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# BUU44510 International Business and the Global Economy

## Assignment #2: Case Study and Teaching Note

## The Global Semiconductor Industry


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# Case Study

## The TSMC Way: How One Company Revolutionised The Semiconductor Manufacturing Industry

### Introduction

Consider a young boy born in war-torn China who embarked on a remarkable journey to found a company that completely transformed the semiconductor industry. This boy was Morris Chang, the founder of the Taiwan Semiconductor Manufacturing Company (TSMC) and the individual often credited with creating the Taiwanese semiconductor industry.[1]

Chang began his 30-year career in the American semiconductor industry after graduating from MIT. He joined Sylvania Semiconductor in 1955 and later moved to Texas Instruments (TI), where he eventually rose to the position of group vice president responsible for TI's global semiconductor business.[2]

After returning to Taiwan, he founded TSMC, a company that quickly rose to prominence, using the knowledge he gained during his career in America. Chang revolutionised the global semiconductor industry by introducing the foundry model, a business model in which a company specialises in the manufacturing of wafers and chips for contract designers.

TSMC experienced tremendous growth under Chang's leadership and is currently one of the world's largest contract chip manufacturers. In 2022, together with other Taiwanese semiconductor companies, it accounted for 63% of global foundry revenue.[3] This single individual's contributions to TSMC have played a significant role in Taiwan's economic and technological growth, and the story of Taiwan’s semiconductor industry provides an insightful look into how a small island nation could become a dominant player in one of the world’s riskiest industries.

## Semiconductors

A semiconductor is a material, commonly made from silicon, that displays electrical conductivity between that of an insulator and a conductor. The properties of a semiconductor can be manipulated depending on the specific use case through doping, a process that involves introducing impurities into the material.[4] The importance of semiconductors comes down to the vast variety of products they end up in, with them being found in almost any electronic device, from refrigerators to high-precision military equipment.

The process of designing and manufacturing a semiconductor is incredibly complex, time-consuming, and expensive. The first step in the production of semiconductors involves research and design, which can take years in itself. Following this, the next step is to produce a silicon wafer, which on average takes about 12-16 weeks. These wafers are then sent to probe testing before being assembled and packaged into chips, which can take up to a month. The transformation of a raw silicon wafer to a chip occurs in a fabrication plant, more commonly referred to as a fab. Precise final testing of the chips is then required, with the whole cycle taking about 6 months in total. Generally speaking, the front-end production (i.e., the production of the wafers) is incredibly capital intensive, whereas the back-end production (i.e., the testing and packaging of the wafers into end product chips), is very labour intensive.[5]

## The Global Semiconductor Industry

The global semiconductor industry plays an incredibly important role in the global economy, with sales of roughly $580 billion in 2022.[6] The industry's growth is expected to continue as demand for electronic devices increases and new technological trends, such as artificial intelligence (AI), autonomous vehicles, and the Internet of Things (IoT), emerge. McKinsey & Company estimates the industry will become a trillion-dollar industry by 2030.[7] Despite the ubiquity of semiconductors across virtually all industries, many underestimated the importance of the industry, even the customers of semiconductor companies, until the chip shortages highlighted their importance. Now more than ever, securing supply of semiconductors is becoming a strategic play for many industry leaders.[8] A highly risky industry, with enormous upfront investment, and huge internal know-how has made it an

incredibly difficult industry to break into, but the players that do survive are driven by the desire to make increasingly smaller, faster, and cheaper chips.

## *Integrated Device Manufacturers, Pure-Play Foundries, and Fabless Companies*

At a high-level, the semiconductor industry can be split into three types of companies: integrated device manufacturers (IDMs), pure-play foundries, and fabless companies. An IDM designs, manufactures, and sells its own semiconductor chips, having full control over the entire process. Famous examples of IDMs include Intel, Analog Devices, and Texas Instruments. Pure-play foundries are outsourcing companies that only manufacture chips designed by other companies. The world's first and most successful foundry is TSMC. In contrast, a fabless company designs and sells its own chips, but outsources the manufacturing process to a foundry. Examples of dominant fabless companies include Qualcomm, Nvidia, and Broadcom. Recent decades have seen the growth of the fabless and foundry models, in part due to the success of TSMC, representing a shift away from the dominance of the vertically integrated IDM model as shown in **Exhibit 1** which breaks down the revenue growth of each of the three types of companies. Although IDMs, by definition, manufacture chips in-house, it is not unusual for them to also outsource some production to a foundry.

## *Major Countries and Companies Involved*

The vast majority of the global semiconductor industry is made up of companies from the United States (US), China, Taiwan, Japan, and South Korea. The Netherlands is also heavily involved, with ASML being responsible for producing many of the machines required to produce the most advanced semiconductors.[9]

**United States**

Many of the biggest semiconductor companies in the world, including Analog Devices, Intel, NVIDIA, and Qualcomm, are based in the US. Specifically, the US is famous for designing specialised, high-value and complex chips.[10] In recent news, the US has implemented the CHIPS and Science Act, which focuses on increasing American semiconductor research and development (R&D) and strengthening domestic manufacturing.[11]

**China**

China is increasingly becoming a major player in the semiconductor industry, being home to players such as SMIC, Huawei, and HiSilicon. The country has generally specialised in producing simpler chips, such as those used in consumer goods.[12] The Chinese government has made significant investment into the industry and is reported to be working on a 1 trillion yuan ($143 billion) package to support the industry, and is rapidly expanding its capacity to design and manufacture cutting edge chips for AI and cloud computing.[13]

