Chapter 6
The Broad and Pivotal Roles of Taiwanese Electronics Industry in the Global Electronics Supply Chain: A Case Study of Foxconn and TSMC

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6.1 Introduction

The global supply chain of the consumer electronics industry can be broadly divided into the labor-intensive segment and the capital-intensive segment. A production activity in the electronics sector can, intuitively, be sorted into one of these two segments based on whether it is more contingent on human labor (labor-intensive) or machinery and technology (capital intensive). The electronics industry of Taiwan, an island of 24 million people, is a pivotal player along the entire global consumer electronics supply chain, being notable for leading both the capital-intensive segment, such as the production of semiconductor chips and other electronics components, as well as the labor-intensive segment, including final assembly of personal computers and smartphones. This landscape is rather unique compared to other Asia-Pacific economies, most of which specialize or lead in only one segment of the value chain.

In this chapter, we will examine the pivotal roles played by the Taiwanese electronics industry in both the labor-intensive and capital-intensive segments of the global electronics supply chain by focusing on two Taiwanese giants, Hon Hai Precision Industry (better known as Foxconn) and Taiwan Semiconductor Manufacturing Company (TSMC), both of which are the undisputed global leader in the respective supply chain segment in which they compete. We will study Foxconn, the world's largest provider of electronics manufacturing services, as the example for the labor-intensive segment of the supply chain, while TSMC, the

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world's largest independent semiconductor manufacturer, will serve as the case study for the capital-intensive segment.

The rest of this introductory section will provide a brief overview of the Taiwanese electronics industry's major players in the capital-intensive and labor-intensive segments, and their critical impact on the electronics industry in the Asia-Pacific region and around the world. This will be followed by two major sections that are dedicated to an in-depth examination of Foxconn and TSMC, respectively. In particular, we will analyze the two focal firms' respective "playbook" that has led to their enormous success, and explore the emerging challenges they face and their strategic responses to these challenges. Finally, we will conclude with a brief assessment of the future prospect of these two firms, and by extension, Taiwan's electronics industry in general.

6.1.1 Taiwanese Electronics Industry in the Labor-Intensive Supply Chain Segment

6.1.1.1 Putting It All Together: Taiwan's EMS and ODM Players

Within the labor-intensive segment of the global electronics supply chain, Taiwanese electronics firms have historically excelled as the contract manufacturers for their clients, many of which are the world's leading consumer electronics companies, such as Hewlett-Packard, Dell Computer, Lenovo, Apple, and Huawei (The Economist, 2013a, 2019b). Taiwanese contract manufacturers provide either electronics manufacturing services (EMS) or original design manufacturing (ODM) services. EMS firms are generally defined as those whose services for their clients are limited to the production process, including component sourcing, circuit board assembly, final assembly, and testing. ODM firms, on the other hand, are those that not only look after the production process for their clients but also assist them in product design (Sturgeon & Kawakami, 2010). These Taiwanese EMS and ODM firms source hundreds of electronics components from Asia and beyond and coordinate the logistics of getting them into their plants around Asia at the right time to be assembled into the electronics products on which the whole world has come to rely (The Economist, 2019b). Owing to the services provided by Taiwanese EMS and ODM firms, many leading consumer companies are able to market products under their own brands without the need to run their own factories.

6.1.1.2 Across the Strait: The Importance of China to the EMS/ODM Firms

The success of Taiwanese firms in the EMS/ODM space was rather opportune. Historically, cost has been one of the biggest drivers for EMS/ODM firms, which prompted them to seek out the cheapest labor force possible. They found this in China, where the availability of a massive labor pool was made even more enticing by a supportive government, which created special economic zones in the 1980s to attract foreign investment. The electronics firms in Taiwan, given their physical proximity to, and cultural and linguistic alignment with, China, became amongst the first to quickly set up bases of operation in government-supported hotspots, such as the southern city of Shenzhen. Soon, aided by China's state subsidies, they were able to expand quickly and develop economies of scale that outpaced that of its competitors (Dean, 2007). As a result, Taiwanese EMS/ODM became dominant players, assembling 80–90% of the world's laptops and 40–50% of the world's desktop PCs (David & Juang, 2017), even though these products bear the names of Lenovo, HP, Dell, and Apple (The Economist, 2013a). It is estimated that as much as 90% of the electronics hardware produced by the Taiwanese EMS/ODM firms are carried out in factories located in the Chinese mainland, erasing any doubt over the importance of China's vast labor pool to the success of Taiwanese EMS/ODM firms (Zhang, 2018).

However, China is no longer the sole focus today. As geopolitical tensions escalate and China's labor costs rise, Taiwanese EMS/ODMs have begun to sprawl out further across Southeast Asia. Today, factories of Taiwanese firms exist in countries such as Vietnam, Thailand, Malaysia, and Philippines, amongst others. These geographies have developed niches of their own, such as the production cluster of hard disk drives in Thailand (Arthur, 2011; Lee & Ke, 2019).

6.1.1.3 The Biggest Company the Average Consumer Has Never Heard of: Foxconn

Although their products are ubiquitous in everyday life, the major EMS and ODM players are not names that consumers readily recognize. These EMS and ODM companies, by revenue, include Taiwan-based Pegatron, Taiwan-based Quanta Computer, Singapore-based Flex, US-based Jabil, US-based Sanmina, and Taiwan-based Wistron (Clarke, 2019). As can be seen, the top firms are disproportionately Taiwanese. So too is the clear market leader, Foxconn.

Founded in 1974, Foxconn is the world's largest contract electronics manufacturer, producing a plethora of electronic goods for global brands like Apple, Google, and Sony. The firm gained global attention after emerging as the primary manufacturer of Apple's core products, including the iPhone and iPad. Today, Apple is believed to contribute around 50% of Foxconn's annual revenues (Li, 2018). Foxconn boasts the status of being China's largest private employer, employing 700,000 Chinese employees, down from a peak of 1.3 million around 2010 (Merchant, 2017; Wu & Lin, 2019). In addition, Foxconn has manufacturing operations in Europe, Brazil, India, Japan, Malaysia, Mexico, South Korea, and some preliminary investment in the United States (Duhigg & Bradsher, 2012). The company is undoubtedly a leader within the labor-intensive segment of the global electronics supply chain, owing to its unrivalled scale. This makes Foxconn an ideal subject to study as its past growth and future challenges are reflective of the many Taiwanese electronics firms occupying the same segment of the supply chain.

6.1.2 Taiwanese Firms' Position in the Capital-Intensive Supply Chain Segment

6.1.2.1 Bits and Bobs: The Role of Electronic Components

A major piece of the puzzle in electronics assembly is the components that go within each device on the assembly line. The typical smartphone contains a plethora of components that greatly range in complexity, and this complexity has been escalating as products evolve. A teardown of the iPhone X found that the bulk of component costs lie in the OLED display (30%), the cameras (9%), memory chip and RAM (9%), and Apple's flagship A11 processor (7%) (Segan, 2017). Predictably, the most expensive components are also the most complex. While Foxconn's primary business has been the final assembly of these components into finished goods, the design and production of these high-value components is the concern of the capital-intensive segment of the value chain. Taiwan's role in this segment of the supply chain, just as with the labor-intensive segment, is disproportionately large. As of 2019, Taiwan boasts the title of being the home base of the largest number of Apple's suppliers, ahead of both China and the United States (Apple Corporate Website, 2019) (see Fig. 6.1). One may wonder how a small island has miraculously accomplished this—the key to Taiwan's success began with semiconductors.

6.1.2.2 The Semiconductor Supply Chain

Semiconductors are the most foundational building blocks within the world of electronics. They are used to power virtually all modern electronics, being integral in the production of integrated chips, electronic components, and electronic devices.

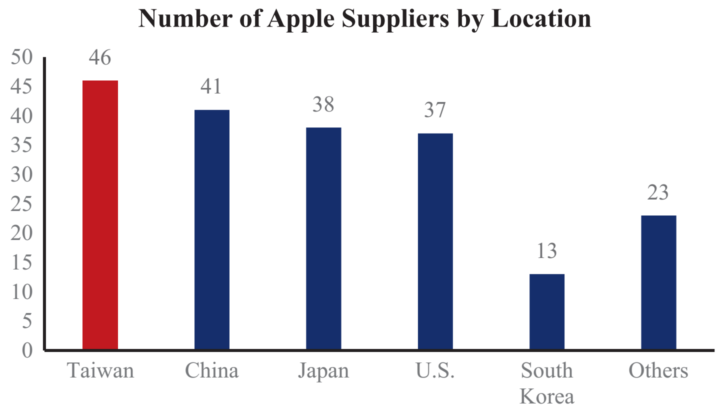

Fig. 6.1 Taiwan hosts the greatest number of Apple suppliers globally, outnumbering both China and the United States. *Source:* Based on information from Apple Corporate Website. 2019. Apple supplier list. https://www.apple.com/ca/supplier-responsibility/. Accessed 2 July 2020

Taiwan's long-standing strength has been in its presence throughout the semiconductor supply chain.

