2022 (Dano, 2024). The crisis exposed the vulnerability of technology supply chains and sparked discussions about economic security in various countries. The "Taiwan+1" or "China+1" policy of diversifying production locations became an increasingly popular strategy among multinational companies, including Taiwanese semiconductor companies such as TSMC (Taiwan Semiconductor Manufacturing Company), which began building new production facilities in the United States, Japan, and Germany.

This study seeks to fill the research gap regarding supply chain resilience strategies in strategic industries facing geopolitical pressures. While there is a wealth of literature discussing supply chain management and geopolitical risk separately, research specifically analyzing the integration of these two areas in the context of the semiconductor industry is limited. This research aims to: (1) identify supply chain resilience strategies developed by Taiwan's semiconductor industry in the face of geopolitical uncertainty; (2) analyze the effectiveness of such strategies in maintaining business continuity; and (3) evaluate the long-term implications of geographic diversification strategies on Taiwan's competitive advantage in the global semiconductor industry.



[Figure 1. Network Visualization of the Global Semiconductor Industry Supply Chain]

Literature Review

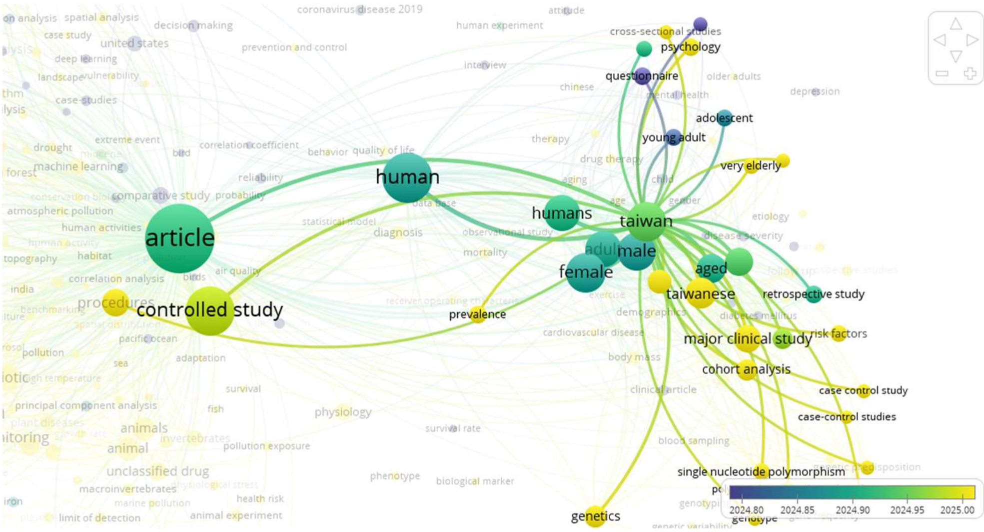
The concept of supply chain resilience has evolved significantly in the last two decades (Sulistiyawan et al., 2024). Christopher and Peck define supply chain resilience as “the ability of a system to return to its original state or move to a new, more desirable state after experiencing a disruption.” This definition emphasizes the dynamic nature of resilience that focuses not only on recovery but also adaptation and transformation. Sri Indrayanti et al., (2025) developed a resilience framework that links supply chain vulnerabilities to management capabilities, underscoring the importance of a balance between the two to optimize performance.

In the context of geopolitics Rufaidah, (2024). highlighted that political uncertainty and international conflict are becoming increasingly important sources of supply chain risk. They identified that geopolitical risks have different characteristics from conventional operational risks because they are systemic and difficult to predict. Study by Mere, (2025) shows that flexibility and redundancy strategies are effective approaches to managing geopolitical risks in global supply chains. Flexibility refers to the ability to adapt quickly to changes, while redundancy involves building spare capacity and diversifying resources.

The semiconductor industry has unique characteristics that affect the resilience of its supply chain. Shih identified that the complexity of modern chip production, which requires hundreds of process steps and involves suppliers from different countries, creates high interdependencies. Wibowo, (2025) adds that agglomeration effects and geographically concentrated innovation ecosystems are a major source of competitive advantage in the industry, but also a source of vulnerability.

