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Semiconductor as the Backbone in the Technological Era: A Case Study of Taiwan's Capacity and Implications for Vietnam

Khue Bao LE

Concordia International School Hanoi, Hanoi, Vietnam

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ABSTRACT

This article explores the crucial role of semiconductors in the technological era, with a focus on Taiwan's significant contributions and their implications for Vietnam's semiconductor sector development. Taiwan's advanced semiconductor industry, bolstered by strategic government policies, infrastructural development, and substantial R&D investments, has established the country as a global leader in the field. Drawing on Taiwan's successes and analyzing Vietnam's current semiconductor landscape, the study suggests pathways for Vietnam's semiconductor sector development. Despite current limitations, Vietnam has the potential to become a major participant through targeted policies, investments in education and infrastructure, and strategic international partnerships.

Keywords: Semiconductor Technology, Taiwan, Vietnam

1. Introduction

The trend of automation, computerization, and AI dominating our world confirms technology to be the driving force in the world's economies in the 21st century. At the core of this revolution is a very small piece of metal, the semiconductor. Nowadays, many electronics with complicated structures that carry mystical traits of technology are born due to the immense growth of semiconductor technology. Indeed, semiconductors have evolved into a billion-dollar industry.

In Taiwan, the semiconductor industry has evolved into a major contribution to the economy. Taiwan is now considered the central hub for semiconductor manufacturing, and its economy depends on semiconductor exports to expand economic growth. In 2022, Taiwan exported integrated circuits worth $184 billion, nearly 25% of their GDP (Jones L., 2022). In recent years, Taiwan's market share has been growing constantly, surpassing 20%. Taiwan's semiconductor industry is critical to the global economy. As semiconductor technologies permeate every part of

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industry and daily life, or serve as enablers for new services, the semiconductor industry is the basis for not only Taiwan's, but the world's future.

Covid-19 followed by a semiconductor war between China and the US in 2022 forced a break on the industry. In the current world where chips are the core of every technology, a delay in the supply chain can cause detrimental effects in the future. A semiconductor supply chain disruption has global repercussions, with Taiwan being a critical hub. Unexpectedly, this crisis opened up an opportunity for ASEAN countries to get on board. Vietnam has emerged as a prominent actor. Though Vietnam did not have any specific start for the semiconductor industry, by having a strong foundation in producing electronics and microchips along with a STEM-based younger generation, Vietnam has set the foundation to embark on this journey. This paper outlines the potential impacts of the semiconductor industry on Vietnam's economy and attempts to evaluate Vietnam's chance of participating in the semiconductor supply chain.

2. Semiconductor Ecosystem in the Economic Development

Semiconductors have a substantial economic influence. Until the 1970s, semiconductor devices were used to create and control electric current, as well as to detect radio waves. The history of semiconductors is an interesting trip through decades of scientific discoveries, technological developments, and industrial uses. From the early discovery of electrical conductivity in certain materials (1890s) to the appearance of integrated circuits (IC) in the late 1950s and Intel's first microprocessor (1971) (Hoeren T., 2015). The advancements in semiconductor technology continued at a rapid pace. The semiconductors triggered the development of the ICT industry. The advancements in semiconductor technology have enabled the development of artificial intelligence, the Internet of Things (IoT), and other emerging fields. The history of semiconductors showcases continuous innovation and their transformative impact on various aspects of our lives.

The semiconductor industry is growing rapidly as semiconductors become essential components of current technologies. Semiconductor devices are electronic components with a semiconducting substance as their foundation. The use of these devices in the creation of various electronics has grown significantly over the last few decades, and it is expected to gain even more traction in the coming years. Global semiconductor value chains have become increasingly complex. In the 1990s, semiconductor value chains were typically vertically integrated within companies and located in the United States and Japan. Over the years, semiconductor value chains have become more distributed across multiple economies. U.S. chip companies continue to generate the majority of value in the global semiconductor industry, primarily through R&D and product design. Taiwan, South Korea, China, and Japan contribute over 70% of the value in