The semiconductor supply chain can generally be divided into three steps: the design of chips, the fabrication of silicon wafers and integrated chips, and finally the packaging of integrated circuits into commercial products (Batra et al., 2018). Firms that have end-to-end capabilities in this supply chain are known as integrated device manufacturers (IDMs) although most semiconductor firms develop niches and specialize in just one stage of the supply chain due to the immense capital requirements of operating across all three. Let us peek further into each stage of the supply chain.

Silicon Artistry: Fabless Design. Firms that focus solely on the design of semiconductor chips are known as fabless firms. Fabless firms first arose in the 1970s as private equity investors funded semiconductor startups that lacked the capital to build fabs ("fab" is short for "fabrication," also the name of factories that manufacture semiconductor chips) and therefore focused on chip design. Fabless firms rely on design talent, innovative R&D, and established distribution networks as sources of competition advantage.

The two major players within the fabless space include US-based Broadcom and Qualcomm, which command 17% and 16% of the global market, respectively. Due to low barriers of entry, the sector remains generally quite fragmented and contains many other players that specialize in different areas, such as US-based Nvidia and AMD with graphics cards, and US-based Xilinx with programmable logic devices (McGrath, 2019). Taiwan's presence in the fabless space is substantial–Taiwanese firms hold in total an estimated 20% of the global market share as of 2017 (McKinsey Global Institute, 2019). They have done so by securing profitable niches, such as MediaTek with entry-range smartphone chips (Qi, 2019).

Silicon Craftsmanship: Pure-play Foundries. Pure-play foundries do not manufacture semiconductor products of their own design. Instead, they manufacture semiconductor chips for their customers based on their specified designs. The pure-play foundry industry is incredibly capital intensive, demanding constant investment to keep up with the rapidly evolving technological needs of customers. Most of the investment goes into R&D of new processes and the construction of immensely expensive fabs to enable cutting-edge capabilities. Because of the high barriers of entry imposed by capital requirements, few players have the economies of scale to operate in this segment of the supply chain (Batra et al., 2018).

Taiwan Semiconductor Manufacturing Company (TSMC) is the clear global leader in foundries, with over 50% of the global market share. Aside from TSMC, which will be a focus of discussion in this chapter, the major pure-play foundries include Taiwan-based United Microelectronics Corporation (UMC), US-based GlobalFoundries, and China-based Semiconductor Manufacturing International Corporation (SMIC), with 6.9%, 6.6%, and 4.5% share of the market, respectively, as of the fourth quarter of 2020 (TrendForce, 2020).

Silicon Polymaths: Integrated Device Manufacturers. IDMs, as previously described, are firms that design, manufacture, and market semiconductor products. The two largest IDMs are US-based Intel and South Korea-based Samsung Electronics (referring to as Samsung thereafter). For the past three decades, Intel has stood as the semiconductor industry's single largest titan by revenue, which reached US$65.8 billion in 2019 (Cho, 2020). Samsung has challenged this crown on multiple occasions, overtaking Intel in 2017 and 2018 when demand surged for Samsung's DRAM and NAND products, before Intel was able to reclaim its leading position in 2019 (Cho, 2020). Some IDMs, such as Samsung, also offer their excess manufacturing capacity to fabless firms and are therefore also foundries (Samsung Official Blog, 2012). No Taiwanese firms are major IDM players.

Silicon Servicing: Integrated Chip Packaging and Testing. At the final stage of the semiconductor manufacturing process comes semiconductor assembly (or packaging) and testing. Many foundries and IDMs carry out these functions for their own semiconductor products, but others outsource at least some portion of them to third-party players. These third-party players are collectively known as outsourced semiconductor assembly and test firms (or OSATs) (Semiconductor Engineering, n.d.). According to Gartner, OSATs accounted for slightly over half of the worldwide semiconductor packaging and testing service revenues in 2017 (Lapedus, 2017).

Taiwanese companies are dominant OSAT players, with approximately 52% of the OSAT market share. Taiwan-based Advanced Semiconductor Engineering, Inc. (also known as ASE Group), is the global leader, accounting for approximately 18% of the OSATs revenue worldwide (*Yole Développement,* 2019). Since packaging and testing are the most labor-intensive stage of the whole semiconductor manufacturing process, these tasks are often performed in countries that have lower labor costs such as China and Malaysia (Verified Market Research, 2019). Unsurprisingly, ASE has substantial presence in these two countries (ASE Group corporate website, n.d.).

6.1.2.3 Beyond Silicon: Electronic Displays

While we have focused on semiconductors, a perceptive reader may have noticed earlier that the most expensive component within the cutting-edge iPhone X was not an integrated chip or processor, but rather the OLED display. Samsung, the world's second largest technology firms (after Apple) by revenue (Fortune, 2020), the largest maker of smartphones (IDC, 2021) and memory chips (Jennings, 2021), is also the largest producer of OLED display. Combined with the NAND and DRAM chips which it also supplies for Apple, Samsung makes more money selling components for iPhones, including OLED screens, than it does selling its own Galaxy smartphones (Gartenberg, 2017). Displays are surprisingly sophisticated—they are becoming increasingly intricate as consumers demand higher fidelity and color quality. We take this brief detour to discuss displays because they have entered the radar of major Taiwanese firms as a gateway to the very lucrative component business, which we shall explore later.

In addition to Samsung, the largest players in the display space are household names, such as Sony and Sharp, as well as rising stars, such as China-based BOE. Keep Japan-based Sharp in mind, as it has an important role to play in our story down the line. Taiwanese suppliers, not to be counted out, also have a major presence in the electronic display sector. Firms like Innolux and AU Optronics have long provided displays for prominent brands like Dell and Lenovo. In fact, one needs to look no further than the 17-inch touch panel of a Tesla car to find a product from Innolux (Niedermeyer, 2019).

6.1.2.4 One Firm to Rule Them All: TSMC

Returning to semiconductors as our focus for the capital-intensive end of the electronics supply chain, there is one firm that is undisputedly vital to global semiconductor production. Founded in 1987, TSMC is the world's largest semiconductor foundry. As of the fourth quarter of 2020, the behemoth firm commands 56% of the foundry market (TrendForce, 2020), boasts a capacity of 12 million 12-inch equivalent wafers, and serves over 500 different corporate customers (TSMC Corporate Website, n.d.). For comparison, the second largest foundry player in the world, Samsung, holds only a 16.4% share (TrendForce, 2020). TSMC's market capitalization has grown at a steady compound annual growth rate of over 30% to more than US$590 billion over the past 5 years, as of March 2021 (YCharts, 2021).

TSMC's massive size has lent it unrivalled superiority in economics of scale and R&D expenditure. This lets TSMC offer the most competitive prices in the industry and over 10,000 specialized products in advanced end markets including the internet of things, autonomous vehicles, and high-performance computing (TSMC Corporate Website, n.d.). So far, competitors can only dream of matching these advantages.

TSMC is also responsible for pioneering the pure-play foundry model by focusing only on white-label semiconductor manufacturing, which allows it to avoid any competition with its customers. This is an attractive pitch to customers such as Apple, as foundry competitors like Samsung may appear to have a conflict of interest by producing chips for rival firms while simultaneously operating in the same end markets (TSMC Corporate Website, n.d.).

6.2 The Case of Foxconn: A Leader in the Labor-Intensive Segment

Having established the macro landscape, we now dive into Foxconn to explore more closely the factors that have helped this Taiwanese firm win in the labor-based segment of the electronics supply chain. Simultaneously, we will investigate the emerging challenges Foxconn faces and its strategic responses.

6.2.1 Foxconn's Playbook: Scale and Cost Is King

Winning in the EMS/ODM space is straightforward—offer the lowest prices without going out of business. When customers looking to outsource production, they likely pick Foxconn because it does exactly this.

6.2.1.1 Size Matters

Foxconn has historically been able to lead on prices because of its unmatched size, providing economies of scale that minimizes the firm's overall operating costs. To get a sense of Foxconn's size, recall that Foxconn is China's single largest private employer with 1.3 million Chinese on its payroll at its peak. Foxconn's largest factory campus, located in Shenzhen, China, was dubbed "Foxconn City" and employed as many as 450,000 workers alone at one point (Merchant, 2017; Wu & Lin, 2019). "Foxconn City" contained 15 factories with dormitories for employees (a quarter of the workforce lived on-campus full-time), a dedicated fire brigade, its own TV network called "Foxconn TV," and a city center containing grocery stores, banks, hospitals, and entertainment facilities (Merchant, 2017; Mozur, 2012). It was here where the bulk of all iPhones were produced before other Foxconn iPhone factories popped up elsewhere in China. Foxconn's scale makes it more cost competitive than Chinese firms tapping into their own country's labor market. Huawei and Xiaomi could both hypothetically manufacture their phones in-house using domestic Chinese labor, but they choose to employ Foxconn because it makes better economic sense (Doffman, 2019).

