Taiwan Semiconductor Industry

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Introduction

This case study will discuss the interactions between Taiwan and the semiconductor industry by taking a closer look at the specific geographic/spatial factors affecting the location decisions in the Taiwan semiconductor industry. We must define what a semiconductor is and why it is so important in modern technology to better understand this important industry. A semiconductor chip is an electric circuit with many components such as transistors, resistors, diodes, and wiring, formed on a semiconductor wafer. These semiconductors "chips" are in turn part of an integrated circuit (IC) in a manufacturing process (Jie, et al., 2021). Semiconductor chips are used in just about every piece of modern technology; refrigerators, TVs, automobiles, you name it and there is probably a semiconductor chip inside. This leads to the question where are these chips made and lately, why do we hear about a shortage of semiconductor chips? One common question is why not ramp up production on semiconductor chips? This question is as difficult to answer as the question why not just create a perfectly pure crystal with not a molecule out of place? This recent shortage has brought to light Taiwan's outsized role in the semiconductor industry. Taiwan dominates it with Taiwan Semiconductor Manufacturing Company (TSMC) at its center accounting for over 60% of total global foundry revenue (Lee, 2021). TSMC supplies companies like AMD, Nvidia, and Apple. iPhone owners most likely have a TSMC chip in their pocket right now. It becomes a geopolitical tug of war

when creating a multibillion-dollar factory that will start production years from the initial investment.

Hsinchu City

Taiwan is by no means the only location where semiconductors chips are made but it is, in production and sales numbers, the main location. Taiwan (aka the Republic of China or ROC) is a small island nation in East Asia. It is near to People's Republic of China and Japan. The area of Taiwan is 13,826 sq mi or about the size of Maryland and has a population of 23.6 million living primarily in urbanized areas, it is one of the most densely populated countries in the world (Textor, 2021). Like many industrialized nations, Taiwan followed the shift from agriculture-based economy to an industry-based economy. During the 1950s, 60s, and 70s, it was dominated by cheap, labor-intensive manufacturing (Copper, 2021). By the 1980s Taiwan's economy had shifted to advanced electronics.

Hsinchu City is the location where TSMC is headquartered along with many other smaller design and manufacturing firms involved in the semiconductor industry. Hsinchu is the 7th largest city in Taiwan. Hsinchu City sits in the northwest corner of the country about 50 miles from Taipei City. This city is an economic hub for Taiwan. The Taiwanese government established Hsinchu Science Park (HSP) in 1980. The Park is a major source of Taiwan GDP making it a vital part of Taiwan's economy. The Hsinchu Science Park is divided into six satellite parks, namely, Hsinchu, Zhunan, Tonglu, Longtan, Yilan, and Hsinchu Biomedical Parks, on a total area of 1,342 hectares and employing 150,000 people. Its main sector is the integrated circuit industry which accounts for 70% of the park's total output value, as well as

the computer and peripheral industries, communications, optoelectronics, precision machinery and biotechnology. Known as “Taiwan’s Silicon Valley”, it is also home to a growing biomedical sector (IASP, n.d.). Industrial Location Theory helps better identify why the semiconductors industry gravitates around Taiwan. Location is valued by its proximity to resources needed for production. In the case of Hsinchu Science Park these resources include proximity to high tech manufacturing, a “one-stop service” for government-related topics such as environmental, safety, labor, and tax issues, access global water transport, industry clusters (agglomeration), and perhaps the most valuable of all of Taiwan’s resources - educated, well-trained, and diligent human capital (Fulco, 2019). Another key factor to Taiwan’s manufacturing success is the close range to global markets. Semiconductors are a very high value good, close proximity to global markets such as China, South Korea, and Japan is key to both producers and consumers of the industry.

Origins

Webber (1985) emphasizes that all firms seek to maximize profit. Thus, in the 1970s with a lack of natural resources, poor land-to-population ratio, little capital, and a discredited government Taiwan needed to focus on its strengths for profitable future economic development. These strengths were a low wage, highly educated, diligent workforce and a unique flexibility and adaptability to change of Taiwanese firms (Wang & Chiu, 2014). The origin of the Taiwan Semiconductor Industry (TSI) is stuff of legend. Pan Wen-yuan, a US-based research director at Radio Corporation of America (RCA), advised Sun Yun-suan, the minister for economic affairs, to develop integrated circuits. In 1976 Taiwan managed to persuade RCA to a

transfer of semiconductor technology (Soo, et al., 2019). Another key initiative was the formation of the Industrial Technology Research Institute (ITRI) to conduct applied research and provide technical help to the industry. The research and technology to create the TSI was born out of the ITRI. Many of the renowned Taiwanese semiconductor company founders have said the ITRI was the most important factor for the success of TSI (Wang & Chui, 2014). Hsinchu Science Park, the scienced-based industrial park discussed above was created around the same time. It is essentially a public-sector version of Silicon Valley. It offers a wide range of tax benefits and allowances to firms and is strategically located close to ITRI and two of the top research universities in the country. The geographic clustering of the semiconductor firms creates an agglomeration economy, significantly enhancing competitiveness of the TSI (Murray, 2009, Wang & Chui, 2014). Other ingredients provided by the government in the early days were public-sector financing, tax incentives, loan subsidies, human capital policies such as attractive offers to Taiwanese high-tech professional working overseas if they agreed to return home, and infrastructure (Wang & Chui, 2014).