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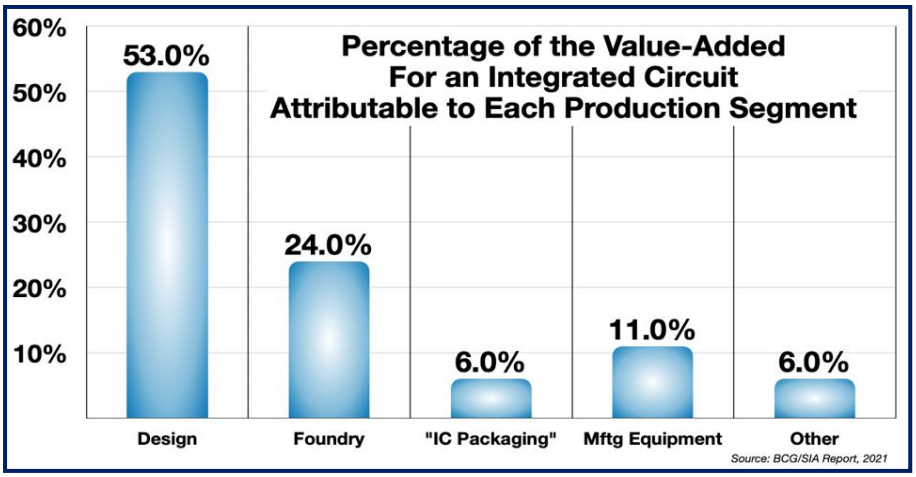
semiconductor manufacturing activities, including wafer fabrication, assembly, testing, and packaging (Varas A., 2021).

The semiconductor industry can be considered the backbone of the electronics and information technology industry. It is also the foundation for the 4.0, artificial intelligence, and automobile industries. The global semiconductor industry created a revenue of 532 billion USD in 2023 and this number is expected to reach 690 billion USD in 2024. The semiconductor industry with an upstream value chain includes Fabless companies (companies specializing in semiconductor design), IDM (companies with both design and production functions under their brands), Foundry (companies specializing in semiconductor processing), OSAT (companies that perform post-production including packaging and testing) creating a Semiconductor Ecosystem.

Statistics for 2021 show that the rate of added value of a microchip product from the design stage is the largest at 53%, while the microchip production stage is 24%, equipment production is 11%, and the remaining amount including package and test is 12%, as shown below.

Figure 1. Percentage of the added value for integrated circuit attributable to each production segment (Varas A., 2021)



Value chain activities in the semiconductor industry are based on two main activities:

2.1. Designing the circuits: Global IC design reached a total revenue of 215.4 billion USD in 2022. Among them, the US IC design sector has the largest scale, with a 63% market share and revenue of more than 130 billion USD. Taiwan's IC design sector is the second largest in the world, with an 18% market share and revenue of nearly 40 billion USD. China ranked third, with a market share of nearly 15% (Wu J., 2023). The market share statistics of IC design companies in countries around the world are shown in Figure 2.

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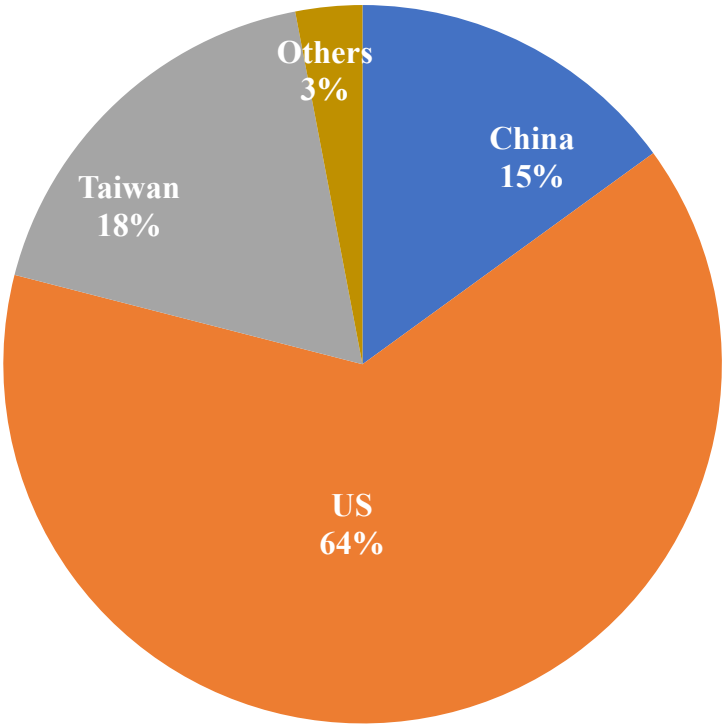
Figure 2. Market share of global IC design company (Wu J., 2023)