6.2.1.2 Right Place at the Right Time

The origin of Foxconn's size advantage is two-fold. Firstly, the firm was an early mover when China opened its economy, establishing a beachhead in the Shenzhen Special Economic Zone as early as in 1988, when Chinese officials had rolled out a red carpet of tax exemptions, cheap real estate and simplified export laws. Seizing this opportunity, Foxconn was then able to take advantage of the inexpensive migrant workers from China's rural area to quickly expand its labor force, soon establishing two main clusters of operations at the Pearl River Delta in the south, where Shenzhen is located, and the Yangzi River Delta in the east, where Shanghai is located. By this point, it had enough access to cheap capital from private investors and eager local governments that its growth would only continue to snowball (Pun & Chan, 2012).

The second source of advantage comes from the common language and culture that Taiwan shares with mainland China. Compared to electronics industry giants in developed Asian economies like South Korea and Japan, which are also in close proximity to China, Taiwanese firms are uniquely capable of being able to do business in mainland China with minimal language and cultural barriers. This has greatly expedited Foxconn's ability to expand in China and recruit local engineering and managerial talent. In tandem, Foxconn has been able to keep ahead of competitors by erecting steep entry barriers as it can easily price out potential EMS (and ODM) rivals. However, recent shifts in the landscape have caused Foxconn's cost advantage to come under question.

6.2.2 Emerging Challenges and Foxconn's Strategic Realignment

6.2.2.1 No Way to Go but Up: Rising Costs in China

China's labor costs have been rapidly rising since the turn of the century. The country's average wage increased by 11.4% annually between 1995 and 2019, significantly outpacing growth in the rest of East Asia (Trading Economics, n.d.). Rising life expectancy combined with the effect of Beijing's now-retracted one-child policy is leading to a rapidly aging society with a steady decline in the proportion of working-age population. China's working-age population, which has begun to shrink since 2014, witnessed a sharp decline and sank below 1 billion for the first time since 2009, causing a major labor shortage in manufacturing (Glenn & Qiu, 2018; Wu & Fu, 2020). The rapid increase of labor cost in China is expected to continue into the foreseeable future.

Foxconn's response 1—Geographic "downstreaming" and automation. Foxconn's management is well aware of the threat that rising costs in China pose to its fundamental business model and have taken steps to mitigate this risk. Foxconn has been investing heavily in automation, with spending reaching US$4 billion in 2018 (Francis, 2018). In 2015, the firm announced that it would automate 30% of its facilities by 2020. While it is unclear if this 30% target was achieved, Foxconn did report a cut of 60,000 factory jobs in Kunshan (a suburb of Shanghai), China through automation in 2016 (Tang & Lahiri, 2018). Additionally, Foxconn partnered with Chinese software company Megvii to increase automation efficiency (Dai, 2017).

Besides automation, Foxconn has also engaged in geographic "downstreaming" by directing its focus away from costal China to inland China and other Asian countries, where labor is less expensive. With respect to inland China, Foxconn has made strategic shifts of its Chinese factories, opening new ones in the inland cities of Zhengzhou, Chengdu, and Taiyuan. Here, wages are still playing catch up to their more prosperous coastal counterparts (Hille, 2011). While some iPhones, iPads, and Macs were still being produced in coastal Shenzhen as of 2017, the bulk of production now occurs in inland Zhengzhou, Taiyuan, and Chengdu (see Fig. 6.2). Management has expressed a desire to eventually move all mass production within China to inland facilities, reinventing its coastal factories in locales like Shenzhen as "engineering campuses" for pilot production (Hille, 2011).

Foxconn's response 2—Placing eggs in many baskets. More interestingly, Foxconn is making a push to diversify from China. In 2019, Foxconn started to assemble iPhone XR in India for the local market (Sudheer & Vengattil, 2019). During the same year, Foxconn revealed a US$213.5 million investment into its Indian subsidiary aiming to expand its existing factories in India (Wu, 2020b). In July 2020, Foxconn was reported to have begun assembling iPhone 11 series in India (Marandi, 2020). In Vietnam, Foxconn is reported to have acquired the usage rights for more land (Wu, 2020b). It appears that Foxconn is under pressure to move more aggressively in diversifying away from China given the quickened pace of

Fig. 6.2 Most Apple products are now being produced inland by Foxconn as costs elevate. *Source:* Based on information from Wu, D., & Cheng, T-F. 2017. Foxconn seeks to raise its own profile after working for others. *Nikkei Asia Review*, July 9. https://asia.nikkei.com/Business/Foxconn-seeks-to-raise-its-own-profile-after-working-for-others2. Accessed 12 April 2021; and Shen, J. 2020. Foxconn breaks ground for new chip plant in China. *DigiTimes*, July 22. https://www.digitimes.com/news/a20200722PD201.html. Accessed 21 February 2021

similar moves by its competitors. Taiwan-based Pegatron, Foxconn's major competitor and the second largest manufacturer of Apple products, has started to move some of its production of Apple products from China to Indonesia (Hille, 2019a). Both Pegatron and Wistron, a Taiwan-based ODM and the third largest maker of Apple products, are building new factories in Vietnam, although it is not clear whether the factories will make Apple products (Wu, 2020a). Wistron has been assembling some low-priced iPhone models in India since 2017 (Phartiyal, 2020).

The effectiveness of automation and geographic downstreaming for Foxconn remains to be seen, as such initiatives are still in their early stages and have yet to be brought to scale. So far, no iPhones have been assembled by Foxconn in Vietnam (Wu, 2020a) and only a small portion of iPhones are made in Foxconn's plants in India (Li & Cheng, 2019). Replicating the production ecosystem in China that has allowed for seamless operation will be no easy feat, as will be discussed in a later section of the chapter.

6.2.2.2 From "Ping Pong Diplomacy" to Viral Blame Game: US–China Trade War

Directly related to the threat of rising costs in China is the US–China trade war. In 2018, Foxconn's founder and Chairman Terry Gou publicly stated, "The biggest challenge we're facing is the U.S.-China trade war" (Shen, 2018). This economic dispute between the Trump administration and Beijing has resulted in crippling tariffs on US$550 billion worth of Chinese products and US$185 billion worth of American goods since beginning in July 2018 (Wong & Koty, 2020). Foxconn's significant investment in China, including its status as China's largest private employer, is now showing itself to be a double-edged sword as further US tariffs, if affecting Foxconn's products, stand to devastate the firm's export-heavy operations.

The outlook of the trade war remains relatively uncertain. Although the White House and Beijing reached a "phase-one" trade agreement in January 2020, in which China promised to buy US $200 billion of American goods over 2 years in exchange for a partial reprieve from the punitive tariffs imposed by the Trump administration on $120 billion of Chinese products (Pramuk, 2020), the more deep-rooted disagreements between the two nations concerning technology transfer and technology rivalry remains unresolved (Kwan, 2020). Further talks to resolve the remaining issues were subsequently sidelined due to the COVID-19 crisis, during which both countries blamed the other for the origin or spread of the virus, which has driven the US–China relationship to one of its lowest points in recent history (Bremmer, 2020). While the new Biden administration is likely less volatile than its predecessor in its dealings with China, most analysts agree that the United States and China will remain at odds when it comes to their bilateral trade relations (Disis, 2021). In fact, in December 2020, then President-elect Biden made it clear that, when he took over the Oval Office, he would not immediately remove the punitive tariffs imposed on China by former President Trump (Lee & Kimball, 2020). Although Foxconn's American clients like Apple have so far safeguarded Foxconn's exports from China (most notably iPhones) from punitive US tariffs as the United States is hesitant to target product categories that would dampen profits of the most iconic American firms (Borak, Collins, & Liptak, 2019), the possibility of a rapidly deteriorating trade environment cannot be discounted given that the strategic rivalry between the United States and China has further deepened (Shangguan & Seow, 2022).