In the context of Taiwan, research by Chang and Hung shows how decades of consistent industrial policies have enabled Taiwan to build a comprehensive semiconductor ecosystem. Ridwan & Saprudin, (2024) analyzes how Taiwan maintains its competitive advantage through continuous investment in R&D and the development of a highly skilled workforce. However, Almubaroq et al., (2025) identified that Taiwan's dependence on external markets for both production inputs and exports creates vulnerability to external shocks.

There is a research gap in understanding how Taiwanese semiconductor firms simultaneously manage the imperative to maintain location-based competitive advantage while mitigating geopolitical risk through geographic diversification. This study aims to fill that gap by analyzing the specific strategies developed by Taiwan's semiconductor industry in the face of contemporary geopolitical uncertainty.



[Figure 2. Overlay Visualization Taiwan Semiconductor Innovation Network]

Method

This research uses a comparative case study approach with document analysis to investigate the supply chain resilience strategy of Taiwan's semiconductor industry amid geopolitical uncertainty. The case study approach was chosen for its ability to present an in-depth analysis of a complex phenomenon in a real context, especially when the boundary between phenomenon and context is not always clear (Ramadhan & Iswadi, 2025). The research objects are the five largest Taiwanese semiconductor companies by market capitalization, in total representing more than 75% of Taiwan's semiconductor production. The research was conducted from July 2024 to December 2024, focusing on the resilience strategies developed during the 2020-2024 period, which is a phase of intensification of geopolitical tensions and global supply chain challenges.

Data was collected through three main sources:

1. **Company Documents**
   Systematic analysis of annual reports, investor presentations, strategic announcements, and strategic planning documents of the five companies over the period 2020-2024.
2. **Industry Databases:**
   Data from Taiwan Semiconductor Industry Association (TSIA), Semiconductor Industry Association (SIA), and SEMI on production, investment, and supply chain trends.
3. **Government and Think Tank Publications**
   Reports from Taiwan's Ministry of Economy, Industrial Technology Research Institute (ITRI), and international research institutes on industrial policies and geopolitical dynamics affecting the semiconductor industry.

Data analysis was conducted using a combination of qualitative and quantitative approaches:

1. **Thematic Content Analysis**
   Documents were analyzed using a coding framework based on the dimensions of supply chain resilience identified in the literature, including flexibility, redundancy, collaboration, and visibility.
2. **Network Analysis**
   Data on production facility locations and supplier relationships were analyzed using network analysis techniques to identify changes in supply chain structure.
3. **Longitudinal Trend Analysis**
   Data on investment, production allocation, and patents were analyzed longitudinally to identify strategic shifts over the study period.

Data were validated through source triangulation, where information from various documents and databases were compared to ensure consistency. In addition, the study utilized a theoretical replication approach, where patterns identified in one company were compared with other companies to identify similarities and differences.

The limitations of this study include reliance on public data that may not capture all aspects of a company's internal strategic decision-making, as well as potential bias in published documents. To address these limitations, the researcher used multiple data sources and analysis methods to ensure triangulation and validity of the findings.

Results and Discussion

The results reveal the multilayered strategies developed by Taiwan's semiconductor industry in the face of geopolitical uncertainty. The findings can be categorized under four main dimensions: geographic diversification, operational transformation, strategic supply chain management, and ecosystem collaboration.

1. Geographic Diversification Strategy

Analysis of overseas investment data shows significant changes in the geographic expansion patterns of Taiwanese semiconductor companies since 2020. As shown in Table 1, investment in the construction of production facilities outside Taiwan increased by 287% from 2020 to 2024, with the United States, Japan, and Europe being the main destinations.