2.2. Semiconductor IC manufacturing: This is the most important step of the semiconductor chip industry. The global integrated circuit manufacturing market is estimated to be USD 562.53 billion by 2022 and is expected to reach approximately USD 1,921.42 billion by 2032, with a compound annual growth rate growth rate of 13.07% over the forecast period from 2023 to 2032 (Precedence Research, n.d)

Thus, it can be seen that the "Semiconductor industry" is the core of the electronics industry, responsible for creating microchips and electronic components used to produce complex products. Soon, the digitalization trend in areas such as automobiles, artificial intelligence, machine learning, cloud storage, and big data is the main driving force driving the strong development of this industry. The semiconductor chip market, which has maintained a rapid and stable growth rate over the past 20 years with a compound annual growth rate of 14%, has the potential to become a trillion-dollar industry by 2030. Largest economies the US, China, EU, Korea, and Japan have all announced subsidy plans for the semiconductor manufacturing industry, creating a competitive position in the world technology industry.

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However, the semiconductor chip design and manufacturing market always has challenges and difficulties in the process of development. The semiconductor chip crisis arose from several fundamental causes (i) stagnation and stoppage of production at a series of manufacturing facilities globally since the Covid-19 pandemic, which is now gradually being restored, (ii) The United States imposes restrictions on access to technology, raw materials, chip manufacturing machinery and semiconductors to Chinese companies, causing delay in the global semiconductor supply chain, (iii) Chip manufacturing technology companies wrongly predicted the market during epidemic conditions, leading to a decrease in output compared to actual demand.

Consequently, it can be seen that the focus of conflict between the US and China leads to the possibility of the semiconductor supply chain being divided into two competing blocks led by the US and China with different technology platforms. The disruption of the supply chain gives rise to the trend of developed economies and adjusting strategies to build and control supply chains and move or expand production facilities outside of China to diversify supply chain optimization. New-generation semiconductor technologies will create opportunities for large technology corporations to appear with new, modern products, and the process of replacing old technology with new technology will take place on a global scale. Also, geopolitical changes in the world are opening up opportunities for new countries to participate in the value chain of this important industry. This also opens up opportunities for Vietnam to participate in the semiconductor supply market and the semiconductor ecosystem.

3. Pathway for Semiconductor Industry Development in Taiwan

Taiwan’s performance in the semiconductor industry in recent decades is nothing short of a miracle, especially considering the nation's size both in total area and population. Indeed, the contribution of the semiconductor industry to Taiwan’s overall economy and its position in the global semiconductor supply chain has earned Taiwan the name “Silicon Island”. Taiwan is currently the world leader in semiconductor manufacturing. The total output value of Taiwan’s integrated chip (IC) industry reached US$145.7 billion in 2021 or about 15 percent of Taiwan’s GDP (Anouk van der Steen, 2022). Taiwan's government has implemented specific policies to promote the development of the domestic semiconductor industry.

3.1. Infrastructure Development

Science and Technology Parks: In the 1970s, policies were focused on creating a conducive ecosystem by creating Hsinchu Science Park to create industrial clusters and synergy, providing infrastructure, regulatory support, and access to talent (Fulco M., 2019). Science and technology parks emerged, nurturing the development of comprehensive semiconductor industry clusters covering all essential stages of the value chain, from IC design to manufacturing, packaging, and

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testing. This facilitated a seamless transition from research to production, enabling a one-day supply cycle time.

Talent and Technology Collaboration: Taiwan leveraged its high-caliber talent pool, advanced technology, low cost, high production capacity, customization flexibility, and received support from the scientific and research capabilities of the US, Europe, and Japan, alongside its own research and development efforts. This collaboration fostered a robust and resilient semiconductor ecosystem capable of efficiently managing challenges across semiconductor development, trial production, and mass production, thereby expediting semiconductor process advancements (Tung, C. Y. , 2024)

3.2. Research and Development

Investment in R&D: The three main trajectories in the semiconductor industry includes - chip design, manufacturing, and ATP (assembly, test, packaging). Taiwan's initial focus on pureplay foundry (manufacturing) in the early years, shifted gradually to design through collaboration with industry leaders such as the US which is specialized in design Crotty P., (2024).