Foxconn's response 1—A balancing act. Keeping the punitive American tariff off assembled-in-China iPhones and other Apple devices is clearly important for Foxconn. Therefore, after the election of Donald Trump in 2016, a campaign by Foxconn to appease President Trump and strike a difficult, if not impossible, balance between Washington and Beijing moved into high gear. In July 2017, standing alongside a beaming President Trump in the White House, Terry Guo, Foxconn's founder and chairman, announced that the company would invest US$10 billion into a plant to manufacture liquid crystal displays (LCDs) in Wisconsin, creating 13,000 jobs (Hess, Quirmbach & White, 2020; Waldmeir, 2018). However, this plan may be ill-fated—in 2019, it was revealed that the LCD plant might not materialize as it was hard to justify the investment given the labor cost in the United States (Beddor, 2019). Instead, Foxconn would establish innovation centers, creating an estimated 1500 jobs—a substantial drop from the promised 13,000 (Patel, 2019). By that point, Wisconsin governor Tony Evers had called for renegotiations of the promised US$4 billion tax break offered to Foxconn by the previous governor to protect taxpayers, citing the deal with Foxconn was "no longer in play." Later that year, Foxconn announced that plans for the manufacturing plant would indeed proceed, producing smaller items such as tablets, glass for tablets, and phones at the plant instead of LCDs. Analysts remain skeptical (Cohn, 2019).

Foxconn's response 2—Cloning China. Besides the delicate dance with President Trump, Foxconn's cost-saving investments outside of China, including India and Vietnam, also double as a hedge against the potential wrath of the trade war. The firm now claims that 25% of its total capacity is outside China, enough to satisfy all US-bound iPhone demand if the threat of US tariff on Chinese-made smartphones materializes (Wu, 2019). However, this push to other Asian countries would force Foxconn to rethink its operating model. The experiences of other Taiwan-based firms outside of China foretell challenges for Foxconn. Firstly, China has over the years built an unparalleled electronics supply chain, or "the great chain of China" as the Economist put it (The Economist, 2018b: 61). For example, as of 2019, of a total of 198 component suppliers for the Apple products, 41 are Chinese firms, compared to 46 Taiwanese firms and 37 American firms. This makes China the second largest home country of all Apple suppliers. More importantly, China is by far the largest host countries of Apple's supply chain. Of the 809 production facilities around the world that makes components for Apple products, 380 are located in China (Apple Corporate Website, 2019) (see Fig. 6.3). This means that even if an Apple supplier is not based in China, it likely operates manufacturing facilities there. Secondly, China also boasts well-organized logistics, supported by extensive network of expressways and railways, well-located modern container ports along its Pacific coast, and efficient customs clearance procedures, all of which can be challenging in India and some Southeast Asian countries (Shih, 2020). Thirdly, it has been observed that workers in Southeast Asia are not as willing to travel far from home

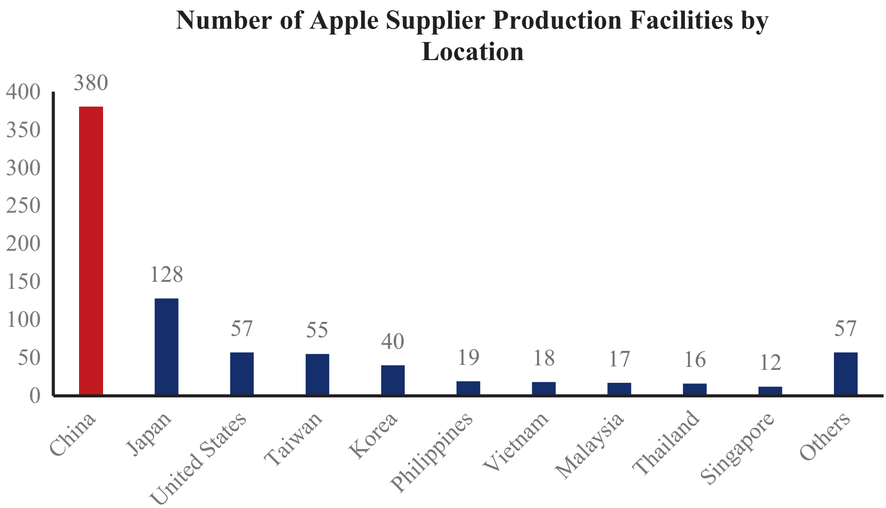

Fig. 6.3 China is home to the overwhelming majority of production facilities that directly supply Apple. *Source:* Based on information from Apple Corporate Website. 2019. Apple supplier list. https://www.apple.com/ca/supplier-responsibility/. Accessed 2 July 2020

for work or live in on-campus dormitories as do Chinese migrant workers. This would restrict the size of any single factory in Southeast Asia to a workforce of around 20,000. Foxconn's factories in China are many times that size (Hille, 2019a). It turns out that it is not trivial to "clone" China elsewhere.

6.2.2.3 From Smartphone to Smarter Devices: Macro Shifts in Demand

While rising wages in China and the US–China Trade War have put pressure on Foxconn's costs, the firm is also facing macro shifts in demand that threaten its topline. The bread and butter of Foxconn's business has been the production of traditional consumer electronics like smartphones, tablets, and laptops. However, the firm's reliance on these products may limit Foxconn as this space is maturing. Global PC and tablet markets have witnessed a downward trend for a number of years (IDC, 2020; Richer, 2019b). Since 2016, global smartphone shipments—a category representing a lion's share of Foxconn's revenues—have dropped every single year for a net decrease of 7% (Richer, 2019a) (see Fig. 6.4). iPhones alone fell 10.7% year-over-year in 2019 (Lovejoy, 2019) although iPhone had a very strong fourth quarter in 2020, especially in China, due to the release of 5G enabled iPhone 12 (Lovejoy, 2021).

Growth in manufacturing has instead shifted towards more advanced AI-driven products like smart speakers, medical devices, and robotics. Global investment in

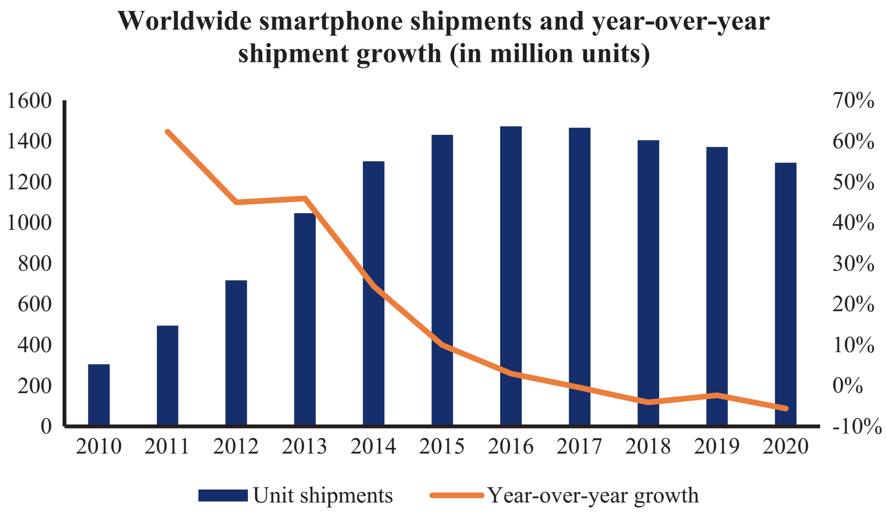

Fig. 6.4 Smartphone growth has steadily declined since 2010, becoming negative in 2017. *Source:* Based on information from IDC. 2021. Smartphone shipments worldwide from 4th quarter 2009 to 4th quarter 2020 (in million units) [Graph]. In Statista. January 27. https://www.statista.com/statistics/728644/quarterly-global-smartphone-shipments-by-quarter/Smartphone shipments worldwide from 4th quarter 2009 to 4th quarter 2020. Accessed 17 March 2021

artificial intelligence is expected to grow aggressively by 36% annually through to 2025, which would drive significant manufacturing demand for advanced, "smart" goods (Wu, 2018). According to International Data Corporation's forecast, worldwide shipments for smart home products will grow by a 5-year compound annual growth rate of 14.4% through to 2023 (IDC, 2019), significantly outpacing growth in smartphones. In particular, China has been identified as the fastest growing market for such products, with a 5-year compound annual growth rate of 22.6% (EP&T, 2019).

Given that Foxconn's core business of electronics assembly already has razor-thin margins (The Economist, 2012), this set of pincer forces has made a deep dent on its profitability. Foxconn's net profit was down 10.7% to US$3.81 billion year-over-year in 2019, declining 24% in the last quarter of 2019 alone (Lee, Shen & Blanchard, 2020).

Foxconn's response 1—A "Sharp" turn into the LCD and chip businesses. Foxconn has been proactive in entering the electronics components business to pursue better margins (Nakamura, 2015). This strategic move has taken on some urgency as the demand in its core markets stalling and costs on the rise. In 2016, Foxconn paid US$3.5 billion to acquire Sharp, a centuries-old Japanese pioneer of the electronics industry (Harding & Inagaki, 2016). This deal has been accretive for Sharp, which has seen the production costs of its home appliances drop by 15% since joining Foxconn's manufacturing sphere (Inagaki, 2019). For Foxconn, this acquisition gives the firm control of an instantly recognizable electronics brand and proprietary technology in LCDs, in which Sharp is a market leader. This last piece is critical, as it represents Foxconn's formal push up the value chain into the section of the components business which tends to command a substantially higher margin than that of final assembly. Incidentally, Sharp's biggest components customer is Apple, which constitutes a quarter of its total sales (Iakamura, Chiba & Osawa, 2018).