**South Korea**

South Korea is home to some of the world's biggest semiconductor companies, such as Samsung Electronics and SK Hynix. The country is known for designing *and* producing specialised chips. Samsung is especially famous for being on the leading edge of advanced chip design and manufacturing, only truly challenged by TSMC.[14]

**Japan**

Famous Japanese semiconductor companies include Toshiba and Fujitsu, and the country is known for producing much of the world's supply of specialised wafers and chemicals used by fabs. At one stage, Japan manufactured more than half of the world's semiconductors; today, it is struggling to maintain its market share, which was about 10 percent in 2021.[15]

**Taiwan**

Taiwan is most famous for producing most of the world's cutting-edge chips, with over-reliance on Taiwan quickly becoming a strategic issue for major players in the industry. TSMC is the world's largest pure-play foundry, accounting for approximately 60 percent of global foundry revenue in Q4 2022[16] and manufactures chips for leading fabless companies such as Apple, Broadcom, Analog Devices, Qualcomm, and Nvidia.[17] **Exhibit 2** breaks down semiconductor foundries by market share, showing both Taiwan and TSMC's dominant positions in the market.

## The Taiwanese Semiconductor Industry

Taiwan is home to one of the largest and most advanced semiconductor industries in the world, and its success is largely driven by TSMC. Smaller than the state of Florida and with a population of just under 24 million, how did this small island nation become a dominant player in one of the world's riskiest industries? It was in part due to Morris Chang, the founder of TSMC and so-called creator of the Taiwanese semiconductor industry, who changed the global semiconductor landscape through the introduction of the foundry model.[18]

The Taiwanese government had made efforts to cultivate a competitive tech industry as far back as the 1970s, not least through the creation of the Industrial Technology Research Institute (ITRI).[19] During the 1980s, Chang was appointed as the president, and later chairperson, of the ITRI with the hopes that he would apply the invaluable knowledge he had gained from working at Texas Instruments to cultivate Taiwan's own semiconductor industry. In 1987, Chang founded TSMC, the world's first pure-play foundry. As shown in **Exhibit 3**, today TSMC accounts for roughly 70 percent of global foundry revenue for common 32-12 nm chips, but where it dominates is in the production of advanced 10-5 nm chips, holding nearly 90 percent of the market share.[20]

### *The Foundry Business Model*

Prior to TSMC, IDMs dominated the industry. However, when Morris Chang founded TSMC, he introduced what we now know as the "foundry model," where a company focuses solely on manufacturing and avoids design. Inspiration for this new model came from what he saw as Taiwan's strengths and weaknesses. Chang believed Taiwan's workforce had the skills to manufacture high-quality wafers and chips but did not believe they could compete with the design skills of the US and Japan.[21] The identification of this sweet spot ultimately provided TSMC with a first mover advantage. The costs associated with setting up a fab are extremely high, with modern factories today costing around $10 billion to set up, and by getting there first, TSMC had a huge advantage over their competitors.[22] Additionally, by solely focusing on manufacturing, TSMC was able to develop fabs that could manufacture a broad range of products at a large scale, something IDMs simply could not afford to do.

### *Concentration of Manufacturing in Taiwan*

TSMC has experienced tremendous profits year on year, largely from concentrating manufacturing in Taiwan as opposed to fragmenting across geographically distant factories. The close proximity of factories achieved through this concentration facilitates support between engineers in different factories, efficiently breaking down bottlenecks. This effect is put into context when a TSMC spokesperson estimated that it saves up to 8 to 10 percent in manufacturing costs when compared to its US competitors.[23]

### *Government Support*

A major barrier to entry in the semiconductor industry are the large capital costs required to invest in R&D and manufacturing assets. Unlike in other industries, these investment costs are not once-off as companies need to continuously invest to be at the cutting edge of technological advances and remain competitive. While most companies found these costs astronomically high, the Taiwanese government invested heavily in R&D for industries it was looking to promote and provided a large bulk of the capital required for TSMC to become established in the semiconductor industry. Additionally, the Taiwanese government provides generous subsidies and tax incentives for those in the semiconductor industry. The latest of such policies includes legislation that will allow local fabs to exchange up to 25 percent of their annual R&D costs into tax credits.[24]

### *Education System and Skilled Workforce*

The Taiwanese education system places great emphasis on the upskilling of its citizens in the information and communication technology (ICT) sector and produces talented engineers who possess the technical and scientific knowledge necessary to not only succeed, but to excel in the semiconductor industry. However, Chang also observed that the Taiwanese education system was not particularly good at instilling creativity and design skills. This shaped his eventual conception of the foundry business model, which excluded the design side of industry. Chang's ability to recognise not only the strengths, but also the limitations of the Taiwanese education system helped propel TSMC into the successful company it is today.[25]

### *Innovation*

Finally, a major factor contributing to the success of TSMC is Taiwan's culture of innovation. When employees at TSMC achieve a milestone by designing a faster, smaller, and more efficient chip, instead of revelling in their success, they continue to research with the aim of developing an even better chip in the future. This cultural desire for innovation has kept TSMC one step ahead of its competitors, leading to competitors constantly playing catch up, before eventually giving up and becoming customers of TSMC. Additionally, close collaboration between the industry, academia, and research institutions in Taiwan further instils continuous innovation.