Government and Academic Support: Taiwan's investment heavily in R&D has enabled its semiconductor industry to make speedy headway. The Ministry of Science and Technology (MOST) & the Ministry of Economic Affairs (MEA) provide funding and incentives. Foster collaboration between industry and academic partnerships, between semiconductor manufacturers and National Tsing Hua University and National Chiao Tung University to drive innovation and knowledge sharing (Vuu C. 2024). Continued investment in R&D allows Taiwan to maintain the leading edge in the global semiconductor industry as it rides the wave and penetrates higher-end segments of the industry. In 2022, revenue from design accounted for 41.4% (United States Trade Representative, 2024).

Role of the State: While the government retreated from subsidizing companies, research and development remains one area where the state plays a prominent role. Today, Taiwan occupies high–end products and most advanced manufacturing of the semiconductor industry.

3.3. Education & Training

Education Reforms: Taiwan has set aside the goal of leading the global semiconductor industry in the 2000s. As a result, Taiwan has consistently invested in research and education networks to support semiconductor technology development since the 1970s (Nenni, 2023). Taiwan has reorganized and strengthened its education system with the goal of producing qualified workers for the semiconductor sector. Taiwan has modified and developed the educational systems in school in the 1960s-70s (Lone Star Tech, 2023).

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University Programs and Incentives: At the higher education level, the government established universities such as National Chiao Tung University and National Tsing Hua University, with specialized courses in engineering, electronics, and semiconductors (Nenni, 2023). Students are given scholarships, grants, and incentives to pursue STEM fields that will help the developing semiconductor sector (Y. J., 2022).

Infrastructure for Education: The infrastructure is being constructed and grown alongside the concentration on STEM education. Hsinchu Science Park was established in 1980 as a hub for semiconductor and IT firms, with convenient facilities to facilitate semiconductor manufacturing (Chang, 2000). Large semiconductor businesses, such as Taiwan Semiconductor Manufacturing Company (TSMC), receives tax advantages as well as infrastructural and utility subsidies for establishing factories and R&D facilities in the region. Hsinchu Park, under government instruction, brings together semiconductor businesses, suppliers, research institutes, and skilled people to focus on the development of the semiconductor industry. Following this trend, comparable semiconductor science parks were eventually developed in Tainan and Central Taiwan.

3.4. Trade Policy

Encouraging Trade: Taiwan's government encourages the elimination of international trade barriers such as tariffs and quotas, allowing countries to capitalize on their comparative advantages in global exports and imports. Boosting exports is a key policy for promoting trade and improving Taiwan's semiconductor industry. Taiwan provides tax deductions and targeted subsidies for domestic and foreign companies operating or investing in its electronics industry, particularly in critical segments such as semiconductors, displays (LCDs), and various electronic components.

Export-Oriented Strategy: This export-oriented strategy has promoted economies of scale, knowledge transfer, and sustained productivity gains despite global competition (Haggard S., 2013). Taiwan has quickly emerged as a key supplier to the United States and several European countries. However, after launching small companies and providing initial assistance for their growth, the Taiwanese government does not further subsidize or attempt to insulate them from competition in the retail industry. Tariff safeguards do not apply in the home market, requiring Taiwan Semiconductor Manufacturing Company to compete globally. This drives domestic companies to constantly innovate and remain competitive, preventing complacency behind protectionist barriers (Y. J., 2022).

Impact on Manufacturing Exports: Taiwan's manufacturing exports increased at an average annual rate of 14% between 1965 and 1990, outpacing GDP growth of 8.9%. This is consistent

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with the concept that export expansion is a significant driver of technological advancement and market-related development (Crotty P., 2024). This trade behavior is the proper approach to encourage the development of Taiwan's semiconductor sector

4. Semiconductor Technology: Vietnam's opportunity in the New Technology Era

4.1. Vietnam's Semiconductor Sector: Current Status and Trends

The electronics industry in Vietnam is currently at the service exploitation level, assembling equipment with main components and imported microchips. At the present, only two companies, Viettel High-Technology Industries Corporation and FPT Semiconductor Joint Stock Company, participate in the design stage of semiconductors. Enterprises manufacturing and trading in the semiconductor industry are still entirely dependent on the supply of semiconductor chips from foreign sources. The technology for manufacturing semiconductor components and circuits has not yet been mastered, leading to Vietnam's inability to proactively create electronic products with high intelligence content, and great added value. Therefore, Vietnam has not yet created electronic products that are new with technological breakthroughs used for significant national purposes.