The Sharp acquisition also equipped Foxconn with semiconductor design and manufacturing technology for the first time in the firm's history—technology which Foxconn was eager to exploit with a flurry of semiconductor-related deals in recent years with local governments in China (Cheng, Li & Ihara, 2018). For example, in the summer of 2018, Foxconn announced plans to develop semiconductor design services, and semiconductor equipment and chip design operations in Zhuhai, a southern Chinese city, in collaboration with the city's government. In October of the same year, Foxconn entered a cooperation deal with the government of Jinan, in the Shandong province, to set up a joint industrial fund of nearly US$530 million to develop the city's semiconductor sector, which will involve establishing new chip design firms. A month later, the company reached an agreement with the government of Nanjing, a large city on the Yangtze River, to construct a US$282 million new factory to make chip manufacturing equipment (Zhang, 2020). In early 2020, Foxconn signed an agreement to build a semiconductor assembly and test plant in Qingdao, an eastern port city in Shandong Province (see Fig. 6.2 for the plant's location), which is jointly financed with China's Rongkong Group. The new plant, which broke ground in July 2020 and is expected to reach full capacity by 2025, will focus on the packaging and testing of application-specific integrated circuits used in

5G communications and artificial intelligence (AI) hardware products (Shen, 2020; Zhang, 2020).

Foxconn's response 2—Leapfrogging into the advanced technology space. Since around 2016, Foxconn has also made multiple acquisitions in an attempt to leapfrog into products in the newer and more advanced technology space. In 2019, the firm stated that the majority of its US$955 m to US$1.5 billion per year capital expenditure would now be channeled to develop technological capabilities for advanced technology fields, including 5G, automotive electronics, industrial internet of things, medical applications, and semiconductors (Hille, 2019b, 2019c).

In 2018, Foxconn acquired Belkin (Boom, 2018), a California-based maker of smart home devices, following earlier investments, including Beijing-based AI tech firm Moran Cognitive Technology (Crunch Base, 2018). Foxconn has also acquired a 20% stake in Japan-based Softbank's robotics venture, which owns Pepper, a popular humanoid service robot in Japan (Inagaki, 2019). Additionally, in 2021, Foxconn took a US$200 million stake in Chinese electric vehicle startup Byton (Taylor, 2021) and is reportedly in talks with Fiat Chrysler Automobiles to establish a joint venture to manufacture electric cars and develop internet-connected vehicles in China (Naughton & Kubota, 2020). A particularly daring move in Foxconn's push to advanced technologies is the creation of Foxconn Industrial Internet (FII), a subsidiary of Foxconn that provides industrial robots, cloud computing, and intelligent manufacturing services to clients. FII was spun off from Foxconn and held an initial public offering in 2018 on the Shanghai Stock Exchange, raising a record US$4.3 billion (Wu, 2018).

Foxconn's response 3—Terry Gou's vision fund. Beyond manufacturing, Foxconn is also seeking to replicate SoftBank's famous (or infamous) US$100 billion Vision Fund, which has sent shockwaves throughout the venture capital community with its staggering size and lead investments in high profile technology companies like Uber, DiDi Chuxing, Grab, OYO, Alibaba, ByteDance, and Nvidia (Paige, Ghosh & Sapra, 2020). Foxconn founder and chairman Terry Gou, despite vowing never to return to management after leaving in 2019 for a failed Taiwan presidency bid, has come back to launch a similar global technology investment fund. Gou envisions this as a driver for Foxconn's future growth and has clearly taken inspiration from the Vision Fund, in which Foxconn is an investor. Gou describes his relationship with Softbank's chairman Masayoshi Son as "just a phone call away," and there is a strong belief that the two will co-ordinate investment strategies once Foxconn's fund is active.

6.3 The Case of TSMC: A Leader in the Capital-Intensive Segment

Moving up the capital-intensive segment of the electronics supply chain, we now take a closer look at TSMC to inspect the factors that have allowed this Taiwanese firm to become the world's largest pure-play semiconductor foundry. Recall that a pure-play foundry is a semiconductor player that focuses only on the manufacturing of chips as opposed to design.

6.3.1 TSMC's Playbook: Technology Leadership Wins

TSMC is not only the world's largest semiconductor foundry, but also the most advanced in terms of leading-edge manufacturing capabilities (The Economist, 2018a). As of 2020, TSMC is one of just two firms in the world capable of producing state-of-the-art 5-nanometer chips, the other being Samsung (Herh, 2020). In the semiconductor industry, the smaller the nanometer, the more advanced the chip (and the more difficult it is to develop and manufacture). TSMC, alongside Samsung, was first-to-market with both the current 5-nanometer chip as well as the previous generation 7-nanometer chip (Toulas & Vatu, 2020) (see Fig. 6.5). TSMC's leading technology has made it very attractive for customers. In 2019, in its attempt to challenge Intel in the CPU market, US-based fabless semiconductor firm AMD switched its chip supplier from GlobalFoundries, a US-based foundry once affiliated with AMD, to TSMC for its superior 7-nanometer chips (Hruska, 2018). As TSMC's customers include technology innovators like Google, Apple, and Huawei, who consistently demand the best, TSMC's technology leadership has kept pace.

6.3.1.1 Born in Silicon Valley East

The origin of TSMC's technology leadership can be traced back to the Taiwanese government's intelligent planning and keen foresight decades ago. In 1973, Taipei decided to support the then-budding semiconductor industry by establishing the Industrial Technology Research Institute (ITRI), a public R&D institution funded by the government, as well as the Hsinchu Science Park, a high-tech cluster located

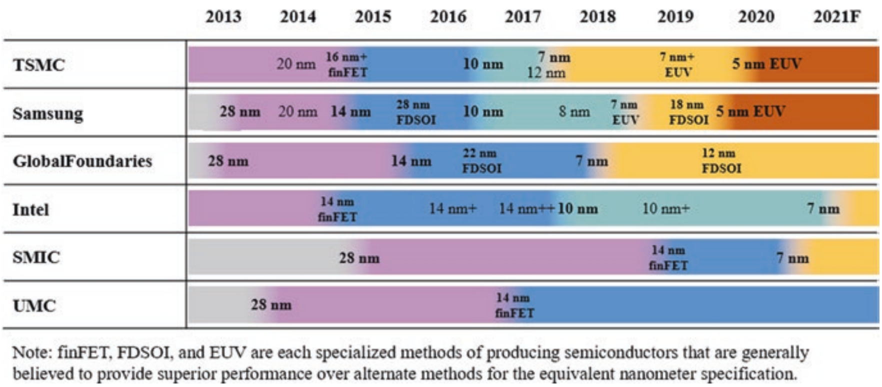

Fig. 6.5 TMC has consistently remained a technology leader among foundries by offering the newest products*

***Lower nanometer represents more advanced semiconductor chips**

Source: **Based on information from Any Silicon. 2019. Semiconductor foundry process roadmap. February 27. https://anysilicon.com/semiconductor-foundry-process-roadmap/. Access 12 April 2020** near Taiwan's best universities with an environment that was meant to mimic the setting of Silicon Valley. It was under these conditions that a number of Taiwanese technology firms were formed using public funding, some of which were later spun off into independent companies (So, 2006). United Microelectronics Corporation (UMC), the world's second largest pure-play foundry by production volume after TSMC, was created this way. Many Taiwanese scientist and engineers abroad returned home during this time, enticed by the bustling activity, including Texas Instruments executive Morris Chang, who came back to lead ITRI. Spotting an opportunity to fill a market whitespace that was pure-play semiconductor manufacturing, Chang left ITRI in 1987 to establish TSMC (Landler, 2000).

6.3.1.2 Brains and Brawn

The rich hi-tech ecosystem in the Hsinchu Science Park fostered a large cluster of semiconductor design firms (also known as fabless firms), which, in turn, created large demand for semiconductor fabs such as TSMC and UMC (VerWey, 2019). In this environment, under the visionary leadership of Morris Chang, TSMC expanded rapidly, which allowed it to commit significant amount of capital to R&D in order to aim for, and maintain, technology leadership. TSMC's dedication of over 8% (US$25 billion) of its annual revenues to R&D annually would not have been feasible if not for its unrivalled size and subsequent economies of scale (TSMC Corporate Website, n.d.). This strength can be observed clearly through TSMC's operating margins of 35% (TSMC Annual Report, 2019) compared to 25.8% industry average in 2019 (CSIMarket, n.d.). This advantage has let TSMC outpace competition in total R&D spending and stay ahead in an industry where costs get prohibitively high as specifications become more advanced. Few can afford to stay in the game. In 2017, both GlobalFoundries and UMC announced that they would abandon all 7-nanometer (nm) development in favor of improving existing designs, citing capital constraints (CDRinfo, 2018).