## Current Industry Trends

Although Taiwan's place in the semiconductor industry is well-established, due to the complexity of the global semiconductor supply chain and the core role technological innovation plays in the industry, it is heavily influenced by prevailing global trends. Specifically, the industry is experiencing a global chip shortage due to supply chain disruptions originating from the Covid-19 pandemic and the Russian invasion of Ukraine. Additionally, over reliance on Taiwan is becoming a greater issue due to the current geopolitical landscape. Technological trends, such as an increase in demand for cloud computing and AI services, as well as a trend towards in-house chip design by tech giants such as Google and Apple, are also affecting the Taiwanese semiconductor industry.

### *Global Supply Chain Disruptions & Geopolitical Threats*

The global semiconductor supply chain is incredibly complex and risky. Geographically speaking, components could potentially travel more than 25,000 miles before becoming an end product.[26] This is due mainly to how specialised many of the processes required along the supply chain are. **Exhibit 4** shows the significant number of countries involved at different stages of the semiconductor manufacturing value chain. Additionally, the process involves a huge degree of risk given how time-consuming and precise it is. For example, when implementing a new design, it may take up to 14 weeks to even know if the wafers work and are viable.[27]

Additionally, the semiconductor industry is highly cyclical, giving rise to what is known as the "semiconductor cycle". The cycle's upturn begins with a period of high demand, which leads to rising prices and high revenue, but ultimately causes supply shortages. Manufacturers react by increasing production levels, however, this leads to an oversupply of semiconductors in the market. The cycle's downturn is due to inventory build-up, which, combined with lower demand, leads to falling prices and revenue. As revenue falls, manufacturers reduce production levels which lead to reduced supply, and the cycle begins again.[28]

**Chip Shortages, Covid-19 Pandemic, and the Russia-Ukraine War**

The stories of chip shortages currently dominating headlines are not only a product of the inherent cyclic nature of the industry but have also been exacerbated by the Covid-19 pandemic and Russian invasion of Ukraine. Pandemic restrictions and infection outbreaks unsurprisingly created disruptions and bottlenecks within the supply chain. This led to increasing lead times and put a huge pressure on key manufacturers such as TSMC. However, due to their focus on front-end production, which is less labour intensive, TSMC was able to reduce the impact of Covid-19 outbreaks among their staff and to safely implement social distancing.[29] Despite this, the increased demand for consumer goods and technologies such as high-speed broadband, both of which semiconductors are critical for, led to unsustainable demand levels during the pandemic bleeding out their stock.[30] Even as pandemic restrictions eased, the Russian invasion of Ukraine caused issues in the supply of essential production materials such as neon which are often sourced from Eastern Europe.[31]

The automotive industry has particularly been disrupted with large manufacturers such as Ford and Volkswagen shutting down production due to a lack of semiconductor-based parts.[32] As revenue dropped for these companies during the pandemic, demand for semiconductors was cancelled. However, the Chinese automotive market recovered far quicker than expected and demand increased. Europe and North America followed shortly after, by lifting pandemic restrictions, further increasing demand. The result was that semiconductor manufacturers had to react quickly to unprecedented demand that was further amplified by panic. Inventory was quickly bled out causing substantial backlogs and lead times reaching over a year.[33]

**Geopolitical Threats and Over-Reliance on Taiwan**

With TSMC being one of only two companies, Samsung being the other, on the leading edge of advanced chip technology, over-reliance on Taiwan has led to political concerns from governments following the exposition of the fragility of the supply chain to world events. Concerns regarding over-dependence on Taiwan have been especially driven by the rising tensions between China and Taiwan, and China and the US. Taiwan's strategic positioning and dominance in the global semiconductor supply chain has led to the coining of the term Taiwan's "silicon shield", which encapsulates the idea that Taiwan is protected from the rising threat of invasion by China through the global dependency on its semiconductor manufacturing capabilities.[34]

**China-Taiwan Tensions and Domestic Manufacturing**

The concern around such a precarious environment has led to governments putting pressure on large semiconductor companies to cease or limit the outsourcing of semiconductor manufacturing, and to focus on domestic production. Research from the Rhodium Group estimates that an attack or blockage on Taiwan from China would impact around $2 trillion worth of economic activity, without factoring in the impact of sanctions or knock-on effects.[35] To facilitate and incentivise domestic manufacturing, policies such as the US CHIPS and the Science Act have been introduced which includes an investment of $52.7 billion into semiconductor R&D, manufacturing, and workforce development, with $39 billion of that being focused solely on manufacturing.[36] Additionally, pressure from the US has led to TSMC investing in two advanced chip plants in Arizona, worth a combined total investment of $40 billion, the largest foreign investment in US history.[37] The Japanese government has also made efforts to secure their supply of chips from TSMC, with plans to invest up to ¥476 billion ($3.6 billion) into a TSMC subsidiary in south west Japan.[38]

**US-China Trade and Chip War**

Additionally, another core geopolitical concern within the semiconductor industry is that of the US-China trade and chip war. This is of great concern to Taiwan due to how reliant both Chinese and American supply chains are on the country. With China being a major market for the Taiwanese semiconductor industry, the US has banned foreign manufacturers that use American intellectual property (IP), such as TSMC, to export products to China. This has led to

TSMC being forced to stop doing business with one of its largest customers, Huawei.[39] However, Taiwan has also used the US-China trade war to their strategic advantage by convincing operations in related industries to move from China to Taiwan.[40]

## *Technological Innovation*

The semiconductor industry has undergone significant changes in recent years due to technological advancements in various areas, such as cloud computing, artificial intelligence (AI), and electric vehicles (EVs), further driving the demand and dependence for semiconductors in both emerging and established markets.