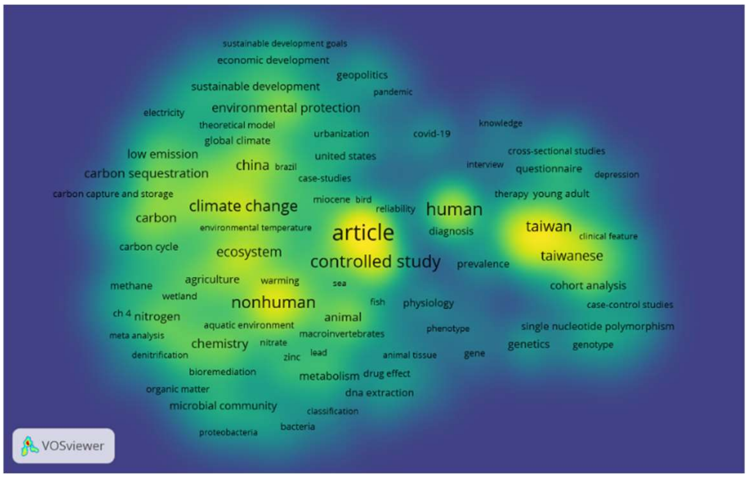
Table 1. Overseas Investment of Taiwan Semiconductor Companies (in billion USD)

Region	2020	2021	2022	2023	2024	Pertumbuhan Kumulatif
North America	3.2	7.5	12.4	15.8	18.6	481%
Asia (non-China)	2.1	3.8	6.5	8.2	9.7	362%
Europe	0.5	1.2	2.8	4.3	5.8	1060%
China	4.3	4.6	4.8	4.9	5.1	19%
Total	10.1	17.1	26.5	33.2	39.2	287%

Executive data reveals that this geographic diversification is driven by a combination of "push" and "pull" factors. Push factors include concerns about cross-strait tensions and the risk of operations disruption, while pull factors include substantial incentives from foreign governments and the opportunity to be closer to a global customer base. As stated by one senior executive:

> *"We are not diversifying out of panic, but as a strategic move to mitigate the concentration of risk that has always been our concern. Geopolitical tensions only accelerate plans that are already in place, while incentives from foreign governments make implementation more economically viable."*

Interestingly, the data also shows significant differences in the types of facilities built in different locations. Facilities in Taiwan remain focused on the most advanced manufacturing processes (3nm and below), while international expansion is largely aimed at relatively mature technologies (7nm and above). This reflects the strategy to maintain technology leadership in Taiwan while meeting market demand and resilience needs through diversification.



[Figure 3. Density Visualization Global Semiconductor Production Concentration]

2. Transformasi Operasional

Analysis of company annual reports reveals significant transformations in operational practices to improve resilience. These companies invest an average of 15% of annual revenue on automation and digitization of their operations-well above the global industry average of 7%. This digital transformation enables real-time monitoring and data-driven decision-making that increases flexibility and responsiveness.

Findings from the analysis of company documents identified three key operational innovations developed by Taiwanese semiconductor companies:

a) Digital Twins and Supply Chain Simulation
   Development of comprehensive simulation models that allow companies to test various disruption scenarios and optimize responses before implementation.
b) Design and Production Modularization
   A modular architecture approach that allows components and processes to be relocated or duplicated with minimal disruption to overall operations.
c) Multifactor Early Warning Systems
   Development of monitoring systems that integrate geopolitical, economic and operational indicators to identify potential risks earlier in the cycle.

3. Strategic Supply Chain Management

Analysis of trade data shows a significant transformation in supply chain management strategies. The number of suppliers for critical inputs increased by an average of 47% between 2020-2024, indicating diversification of sourcing. Meanwhile, inventory value as a percentage of revenue increased from an average of 9.6% in 2020 to 14.2% in 2024, reflecting a greater emphasis on security of supply versus lean efficiency.

Analysis of the company's annual reports and strategic documents revealed a new approach to supplier management, with an emphasis on:

a) Supply Chain Regionalization
Efforts to build local supplier ecosystems around each major production hub to reduce dependence on long-distance transportation.
b) Dual/Multiple Sourcing
While dual sourcing has been a common practice for some components, companies are now applying it for almost all critical inputs with at least one supplier located in a different political region.
c) Co-development and Vertical Investment
Increased direct investment in key supplier companies and co-development programs for strategic materials and components.