To gain a sense of just how expensive advanced semiconductor production is, consider the size of a 5 nm chip. 5 nm is 15,000 times smaller than a single human hair, 1000 times smaller than a red blood cell, and 100 times shorter than the wavelength of visible light (The Economist, 2019a). Not only does the machinery to produce these circuits have to be precise enough to work at molecular levels, but at this scale, a single dust particle can cause catastrophic failure, meaning the main process floor must operate in an airlock at Class 0–10 cleanroom standards—up to 10 times cleaner than a hospital operating room (JJP Architects & Planners, n.d.). Take a moment to imagine how expensive building and operating such facilities would be.

The exact number is US$17 billion. That is the cost of Fab 18, TSMC's newest 5-nanometer production facility as of 2020, which holds the title of the most expensive factory ever built. For comparison, Tesla's industry-leading factory in Shanghai cost just a fifth of that amount (The Economist, 2019a). On top of all this, in 2021, TSMC announced that it would invest an astonishing $100 billion over the next

3 years in capacity development (Yang & Jie, 2021). With so little competition at the top, TSMC has flourished in a "winner takes all" market that allows it to cash in on customers looking for the best, thereby securing the capital needed to continue investing in newer advancements that lock out competition.

6.3.1.3 No "Moore"?

The empirical observation that semiconductors have been improving in a predictable pattern is captured in Moore's Law, which states that every 2 years the number of transistors on a microchip approximately doubles, and the cost is halved (Intel Corporate Website, n.d.) (see Fig. 6.6). In practice, this is due to semiconductor firms constantly racing to produce the best products at the lowest costs. TSMC has always been a frontrunner of Moore's Law, but this may be jeopardized as Moore's Law is expected to come to an end soon as the limits of physics draw near.

The 5-nanometer specification was once believed to be the end of Moore's Law, as at this level, quantum tunneling begins to occur, in which transistors are so physically close to each other that electrons begin to jump from their intended logic gate to other gates. This would make it impossible to maintain a controlled flow (Gartenberg, 2016). Clearly, TSMC has found a solution to quantum tunneling, given their successful commercialization of the 5-nanometer standard. In fact, TSMC has already announced development for 3-nanometer chips, expected to enter production in the second half of 2022 in a newly constructed plant in the Southern Taiwan Science Park (Chen & Shen, 2020).

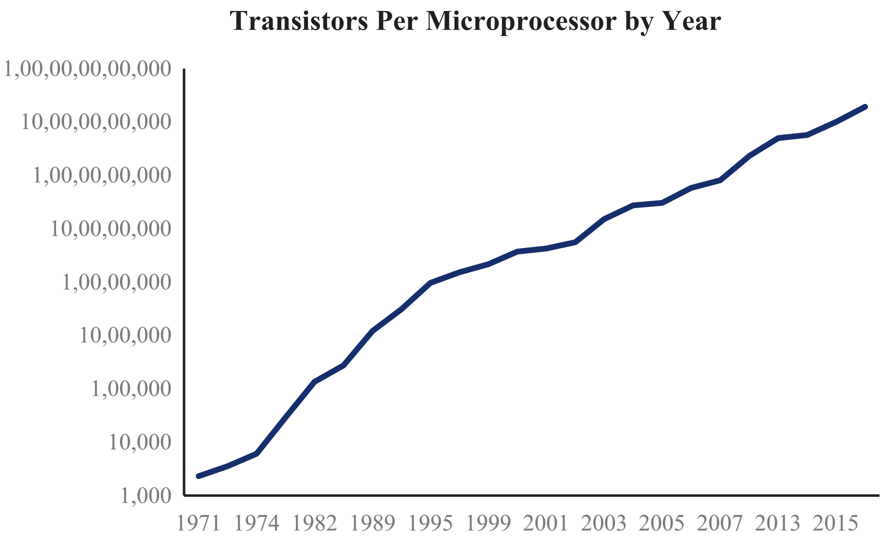

Fig. 6.6 Moore's Law shows a linear progression in the doubling of transistors per microprocessor. *Source:* Roser, M., & Ritchie, H. 2013. Technological progress. *Our World in Data*. https://ourworldindata.org/technological-progress. Accessed 12 April 2020

6.3.2 *Emerging Challenges and TSMC's Strategic Realignment*

6.3.2.1 A Modern-Day "Arms Race": US–China Hi-Tech Rivalry

The US–China rivalry is not limited to spats on tariffs, which deescalated somewhat as the two sides reached the "phase-one" deal in January 2020. Instead, the root cause of the US's grievance against China has much to do with the greater contest between an incumbent superpower and a rising challenger (Shangguan & Seow, 2022). The semiconductor sector sits at the very center of this contest (Kwan, 2020).

"Made in China 2025." It turns out that mass producing foreign branded products for export, aided by firms such as Foxconn, is not China's end game. In a bid to move away from being merely the "world's factory" and up the value chain, China has introduced its "Made in China 2025" plan with the aim of increasing Chinese domestic content of core materials and components to 40% by 2020 and 70% by 2025. Beijing has identified the domestic production of semiconductors as the number one priority of these targets (Cheng & Li, 2020a). The reason for this prioritization is one of self-sufficiency and national security. Between 2013 and 2018, China's balance of trade in integrated chips worsened from a US$144 billion deficit to a $227 billion deficit, and this gap is expected to increase in size as the number of chips in the electronic goods assembled in China has been increasing (VerWey, 2019). Furthermore, given that integrated chips have applications in military and other highly sensitive contexts, China's inability to supply its own chips leaves it vulnerable.

The gloves are off. For many of the past decades, China's rise as an export powerhouse did not cause a great deal of alarm in the United States other than the frequent complaints about China's unsavory practices of state subsidies and technological theft. This is mostly because China's manufacturing efficiency has benefited many American firms by keeping their products price-competitive. However, China's ambition to challenge the American supremacy in advanced technology as outlined in the "Made in China 2025" initiative is a game changer. "… [T]he age of perceived mutual benefit is over. It is hard for the world's powerful countries, particularly America, to tolerate a China with a global outlook, access to advanced technology and real geopolitical heft" (The Economist, 2020b: 12).

Huawei, the world's largest telecom equipment provider and second largest smartphone maker up until 2020, is the poster child of China's tech success and ambition. Not surprisingly, it is in the *crosshairs* of the US government, which is determined to stop Huawei from dominating the global 5G roll out (The Economist, 2020a). The Trump administration pressured allies to block Huawei from their 5G build out. In May 2019, the US Department of Commerce blacklisted Huawei by adding it to the Department's "entity list," which bans American companies from doing business with Huawei without first applying for and receiving a license (Chen, 2019). For Huawei and potentially other Chinese firms, the inability to procure advanced semiconductor chips from US companies, such as Qualcomm and Xilinx would be a huge blow (Addison, 2020). This threat from Washington has come as a wakeup call to Huawei and Beijing, kicking China's semiconductor industry into higher gear (Kharpal, 2019). So strong was the resolve to achieve semiconductor self-sufficiency that Beijing permitted Yangtze Memory Technologies, a leading Chinese domestic IDM, to continue operating its memory chip facility located in Wuhan, the epicenter of the COVID-19 outbreak, during the entire period of a total city lockdown in early 2020 (Cheng & Li, 2020a). In May 2020, China's largest domestic chip fab SMIC received a $2.2 billion capital injection from Beijing-backed investment (Horwitz, 2020). Huawei, wary of further attack, has also moved towards more self-sufficiency. Through its wholly owned subsidiary HiSilicon, China's leading semiconductor designer, has designed its own *Kirin* series of processors for smartphones and 5G modem (Kharpal, 2019). Because HiSilicon is a fabless designer, it needs a foundry to manufacture its chips. This is where TSMC comes into the story.

A rock and a hard place. It turns out that TSMC is one of few foundries capable of manufacturing the advanced chips designed by HiSilicon (Hille, 2020; Li & Cheng, 2020b). In fact, according to Li and Cheng (2020b), Huawei became TSMC's second largest customers behind Apple, accounting for approximately 10% of TSMC's annual revenues (Li & Cheng, 2020b). The US's blacklist of Huawei also prohibits foreign firms from selling to Huawei any products that contains more than 25% of materials or components of US origin, but TSMC's export to Huawei falls below that threshold. This, however, did not stop Washington from its determination to cut Huawei off from TSMC's chip manufacturing capability (Hille, 2020). In May 2020, the Trump administration announced a new export control rule that prohibits any semiconductor manufacturer using US technology and software in chip making from supplying Huawei without US government permission, regardless of whether or not the manufactured semiconductors actually contain US materials or components (Fox, 2020). Given that US-based firms, such as Applied Materials and Lam Research, supply more than half of the world's semiconductor manufacturing equipment, TSMC is reliant on the US equipment to run its massive foundries. Therefore, TSMC had no choice but to sever its tie to Huawei (Addison, 2020).