### Cloud Computing

Cloud computing has created increased demand for higher-performing chips. In 2022, it was estimated that the cloud computing market size was $545.8 billion and is projected to grow $1.24 trillion by 2027.[41] This industry is expanding due to increased automation, enhanced customer experience, and the adoption of remote work culture. Since the beginning of the Covid-19 pandemic we have seen a sudden preference towards remote and hybrid work which has caused many businesses to focus on providing their services over the internet through cloud solutions. The continuous release and rapid popularity of new generative AI models, such as ChatGPT, have also increased the demand for cloud computing resources, which rely heavily on advanced semiconductors.

### Artificial Intelligence (AI)

This sudden craze in new AI models has also resulted in companies such as Nvidia now reverting to the cloud to sell their AI services to customers. Major companies like Google and Microsoft, who are customers of Nvidia for their AI chips, are now creating their own in-house chips to handle their newly developed AI models. This reduces their need for Nvidia chips in the long term. The loss of sales from their AI chips may seem like a negative outlook for semiconductor manufacturers, such as TSMC, but the move to the use of cloud in AI will increase demand for Nvidia's specialised chips. Additionally, as the demand for AI services continues, new competitors are consistently coming to the market with Nvidia's share price gaining 54% this year due to new AI start-ups purchasing their chips.[42]

These emerging trends in AI and cloud computing are driving explosive data growth. To handle this unprecedented demand for compute power, TSMC and their High-Performance Computing (HPC) platform offer leading-edge process technologies and connectivity solutions, among others, to power their HPC customers' innovation. This platform is powered by their X-technology series that is designed to tackle high performing applications in the cloud and handle the increased traffic due to online business and remote working.[43]

**Electric Vehicles (EVs)**

Additionally, the rise of EVs has created a huge demand for semiconductors. Semiconductors are used in various components of EVs, such as electric powertrains, battery management systems, sensors, infotainment systems, and charging stations.[44] According to some estimates, an EV requires about twice as many semiconductors as a conventional combustion-engine car[45], and some EV models can have up to five times more chips than a normal car.[46] This means that the semiconductor industry needs to ramp up its production capacity and innovation capabilities to meet the growing needs of the EV market.

Taiwan and TSMC have reacted to the growing demand for EVs by expanding their production capacity and developing new technologies for automotive electronics. TSMC has a dedicated Automotive Electronics Platform that provides a range of technologies and services for the automotive industry, such as advanced CMOS technologies for compute intensive ADAS applications.[47] TSMC also plans to invest $100 billion over three years to increase its chip output.[48]

**In-House Chip Design**

In recent years, major tech companies, such as Apple and Google, have invested in the design and production of their own in-house chips. Apple's M1 and M2 chips, along with Google's Tensor chips, have received positive results for both companies. These chips are specifically tailored to the products they're built for, resulting in improved performance and lower power consumption. However, established players in the industry, such as Analog Devices, tend not to see this as a threat and would even argue that this is not a new phenomenon, with many companies having their own in-house development teams for decades.[49] To put this into perspective, Analog Devices design and manufacture 75,000 different chips for around

100,000 customers, whereas companies such as Apple and Google are trying to target a particular use case or IP through one or two custom chips.

Apple's determination to gain complete control over almost all components in their products may reduce reliance on business partners such as Intel, Qualcomm, and Broadcom. However, it will not change their partnership with TSMC, the chipmaker for their in-house chips. As mentioned previously, TSMC has invested $40 billion into the construction of two fabs in Arizona. One of the fabs being built will produce TSMC's first-generation 3nm chips, known as N3 chips.[50] These chips will offer up to 70% logic density gain, up to 15% speed improvement at the same power, and up to 30% power reduction at the same speed, as compared with N5 technology.[51] The production of N3 chips will begin in 2026 in the Arizona plants, but current fabs have begun mass production on this chip. It is reported that Apple has acquired 100% of the initial production of these N3 chips and they are expected to make its way into Apple products later this year.[52]

Overall, TSMC and the Taiwanese semiconductor industry are in one of the strongest positions globally to tackle the increased demand for advanced chips from the rapid technological innovation we are seeing today. As already mentioned, through their focus on manufacturing, TSMC has been able to steadily build fabs that can manufacture a broad range of chips at scale far earlier than their competitors. Additionally, TSMC and Samsung are currently the only manufacturers that can produce the 3nm chips on the leading edge of technological innovation. In a recent press release, TSMC estimated that the manufacturing of 3nm chips will create $1.5 trillion worth of chips within five years of producing at volume.[53]

## Conclusion

The global semiconductor industry supplies some of the most valuable and ubiquitous products needed for all facets of our lives, from homeware to warfare. Despite being an extremely competitive industry with high upfront investment and extreme risk, Taiwan, with TSMC, was able to break in and establish itself as a main player through a combination of cultural and political factors, and an innovative foundry model designed by Morris Chang.

However, recent world events have made it clear that the complexity of the global supply chain and an overdependence on Taiwan and TSMC could be disastrous.