However, Vietnam has a solid foundation in STEM with many investments made in the field of electronics manufacturing. Notably, Vietnam has more than 50 microchip companies in Vietnam such as Intel (USA), and Renesas Vietnam (Japan). In 2022, mobile phone exports brought in 57.9 billion USD for Vietnam, and exports of computers, spare parts, and electronics components reached 55.54 billion USD (Vietnam News Agency, 2023).

It can be seen that developing Vietnam's microchip industry with domestic resources and increasing the added value of domestic electronic products, will contribute to promoting the country's economy. Vietnam is one of the leading electronics exporters in the world. In 2020, Vietnam rose to rank 12th in the world from 47th in 2001 and ranked 3rd in ASEAN in electronics exports. The investment made by domestic and foreign companies in semiconductors and electronic equipment makes Vietnam stand out as a potential destination for the semiconductor industry in Southeast Asia.

4.2. Strategic Policies for Advancing Vietnam's Semiconductor Industry

To be able to catch up with this chance, Vietnam has to develop extensive policies for the semiconductor industry specifically. The current policies only label the semiconductor industry under “innovation ecosystem”. With a strategy to develop the domestic semiconductor industry, Vietnam focuses on implementing supportive and sustainable policies. The Vietnamese government has introduced numerous measures to attract investment and support the growth of

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the semiconductor industry. Similar to Taiwan in its early stages, Vietnam supports the promotion of businesses operating in the semiconductor sector. The 2020 Investment Law stipulates various investment incentives, including corporate income tax benefits and reductions or exemptions of land use fees. For instance, throughout the lease period, enterprises investing in this industry and operating in challenging locations are exempt from paying land and water surface rent (Bui H., 2024).

The income of enterprises conducting new joint ventures in the field of technology is taxed at a 10% rate for 15 years, allowing enterprises to enjoy tax exemption for up to four years and a 50% reduction in tax payable for up to nine years. In addition, investment funds have been established by the Vietnamese government to support the development of the semiconductor industry. For instance, the National Technology Innovation Fund (NATIF) was created to fund R&D activities. The Vietnam-Korea IT Incubator (VKII) was established to provide funding and support for start-ups in the semiconductor industry (Trong-Dat, 2024). In addition to the current rules, Vietnam has implemented new policies and attempts to promote the semiconductor sector in general and especially the semiconductor chip industry.

Despite Vietnam's efforts in semiconductor chip production, some aspects of its existing policies could hinder corporate development compared to those in other countries, especially Taiwan. Although the issuance of the Government’s Decree 94/2020/ND-CP has already promised semiconductor companies reduction for tax payments, reduction in tax payments, and import tax exemption, there should be more policies developed to create incentives for foreign businesses to make new investments and to create more jobs for Vietnamese IC engineers. To achieve the goal of training about 50,000 engineers specializing in the field of chips and semiconductors from now to 2030 as stated by the Minister of Planning and Investment Nguyen Chi Dung, the government must develop policies in sectors such as business incentives, education, training programs, and taxation.

4.3. Human Resources for Vietnam's Semiconductor Development Strategy

Because of its abundant human resource supply, Vietnam has a substantial advantage in training high-quality people resources in the Engineering Technology industry. However, there is a lack of focus on training engineers in trending industries such as Semiconductors, resulting in a large supply and demand imbalance in the business. As a result, focusing on training Semiconductor engineers is a strategic approach for maximizing resources and fostering the growth of Vietnam's "billion dollar" industry.

To develop the domestic semiconductor industry, Vietnam needs to build and develop stable human resources, meeting the goal of development and autonomy of the domestic semiconductor

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industry by (i) focusing on developing human resources for the semiconductor industry by supporting and promoting major universities in Vietnam to focus on professional research and develop high-quality human resources in this field (including research and development of core technologies and resources). Or the country can develop specialized industries/majors in the fields of research, design, and manufacturing of semiconductor devices. (ii) establish a national center to support the semiconductor industry like Japan, Taiwan, and Korea's coordination center which connects universities to companies and businesses; (iii) promote attracting and calling for semiconductor manufacturing corporations to invest in Vietnam, and the same time has an attractive and long-term support mechanism for them; (iv) build a mechanism to support and promote Vietnamese research institutes, universities, and businesses to focus on research and development of the semiconductor industry, including the development of core technology research and development; (v) build and develop specialized training codes in the field of semiconductors along with specific incentive policies, specifically focusing on support policies in core technology research.

By achieving stage by stage of the list above, Vietnam will be able to build a strong and secure workforce to ensure its steady ground for the upcoming semiconductor.