Paradigm Shift

It takes more than government policies to explain the rise of the semiconductor industry in Taiwan. Around the mid-1980s, a major paradigm shift occurred for the industry; the separation of design and manufacturing (Wang & Chiu, 2014). Previously, the industry was dominated by a few large integrated device manufacturers like Intel and Texas Instruments. At that time, these companies designed, manufactured, branded and sold their integrated circuits (ICs) totally in-house, meaning all within a singular company in a production model is called

vertical integration. This system worked in the early days when IC complexity was low and the design, fabrication, and test processes were forming (SemiconductorEngineering.com, 2021). Several Factors contributed to vertical disintegration which is a production process distributed between separate companies opposed to just one. Surging demand, increasing capital investments for manufacturing equipment, complexity of the ICs, and shorter product life cycles made it impractical and cost prohibitive for one company to handle everything. This shift led to a mix of artificial and organic economic boom in Hsinchu. Semiconductor consumers flocked to Hsinchu and TSMC as capital was funneled into the semiconductor industry. Wang and Chiu say, "these factors have facilitated the division of labor … and supported greater codification or diffusion of formerly tacit knowledge" (2014). There were now opportunities for specialist firms to enter specific stages of the value chain.

Ecosystem

A key factor in the success of the TSI was the innovation of the "dedicated foundry", this was a proposed business model implemented by TSMC's founder Dr. Morris Chang. This allowed for the creation of firms solely based on others' chip designs. "His innovative business model greatly lowered the threshold needed to establish an IC design company by solving challenges of the increased complexity of technology development and the sizable investment for building wafer manufacturing fabs. It catalyzed and accelerated fabless start-ups and system houses IC design efforts, and in turn unleashed the tidal waves of innovation in chip design and product applications" (TSMC, 2021). The model focuses on developing high-tech process technology. Reliable IC fabrication, on-time delivery, and cost effectiveness, all while upholding

customer intellectual properties (IPs). The philosophy is to treat customers as partners and never compete against them. Other firms are highly specialized, each focused on a highly specialized chip or a particular stage of chip manufacturing. This creates an ecosystem in Hsinchu and the surrounding areas of Taiwan. Integrating research with technology allowing manufacturing done in different locations by separate companies, each with its own expertise; IP designers, fabless (fabrication-less) semiconductor companies that own the chip brand, and pure-play foundries who make the chips, along with outsourced semiconductor assembly and test firms who package and test (SemiconductorEngineering.com, 2021).

Industrial Location and TSI

Many decisions and factors contributed to making Taiwan the semiconductor industry world capital. Of the location theories covered in class; Weber's Least Cost Location, Christaller's Central Place, and Hotelling's Market Access (Wilson, 2021), the most applicable to the TSI is the Least Cost Location or more concisely, the Profit Maximizing Location. Again, all firms seek to maximize profit which is defined as revenues minus costs. Chapman (2009) presents a typology of industrial location factors which influence cost and revenue. Costs are affected by material, energy, land, labor, and capital. Revenues are affected by markets and competition. Both costs and revenues are affected by transport, infrastructure, agglomeration, and public policy. Public policy was and remains a large factor in the location of semiconductor industries in Taiwan. Top-down government planning like facilitating the US technology transfer, wooing overseas talent, establishing the ITRI, coupled with public policies like government funding, tax benefits, and public infrastructure like the construction of science and

industrial parks created an ecosystem in Taiwan where the TSI could flourish (Soo et. al., 2019 and Hui, 2021). The TSI was created through a combination of artificial and organic factors allowing for firms to best utilize the Profit Maximizing Location.

Conclusion

Aspects of Weber's Least Cost Theory do help explain the dominance, especially factors of public policy, labor, infrastructure, and agglomeration. Agglomeration and exceptional human capital are probably currently the two most significant factors influencing a company's decision to locate in Taiwan. Perhaps the simplest explanation for why the semiconductor industry is so concentrated in Taiwan is the fact that, right now, they are the only ones in the world that have the capability to do it, they are so advanced there is just no other competition out there (Lee, 2021 and Jie, et al., 2021).

Taiwan faces many challenges in the coming years. Tackling sustainability and a greener future is a daunting task while trying to maintain production for much of the world. China and the Chinese Communist Party continue to take bold steps on the geopolitical stage leaving Taiwan vulnerable to a Communist takeover. How would Taiwan react to changes in public policy or a stunted US relationship? These questions remain uncertain. But change is nothing new to Taiwan and with their great organizational and operational flexibility and conscientiousness the future looks promising.

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