Taiwan is currently sitting at a major inflection point in their history that could go either way. It is unclear how much longer Taiwan's "silicon shield" will protect them, especially if China decides to follow in the footsteps of Russia. Additionally, the shield is only being weakened by a rise in protectionism being seen throughout the industry. New American policies such as the US CHIPS and Science Act could mean the end of TSMC's dominant market share, and political pressure from the US has already led to TSMC ceasing business with Huawei, its previously second-largest customer. It may be that the future of Taiwan and TSMC will be in their subsidiaries dotted around the globe, following in the footsteps of those currently being set up in countries such as the US and Japan.

Perhaps, however, TSMC's saving grace will be its technological lead, which is being challenged only by Samsung. Other companies may have to face the reality that they cannot afford the monumental investment required to catch up with the likes of TSMC and may ultimately trade supply chain security for increased profits. Ultimately, only time will tell and recent events have made clear that the future is much harder to predict than we expected.

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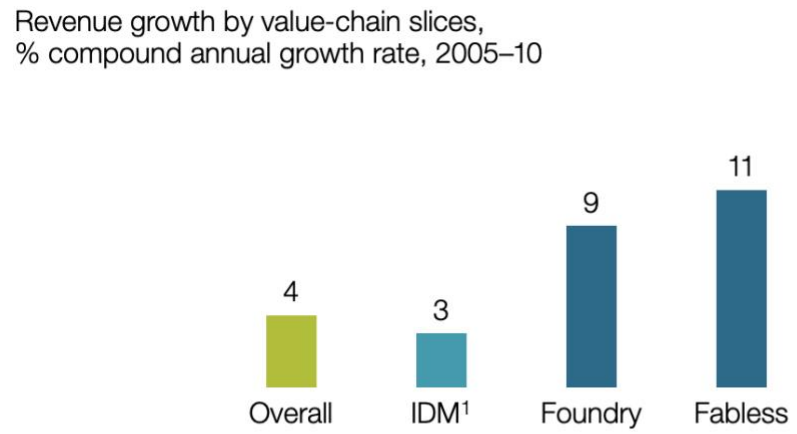
## Exhibits

**Exhibit 1** Revenue Growth of IDM, Foundry, and Fabless Businesses Compared to the Industry Average.

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Source: Ulrich Naeher, Sakae Suzuki, and Bill Wiseman, "The evolution of business models in a disrupted value chain", *McKinsey & Company*, Autumn 2011. Available at: https://www.mckinsey.com/~/media/mckinsey/dotcom/client_service/semiconductors/pdfs/mosc_1_business_models.ashx.

**Exhibit 2** Breakdown of Country and Company Market Shares for Semiconductor Foundries in 2020.

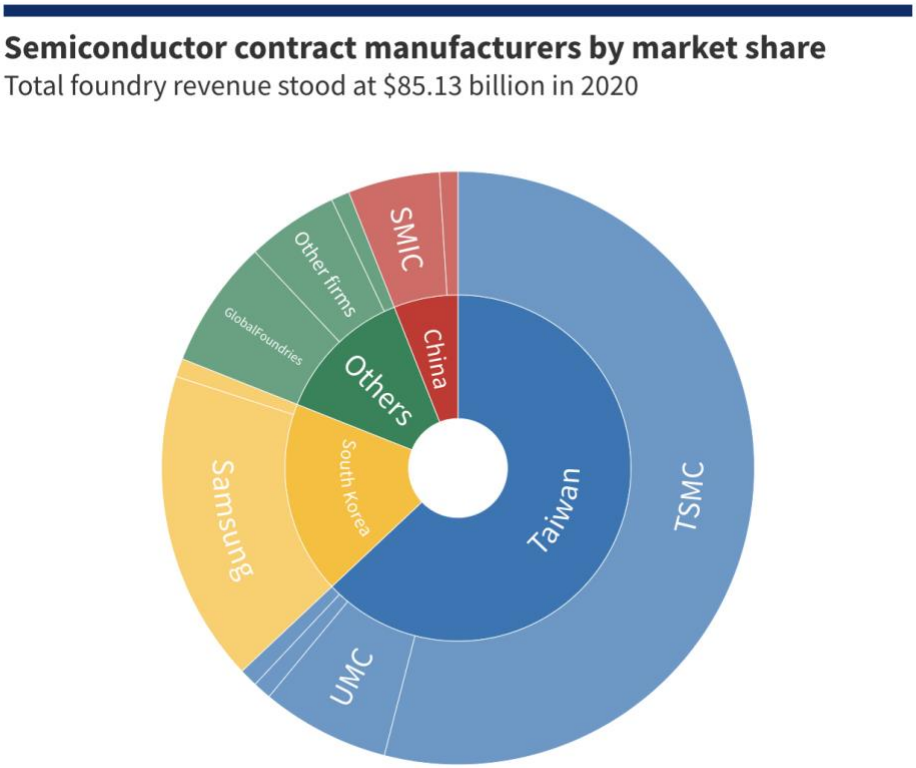


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**Exhibit 3** Total Market Revenue for Pure-Play Foundries by Chip Type and Company.