4.4. Physical Facilities for Education and Training

Whereas policies and training human resources are essential parts of this semiconductor production, to achieve those goals physical facilities are indispensable. In particular, we should concentrate on the following points: (i) Form human resource training and teaching centers, research facilities and shared laboratories at institutes and schools in all three regions: North - Central - South. (ii) Investing in new construction, upgrading part or all of facilities, equipment, multi-project wafer program (MPW), process design suite, storage server room, operating system, computer, Software copyrights, IC design tools, educational packages from leading corporations in the world, and VPN software. (iii) Develop and implement incentive programs to encourage organizations and institutions to expand access to existing semiconductor infrastructure, grow the number of users, and support equipment refurbishment. (iv) Invest in training support tools using virtual reality software (AR/VR) and online IC lab simulation platforms.

4.5. Challenges for Vietnam's Semiconductor Industry Development

Vietnam is strategically located in the heart of Southeast Asia, making it an ideal location for manufacturers looking to tap into the region's rapidly growing semiconductor market. Despite Vietnam's opportunities for global collaboration on the semiconductor front, there remain challenges and limitations. Vietnam is currently primarily involved in the semiconductor

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industry's low-margin packaging and testing sectors. This may prevent its potential growth up the value chain toward the semiconductor design and manufacturing areas, which require specialized labour and manufacturing facilities. On the other hand, Vietnam still lacks a skilled semiconductor workforce. However, according to Filippo Bortoletti, Country Director at Dezan Shira and Associates, Vietnam still has the potential to become a semiconductor manufacturing hub. This will depend on the government's support (Nguyen U., 2023).

The Vietnamese government has strong policies to promote the development of the domestic semiconductor industry. However, to soon achieve the goal of developing the semiconductor industry in Vietnam in the new era, it is necessary to follow the ideas as foundations for policies that the Vietnamese government can issue. Measures should include efforts to attract foreign investment, generate job opportunities for local engineers, and encourage career advancement through training programs and internships. Furthermore, assistance should be offered for labour export and exchange programs to enable the transfer of expertise. Efforts from the government should also be made to build a competitive and transparent legal environment and provide tax breaks to encourage semiconductor companies to expand and invest, especially in times of financial crisis as recently. Policies should be in place to encourage experienced engineers to participate in training programs, while also cutting down on their income tax: thereby increasing the industry's talent pool and abilities.

5. Conclusions

The semiconductor sector has a significant impact on the growth of technological industries. Taiwan stands as a paradigmatic success story in semiconductor sector development, exerting a profound influence on the global technology landscape. Taiwan's journey from inception to global leadership in semiconductor technology exemplifies the importance of strategic planning, robust infrastructure, and investments in R&D. Vietnam boasts a favorable geographical location and several advantages for promoting semiconductor technology. Vietnam must formulate specific plans and strategies drawing on Taiwan's development model and its own strengths. In terms of policy, Vietnam should prioritize comprehensive growth of the semiconductor sector, bolstering R&D capabilities, and cultivating a skilled workforce tailored to semiconductor industry needs. Moreover, it is crucial to invest in educational institutions and foster partnerships between universities and industry. Additionally, Vietnam needs to reduce its dependence on imported semiconductor components by enhancing production capacity, necessitating government support through regulatory frameworks, tax incentives, and infrastructure development. Clear directions and strategic steps will lay the groundwork for Vietnam's sustainable semiconductor ecosystem development.

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Vietnam has the potential to emerge as a key competitor in the global semiconductor market by implementing Taiwan's model, combined with strategic initiatives and government support, promoting long-term growth and supporting innovation in Southeast Asia and elsewhere.

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Biography

Khue Bao Le is currently a senior at Concordia International School Hanoi, Vietnam. She is the founder of Cup Cats, a social enterprise that raises funds for Operation Smile Vietnam, where she also volunteers. Khue presented her research on "A Study of Knowledge, Attitude, and Practice Regarding the Use of Antibiotics Among Children with Cleft Lips," at the International Young Researchers' Conference at Tokyo University. With a passion for Economics and Policy, she has participated in the Vietnam Economics Olympiad, earning second prize. Khue completed a research internship at Vinacapital Hanoi, where she focused on semiconductors and economic trends. Inspired by internship at Vinacapital, she researched semiconductors' role in the tech era: dissecting Taiwan's success and providing implications for Vietnam. She aims to pursue higher education in economics to contribute to Vietnam's economic development.