One important finding was the shift from a "just-in-time" model to a "just-in-case" approach for critical materials. As explained by the VP of Supply Chain Management of one of the companies:

> *"We have moved from a paradigm of cost optimization to resilience optimization. This means maintaining larger safety stocks of critical materials, building redundancy in the supplier network, and sometimes sacrificing short-term margins for long-term stability."*

4. **Ecosystem Collaboration**

Analysis of patent data shows a significant increase in collaborative innovation activities. The number of co-patenting patents between Taiwanese semiconductor companies and international partners increased by 78% from 2020 to 2024. In particular, collaborations with international universities and research institutes showed the fastest growth (112%), indicating efforts to geographically distribute the innovation network.

Analysis of reports and strategic documents revealed four main collaboration mechanisms:

a) Transnational Industry Alliance
Formation of industry consortiums involving semiconductor manufacturers, equipment suppliers and end-users to develop common standards and technologies.
b) Talent Mobility Program
An initiative to facilitate the exchange of engineers and researchers between facilities in different countries, enabling knowledge transfer without relying on the concentration of talent in one location.
c) Open Innovation Platforms
Development of open innovation platforms that enable virtual collaboration between teams in different geographic locations.
d) Public-Private Partnerships
Collaboration with governments and universities in various countries to build a distributed research and development ecosystem.

Implications for Taiwan's Competitive Advantage

A comprehensive analysis indicates that the resilience strategy developed by Taiwan's semiconductor industry involves a complex trade-off between geographic concentration and risk distribution. Quantitative data shows that despite rapidly increasing overseas investment, Taiwan retains dominance in advanced production capacity with 78% of global sub-5nm chip production still concentrated in Taiwan in 2024.

Qualitative findings reveal ambiguous perceptions among industry executives and policymakers about the long-term implications of geographic diversification. On the one hand, international expansion is seen as an important step for risk mitigation and market access. On the other hand, there are concerns that excessive dispersion may erode the competitive advantage derived from geographic concentration of the innovation ecosystem.

One policymaker stated:

> *"The paradox we face is that our industrial strength comes from geographic concentration, yet this is also our greatest source of vulnerability. The challenge is to find the optimal balance-maintaining a critical mass of innovation in Taiwan while building enough distributed capacity to survive geopolitical disruptions."*

Patent data shows that despite increasingly distributed R&D activities, Taiwan remains a major innovation center with 72% of fundamental patents related to advanced manufacturing technologies still coming from Taiwan-based teams. This indicates that while production capacity is increasingly distributed, the center of gravity of innovation remains concentrated.

Conclusion

This study analyzes how Taiwan's semiconductor industry develops supply chain resilience strategies in the face of geopolitical uncertainty. The main findings show that Taiwanese semiconductor companies have developed a multi-layered approach to resilience that includes geographical diversification of production facilities, operational transformation to increase flexibility, evolution in strategic supply chain management, and strengthening ecosystem collaboration.

The results reveal that these firms have successfully developed a dynamic balance between geographic concentration that supports innovation and diversification that enhances resilience. This "di-versified concentration" strategy maintains a critical mass of high-tech activities in Taiwan while selectively distributing production capacity to mitigate geopolitical risks.

A significant contribution of this research is the identification of specific mechanisms used by strategic industries to maintain competitive advantage while facing geopolitical challenges. This study extends the supply chain management literature by demonstrating that in the context of high-tech industries, supply chain resilience involves not only mitigation of operational risks but also preservation of innovation capabilities that are a source of competitive advantage. Limitations of this study include a focus on one industry in one country, which may limit the generalizability of the findings. Future research could expand the analysis to other strategic industries and conduct comparative studies with countries facing similar geopolitical challenges. In addition, a longitudinal study would be beneficial to monitor the evolution of resilience strategies over the long term as the geopolitical landscape changes. The practical implications of this research are relevant for policymakers and industry executives managing strategic supply chains amid geopolitical uncertainty. The strategies identified in this study suggest that effective resilience requires not only geographic diversification but also operational transformation and strengthening of innovation ecosystems that transcend national borders.

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Conflict of Interest

The authors declare that they have no conflicts of interest related to the research, authorship, and/or publication of this article.

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