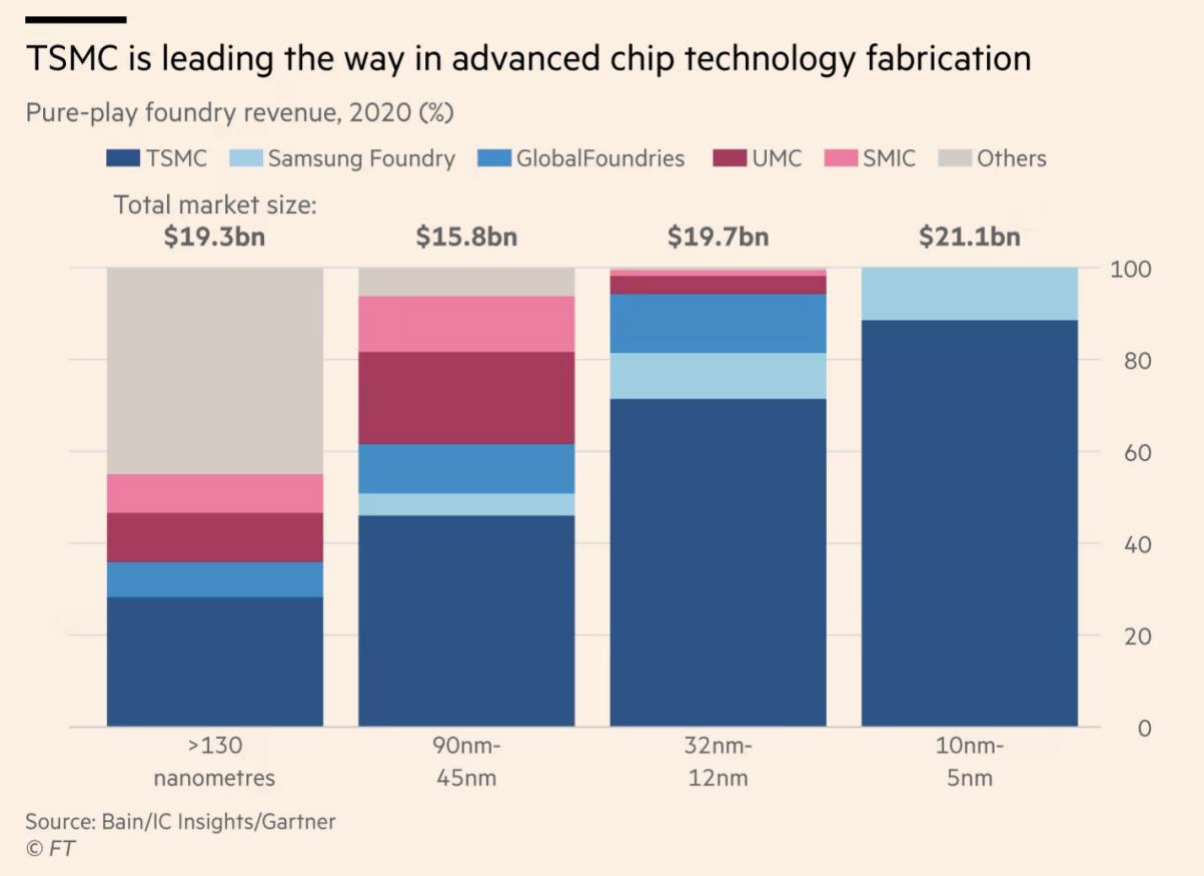


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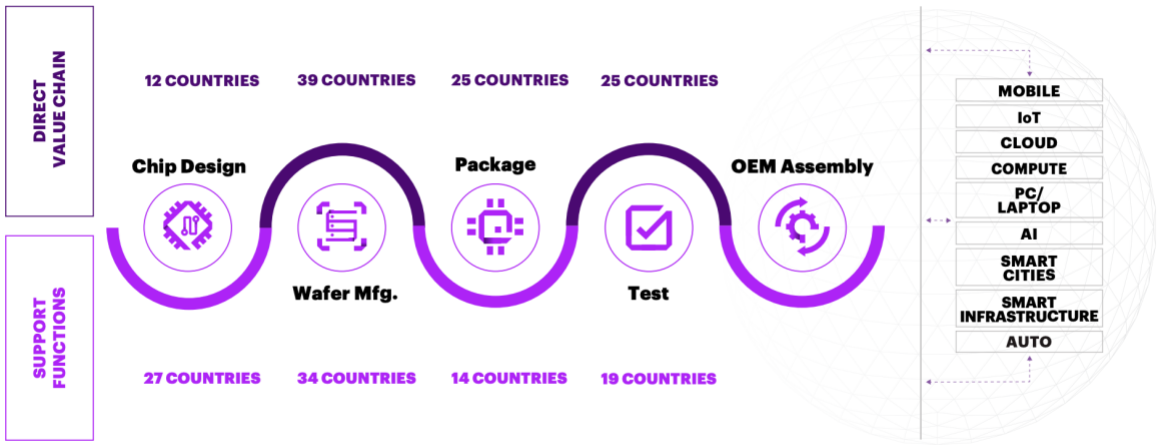
**Exhibit 4** Number of Countries Involved in the Stages of Semiconductor Manufacturing.




Source: Syed Alam et al., "Globality and Complexity of the Semiconductor Ecosystem", Accenture, 2020. Available at: https://www.accenture.com/_acnmedia/PDF-119/Accenture-Globality-Semiconductor-Industry.pdf.

# Teaching Note

## The TSMC Way: How One Company Revolutionised The Semiconductor Manufacturing Industry

### Case Summary

This case analyses the Taiwanese semiconductor industry and TSMC by looking at its history, unique positioning within the semiconductor supply chain, and how geopolitical and technological trends affect it.