On the other side is China. Chinese firms currently provide approximately 22% of TSMC's revenue. This is dwarfed by the demand from American chip design firms, such as Apple, Broadcom, Qualcomm, and Nvidia, which account for roughly 59% of TSMC's revenue (Wong, 2020). However, with a government-led policy to supercharge the country's advanced technological sectors, the demand from Chinese firms is expected to grow at a much faster pace than that from the United States. Between 2018 and 2019, TSMC's share of revenue from China grew by a stunning 85% (Wong, 2020). The Chinese market is simply too vital to neglect, regardless of the Huawei saga. With its two biggest markets at odds, TSMC is caught between a rock and a hard place.

China Waging a Talent War. To enact "Made in China 2025" and under the pressure of the US–China tech rivalry, Beijing has introduced various measures to support domestic semiconductor industry, including dedicating a total of $150 billion in investment funds (Yap, 2018). Enormous multi-billion dollar semiconductor fabs have been co-financed by firms and the Chinese government, enough for China to double its semiconductor manufacturing capacity by 2023 (Woo & Kubota, 2019). The contest for semiconductors, however, will not won by massive investment alone. Technology and expertise, which will take years to develop, are critical. According to a Chinese government white paper, as of 2017, China's talent pool in the semiconductor industry is estimated at 400,000, while it is believed that 720,000 are needed to meet the domestic development goal of expanding the industry's revenue fivefold by 2030 (Cheng, & Sato, 2018).

To attract expertise, China has begun a talent war with Taiwan. The same cultural alignment that once allowed Taiwanese factories to easily leverage China's labor pool cuts both ways. There is minimum language and cultural barriers for Taiwanese engineers to relocate to the mainland. In February 2018, China released 31 incentives to encourage Taiwanese professionals to work in China. These included huge pay increases, free trips home, and generous living stipends. It has worked—as many as 3000 Taiwanese chip engineers have since joined the Chinese chipmakers (Ruehl, 2019). High-level executives were poached too—in 2017, two of TSMC's leading researchers joined SMIC, while in the same year fellow Taiwanese foundry UMC's former CEO joined Tsinghua Unigroup, a Chinese state-backed semiconductor conglomerate (VerWey, 2019).

Furthermore, some Chinese firms have also shown a willingness to "hop the fence" by engaging in industrial espionage. In late 2016, a TSMC engineer was sentenced to a suspended 18-month prison sentence by a Taiwanese court for downloading TSMC trade secrets which he intended on transferring to a Chinese state-owned rival, Shanghai Huali Microelectronics Corp, where he was due to start a new job. In the same year, an engineer at the Taiwan unit of Idaho-based Micro Technology was prosecuted for transferring chip designs to a Chinese chipmaker, Fujian Jinhua. According to a 2018 study by the Wall Street Journal, of the ten recent technology-related prosecution cases in Taiwan, nine was related to technology theft for firms in China (Yap, 2018).

TSMC's response—Being everyone's foundry. TSMC is not interested in taking sides. In response to the intense pressure from Washington to stop supplying chips to Huawei, TSMC's current chairman, Dir. Mark Liu stated, "[w]e are everyone's foundry …. We will deal with every customer equally and fairly" (Hille, 2020). Nonetheless, TSMC is taking the tightening of export ban by the United States seriously and has stopped taking new orders from Huawei (Cheng & Li, 2020b). TSMC is said to have hired Intel's former chief lobbyist to gauge the temperature in Washington and prepare for any further fallout from the US–Chinese clash (Wu & Gao, 2020).

The Pentagon has also increased pressure on TSMC to move the production of defense-related semiconductors from Taiwan to the United States, arguing that TSMC currently manufactures US Defense Department-approved "military grade" chips that go into F-35 fighter jets and other classified applications. Facing tremendous government scrutiny, TSMC announced in May 2020 that it would invest US$12 billion to build a new fab in Arizona. In 2021, it was further reported that the eventual investment amount might be raised to US$35 billion (Kim, 2021). This would be TSMC's second plant in the United States, the first being built more than 20 years ago. The new fab, expected to begin operating in 2024, would produce advanced 5-nanometer chips directly on US soil, although TSMC is expected to have commercialized 3-nanometer products by 2024 back in Taiwan (Kharpal, 2020). Several sources believe that it is impossible for TSMC's US operations to be as profitable as its Taiwanese ones unless its American clients and the US government shoulder some of the billions of dollars of investment cost (Li & Cheng, 2020b). Washington has taken clear steps to address this barrier—in June 2020, US lawmakers introduced a bill that would offer US$22.8 billion of aid to semiconductor firms, including a 40% refundable income tax credit for semiconductor equipment and US$10 billion in fab construction incentives (Nellis, 2020). The timing of this bill's introduction and TSMC's decision to invest in Arizona is no coincidence—TSMC's Arizona plant stands to receive a subsidy of US$205 million (Kim, 2021). Furthermore, in 2021, President Biden sought a budget of $37 billion to provide further incentives for semiconductor development and production in the United States given the supply droughts. TSMC's attempt to assuage the US government while limiting losses appears to be a direct page from Foxconn's playbook.

The pressure from Beijing for TSMC to manufacture locally is also persistent, as China gears up to add domestic expertise in semiconductor fabrication. This pressure is likely to intensify given Washington's intention to cut off Chinese firms' access to advanced chip manufacturing as discussed above. While the Chinese semiconductor design firms, such Huawei's HiSilicon, has advanced at a rapid pace, the Chinese semiconductor foundries are still behind rivals such as TSMC by at least 5–10 years. As of 2020, SMIC, China's largest semiconductor foundry, is only capable of producing 14-nanometer chips, a standard achieved by TSMC in 2013. SMIC's 200-mm wafer capacity, measured in wafer starts per month, is approximately 330,000 as of 2020, while TSMC's is 2,439,000 (Jorgensen, 2020; VerWey, 2019). In other words, SMIC, the foundry champion of China, is still producing chips that are 7 years behind TSMC's state-of-the-art products at less than 15% of the volume. This is the reason why HiSilicon and other Chinese technology innovators find TSMC's manufacturing service indispensable, and why Beijing considers the local presence of TSMC to be a top priority (White, 2019a).

TSMC has conceded to moving some of its low-end manufacturing facilities to China in order to appease Beijing and maintain market access. TSMC opened a 12- and 16-nanometer facility near Nanjing in 2018, following an earlier facility near Shanghai (Industry Week, 2016). In late 2019, the firm signaled intention to continue this expansion. TSMC has acknowledged that costs are higher in the mainland due to the smaller scale of operations but is aware that opening domestic facilities may be the only way to guarantee access to the Chinese market. Dr. Morris Chang, TSMC's founder and chairman until 2018 recently told the firm's investors, "… building a plant [in China] will indeed enhance our access to the Chinese market … [a]nd reversely, not building a plant there will not enhance." (Bloomberg View, 2016). This is critical for TSMC as 22% of its 2019 revenues came from Chinese firms (Wong, 2020). Furthermore, a large proportion of the chips manufactured by TSMC for their US clients, such as Qualcomm, are shipped to China as input into the country's massive electronics industry. In fact, 60% of the semiconductor chips produced globally are consumed in China (Comet Labs, 2018). This is precisely why TSMC's customer Qualcomm, in order to assure its access to the Chinese market, has partnered with the Chinese chip foundry SMIC to develop advanced chip production (Mozur, 2015).

While intellectual property and talent leakage is not entirely preventable, TSMC is vigilant in guarding its intellectual properties as it gradually migrates lower end production to China**.** Firstly, unlike Qualcomm, Intel and IBM, which gained access to China's semiconductor industry through partnerships or technology licensing to Chinese domestic players, TSMC insists on maintaining 100% control over its fabs in China. Secondly, TSMC also ensures that its plants in Taiwan are at least a generation ahead in capability by the time its Chinese plants commence operation (Mozur, 2015).