Morris Chang put Taiwan on the map through the creation of TSMC, the world's first foundry. With financial support from the Taiwanese government and by identifying Taiwan's strengths, Chang catapulted TSMC into the dominant position it holds today.

Despite Taiwan's well-established position in the industry, global trends, such as supply chain disruptions, geopolitical conflicts, and technological innovation continue to influence its position. Recent global events have exposed the fragility of the supply chain and have led to widespread chip shortages, highlighting the dangers of over-reliance on Taiwan. Such concerns are leading to governments incentivizing domestic manufacturing to protect against potential supply chain disruptions that are at heightened risk due to factors such as the US-China trade war. Taiwan's "silicon shield" has provided safety thus far, but rising China-Taiwan tensions may prove too strong. Additionally, TSMC is one of the few companies on the leading edge of advanced chip manufacturing, for which demand is increasing due to advancements in areas such as cloud computing and AI. Key players in the industry are aware of the overdependence on Taiwanese supply, but resolution is not easy due to the required capital investment, and the promise of success in the technological expertise demonstrated by TSMC. This case was prepared through a combination of primary and secondary research including an interview with John Kirwan, Head of Global Customer Operations at Analog Devices.

## Objectives

- Develop an understanding of the complexity of global supply chains and the benefits and challenges associated with this.
- Enhance understanding of the importance of strategic business models in the context of the global semiconductor industry.
- Develop an appreciation for the factors influencing the international business operating environment, such as technological innovation and geopolitical concerns.
- Gain a deeper understanding of the effects competition and cooperation play in international business conduct, and the safety or challenges they bring.
- Understand the role governments play in global markets.

## Questions

1. What geopolitical threats to Taiwan's semiconductor industry were identified in the case. What is Taiwan's "silicon shield"?
2. What is the semiconductor cycle? How do semiconductor companies balance the need to invest in new manufacturing capabilities with the potential risks associated with cyclical fluctuations in demand?
3. How did TSMC's foundry model revolutionise the semiconductor industry? Why are more semiconductor companies moving towards a foundry-fabless model?
4. Complex political issues were raised in the case, such as rising tensions with China. What role do semiconductor companies play in modern warfare and conflicts such as the Russian-Ukraine War? Do you believe they have a moral obligation to prevent their products from being used in such conflicts?
5. What actions do you propose players in the semiconductor industry take to tackle the over-reliance on Taiwan presented in the case? Knowing this existing vulnerability, do you think there is an easy solution to implement?

## Potential Responses

### *Question 1*

Taiwan has faced the threat of invasion from China throughout its history. Taiwan's "silicon shield" describes how it uses its dominance in semiconductor manufacturing as a type of

economic defence against aggression. Taiwan has made massive investments to stay at the cutting edge of semiconductor development. Because of its technological advantages and market share, major powers like the US and China are reliant on Taiwan's supply of semiconductors for both military and consumer applications. Many countries are also reliant on Taiwan as a customer in the industry, such as the Netherlands which produces the lithography machines used during manufacturing, or Japan, which exports many of the chemicals and components used in the chips. The theory is that this reliance on Taiwan would compel the world to come to its aid in the event of an invasion, while also discouraging China from causing disruptions to the semiconductor industry that would have repercussions on its economy. It is a good example of what Goldin and Mariathasan describe as the Butterfly Defect. In the case of a conflict between the US and China, the hyperconnected semiconductor industry would likely collapse, hurting the economies of all nations involved and blocking the production of complex electronics.

However, multiple factors have recently caused countries to reconsider this relationship. China and the US have increasingly been at odds on several issues including the status of Taiwan as an independent nation, and access to advanced chips for military and AI applications. The global chip shortage has also made both nations reassess their reliance on Taiwan. The US has realised it has few alternatives to TSMC when it comes to advanced chips, and the conflict in Ukraine has made it obvious that modern war requires far more chips than previously thought. Realising that the semiconductor industry is both integral to national security and extremely vulnerable, the US has increased its investments in domestic chip production with the CHIPS and Science Act. Other countries such as Japan have followed suit with their own investments.

## *Question 2*

Semiconductor companies balance the need to invest in new technologies and manufacturing capabilities with the potential risks associated with cyclical fluctuations in demand by carefully forecasting demand and managing their supply chains. The “Semiconductor Cycle” from the case study is a great example of the bullwhip effect. This effect causes fluctuations in order quantities as they move up the supply chain. At retail, a small change in customer

demand may be distorted as it travels through the supply chain and is perceived as a greater increase in demand than it actually is.

To manage their supply chains, they need to improve their inventory planning process and improve communication at all levels of the supply chain. Many retailers may place orders with suppliers after demand has had time to accumulate. This causes a sudden surge and dip in demand when in reality demand could have been at a constant flow.

Companies such as TSMC must be careful when investing in expensive technologies required to manufacture these products. For example, if they have a sudden surge in demand from a situation like mentioned above, TSMC could invest money into new fabs and technologies needed to manufacture a certain product that will meet demand, however, this demand may be temporary and TSMC may not receive a profitable return. In the case of the fabs being built in Arizona, production of the N3 chips will begin in 2026. Mass production has already recently begun in Taiwanese fabs for these chips, so by the time 2026 comes, the demand for these chips may be reduced due to the release of faster and longer-lasting chips.

To minimise the risk of the cyclical fluctuations in demand the semiconductor industry faces, companies such as TSMC have research teams that anticipate the advances in semiconductor technology and trends in the industry as a whole in the coming decades. Relating back to the N3 chip, TSMC have teams that research how demand will look for this chip in many years to come and from that they can manage what new technologies and manufacturing capabilities are needed to meet the constant cyclical fluctuations in demand.

### *Question 3*

As opposed to the vertical integration model of integrated device manufacturers (IDMs), foundry-fabless business models are increasingly being used in the semiconductor sector. Morris Chang introduced this business model and revolutionised the semiconductor industry which had previously consisted mainly of IDMs. TSMC placed focus on manufacturing, allowing them to mass produce a variety of products and take advantage of the skills of Taiwanese workers which in turn allowed them to overtake their competitors in manufacturing.

The move to outsource production to foundries has since become increasingly popular due to its cost-effectiveness, with successful companies, such as Analog Devices, following suit and outsourcing at least part of their operations to foundries such as TSMC. In addition to manufacturing, foundries now also offer a variety of services including design, testing, packaging, and back-end integration, which has led to some successful fabless companies also outsourcing their design production to foundries.[1] Another reason more semiconductor companies are moving to a foundry-fabless model today is because it provides an opportunity for poorer nations to generate revenue and succeed in certain industries as explained in the IBGE reading "How Finance Gutted Manufacturing".[2] Taiwan is a perfect example of a smaller country that has taken advantage of the move away from vertically integrated companies to grow their industry, resulting in more semiconductor companies following suit and transitioning to this lucrative foundry business model developed by TSMC.

Although foundries have grown in popularity in the semiconductor industry in recent years, there could likely be a limit to this growth. IDMs have an advantage when it comes to speciality technology, which is an area that foundries may struggle to intercept. Because of this, some predict that instead of the 10-15% it has grown in the past, the industry will only grow by 5-10% per year into the future.[3]

## *Question 4*

Semiconductor companies, which enable nearly every modern industrial, commercial, and military system, play a critical role in modern warfare and national security. Taiwan's semiconductor industry is particularly important due to its chip manufacturing dominance.[4] Because of this dominance, some refer to Taiwan's semiconductor industry as its "silicon shield," giving the rest of the world a compelling reason to defend the island.

Opinions on whether semiconductor companies have a moral obligation to prevent their products from being used in conflicts such as the Russian-Ukraine War vary. Some argue that these companies have a responsibility to ensure that their products are not used in conflicts, whereas others may believe that it is ultimately up to each company.[5] We ultimately believe that companies have a moral obligation to ensure that their products are not being used to

escalate global political tensions. For instance, according to a report by the Asia Times, TSMC said it ships almost no products to Russia.[6]

As the world's leading semiconductor manufacturer, TSMC has a major role in global conflicts. This puts TSMC at the centre of the geopolitical tensions between the US and China, particularly as Taiwan is a potential flashpoint for conflict between these two superpowers.[7] TSMC would likely be a key target for both sides if a war broke out between the nations. China might try to take over TSMC's manufacturing capabilities, which would give it a technological edge in the battle. The US, on the other hand, may seek to prevent China from gaining access to TSMC's technology, potentially imposing export controls or seizing TSMC's assets.

Overall, risk management plays a large part in how TSMC responds to international conflicts. The business must be ready for potential interruptions brought on by both ongoing geopolitical tensions and any potential negative effects that a conflict may have on its clientele and supply chain. While keeping in mind the potential effects of its products on international security and stability, TSMC must also make sure that it conducts its business ethically and responsibly.

### *Question 5*

In-house manufacturing is an obvious action to tackle the overdependence on Taiwanese supply. However, as illustrated in this case, becoming established in the manufacturing sector of the industry requires immense capital investment. Continuous investment is required in machinery and R&D to stay ahead of competitors, such as TSMC investing $100 billion over three years on manufacturing infrastructure and R&D, as illustrated by the case.[8] The chip manufacturing process takes months to know if chips will even work. On top of this, by this time, industry leaders such as TSMC and Samsung may have already managed to manufacture a more advanced chip. Clearly, developing one’s own chips does not seem wise at first.

To reduce the risk involved with in-house manufacturing and keep the gains procured if a disruption to TSMC supply were to occur, we propose to focus on manufacturing a specific type of chip, potentially one targeted specifically for a certain area of technology development. As John Kirwan from Analog Devices explained, many companies have had in-

house development teams for decades.[9] Specifically, we propose to take inspiration from the success of Apple and Google, which target a particular use case or IP through their custom chips.

If you continue to outsource chip manufacturing, and disruption to TSMC's supply of semiconductor chips was to occur, this could lead to a total halt in business operations, drastically cutting your profits. For example, if the rising China-Taiwan tensions were to boil over, and the "silicon shield" was to break, supply from TSMC would be at risk, threatening your company's financial health. With in-house manufacturing, any disruptions to TSMC's supply would have little effect on your business. If anything, you could increase profits by raising costs since the supply of semiconductor chips will drastically decrease, with demand simultaneously increasing. Once again, we see the bullwhip effect of the semiconductor cycle.

Ultimately there is no easy solution to implement. Depending on the needs of your business, your tolerance for cash flow disruptions and your available capital, in-house manufacturing may be a viable option. In the end, there is no easy solution to resolve this conundrum, if there was it would have been implemented years ago!

# Endnotes

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