6.3.2.2 Semiconductor Industry in Flux

A behemoth entering the fray. As mentioned earlier, TSMC sits comfortably at the apex of chip manufacturing space with 55.6% of the global foundry market with Samsung Electronics, an IDM, a distant second with 16.4% of the global foundry market (TrendForce, 2020). With its dominant size, TSMC has been able to keep competition at bay given the enormous capital required to compete. However, for players that can put up the money, such as Samsung, the market potential of semiconductor manufacturing is proving to be very tempting. As identified earlier concerning Foxconn, global demand is shifting from traditional consumer electronics to more sophisticated products in the areas of Internet of Things (IoT), artificial intelligence (AI), 5G, augmented/virtual reality (AR/VR) and blockchain technology. These new applications will further drive up the demand for advanced semiconductors. It is estimated that AI could allow semiconductor firms to capture 40 to 50% of total value from the technology stack, representing the best opportunity for semiconductor firms in decades (Batra et al., 2019). 5G is the biggest of these new trends, with countries like China already dedicating more than US$400 billion to 5G infrastructure (Amaro, 2019). 5G-supported industries are expected to generate up to US$12 trillion worth of goods and services by 2035, of which a substantial share is expected to be captured by the semiconductor industry in the form of goods like advanced memory chips, field programmable gate arrays, and radio frequency front end components (Wood & Tong, 2018). Advances in the automotive industry, including vehicle electrification and the development of self-driving cars, are also increasing chip demand. In fact, the worldwide semiconductor shortage, partly spurred by the surge in demand for computer and other electronics devices during the COVID-19 outbreak, has led to extensive production cut in the automobile industry in the early 2021 (Leswing, 2021).

TSMC may have found a worthy competitor in Samsung. Samsung rivals TSMC in semiconductor manufacturing technology, with the two East Asian firms being viewed as neck-in-neck in launching the 5 nm-chips (Shilov, 2019; TSMC Press

Release, 2019) (see also Fig. 6.5). Samsung has reportedly dedicated US$116 billion to an all-out effort to mass-produce 3-nanometer chips for external clients by 2022—the same year as when TSMC are expected to pass that milestone (Kim, 2020). To further compete against TSMC for US fabless clients with the most cutting-edge chip designs, such as AMD and Nvidia, Samsung is also considering building a chip plant in the United States with a potential outlay of as much as US$17 billion (Hosokawa, 2020; Jennings, 2021). Samsung appears determined to wrestle the title of the world's biggest contract chip foundry away from TSMC.

Bigger and more sophisticated customers. This era of profound technological transformation has also brought some major changes in the structure of the entire semiconductor industry. Between 2012 and 2017, the number of semiconductor companies fell from 208 to 173 due to mergers and acquisitions. The fabless segment saw the greatest extent of consolidation. The key driver of consolidation has been to achieve cost synergies, efficiencies and acquire expertise. As semiconductor outputs become more advanced, the cost of designing chips also become prohibitively higher. These forces are pushing smaller firms to join the umbrella of industry giants (de Jong & Srivastava, 2019). Another impactful change for the semiconductor industry is the rise of in-house chip design at some of semiconductor industry's largest customers, like Apple and Huawei. Apple now design its core chips for the iPhone, Apple TV, Apple Watch, and some other offerings in-house, and then outsources chip manufacture to foundries. By opting for in-house design instead of outsourcing the work to external chip design firms, Apple is able to provide a consistent customer experience across devices and develop proprietary differentiated technology. Apple has now become the third largest fabless player in the world, behind Broadcom and Qualcomm. These trends raise the size, and therefore the negotiating leverage, of the customers of chip foundries such as TSMC (de Jong & Srivastava, 2019).

TSMC's response 1—Staying pure. TSMC has demonstrated extraordinary capability in packing ever more computing power onto each chip. From this point forward, however, it will become exponentially more difficult to push against the very limit of physics. For TSMC, the natural implication of this is that its competitive advantage will increasingly rely on the close partnership it holds with its customers, which might also be its competitive advantage over its formidable rival Samsung.

TSMC's long-standing value proposition, besides best-in-class technology, has been its status as an independent pure-play firm. Unlike semiconductor giants such as Intel and Samsung which span the entire semiconductor value chain, TSMC focuses solely on semiconductor manufacturing and does not compete in the same end markets of its own customers (Lee et al., 2010; The Economist, 2018a). These end markets include both consumer electronics (e.g., smartphones, laptops, or telecom equipment) in the case of Apple and Huawei or chip design in the case of Qualcomm, Broadcom, and now also Apple. Even though Samsung promises there is an impenetrable wall between its component business (including chips) and its consumer electronics business, Apple would certainly prefer not to deliver its flagship processor blueprints to Samsung on a golden platter while the Galaxy smartphone line is a top competitor to the iPhone (White, 2019b). In fact, Samsung was once the exclusive manufacturer of Apple's A-series processor. However, Apple gradually migrated its orders to TSMC as its competition with Samsung intensified in the smartphone market. TSMC became the sole manufacture of Apple's A-12 processor in 2018 and the partnership continued in 2019 with the A-13 processor (Owen, 2018). Over the years, Apple has also persistently attempted to reduce its reliance on Samsung for memory chips (Kim, 2012; Nellis, 2018). TSMC's intentional absence in other business segments has helped it gain the trust of top customers who would otherwise cast a wary eye.

TSMC's response 2—Becoming customers' virtual fab. In addition to its technological and manufacturing excellence, TSMC also builds close relationship with their customers. It defines itself as their customers' "virtual fab" (Hsieh, Lin, & Chiu, 2002: 110) and has invested heavily in internet-enabled platforms to provide its customers with real-time information on technology, inventory, and shipments as their chip orders move through its manufacturing process (Hsieh et al., 2002; Hwang et al., 2008). As a result, "through interactieons with TSMC, customers can have all the benefits of in-house fabrication but without the risks of capital" (Hsieh et al., 2002: 115). In other words, with TSMC, these customers now have their very own virtual fab. Through this strategy of embedding customers within its "ecosystem," TSMC has built substantial capabilities which are not easily imitable even by technologically and financially formidable competitors such as Samsung. According to the resource-based view of the firm (Barney, 1991), this type of capabilities is TSMC's sustainable competitive advantage in the long run.

TSMC's response 3—Be fluid. At the same time, TSMC is not permanently tied to its existing customers. TSMC founder Dr. Chang once attributed his firm's success to good fortune, "[t]he market moved in the direction in which we were heading." (The Economist, 2013b: 55). However, TSMC's success in consistently positioning in the forefront of technological trends might have more to do with its business model than serendipity. By sticking to chip fabrication and never attaching its own brand name to products, TSMC is far more adaptive to the shifting technological landscape than vertically integrated players, such as Intel and Samsung. Intel specializes in, and is a leading brand for, computer processors while Samsung is renowned for its smartphone chips. TSMC excels in manufactures chips for both computer and smartphone sectors. Standing ready to manufacture chips for any rising clients who embody newer technology trends is TSMC's *modus operandi* (Lee, et al., 2010; The Economist, 2018a). Dr. Mark Liu, TSMC's current chairman, points out that TSMC's top five customers always account for roughly half of its revenues, but the company names in the top five change over time. This built-in fluidity is evidence of TSMC's nimbleness during times of technological transformation (The Economist, 2018a).

6.4 Conclusions

The examples of Foxconn and TSMC clearly showcase the enormous achievement of the Taiwanese electronics industry in leading both the capital-intensive and labor-intensive segments of the global electronics production value chain. This is rather unique as most economies have historically dominated only one segment of the value chain. For example, South Korean and Japanese firms tend to congregate in the capital-intensive segment, while Vietnamese, Thai, Filipino, and Malaysian firms are prominent in the labor-intensive segment. Ruchir Sharma, Morgan Stanley's chief global strategist captures the state of global electronics industry succinctly when he stated recently: "Pound for pound, Taiwan is the most important place in the world" (Sharma, 2020).

Two factors contribute to the enormous success of the Taiwanese electronics industry. Firstly, many Taiwanese firms acted decisively to leverage the cultural alignment and common language they shared with mainland China to capture the country's vast labor pool. This allowed these firms to swiftly establish beachheads on the mainland for labor-intensive activities while seeding potential for higher value activities, a move that Japanese and Korean firms could not match. Secondly, many Taiwanese firms were able to rapidly expand their activities up the value chain through innovation, activities which were initially backed by the government (specifically, in semiconductor technology). While the same dynamics unfolded in Japan and South Korea as well, what set Taiwan's electronics industry apart was that it did not simultaneously step off the lower rungs of the value chain. This way, Taiwan's electronics industry was able to maintain its foothold in the labor-intensive segment of the value chain through firms like Foxconn while still ascending the value chain to lead in the capital-intensive segment through firms like TSMC.

Looking ahead, it seems that TSMC is poised to capitalize upon new technological and industry trends in electronics manufacturing. Its scale, technological leadership, capital resources, and adaptive business model have allowed TSMC to dig an economic moat to keep out competitors and stay above the fray of geopolitical tussles. Many analysts expected that TSMC would suffer massive losses when it lost its ability to manufacture Huawei-designed semiconductor chips due to the US sanction (Culpan, 2020). Instead, a combination of rising demand for computing and communication devices due to COVID-19 and a shortage of supply from struggling competitors has greatly increased its profitability—TSMC's 2020 full year profit rose 50% year-over-year (Wong, 2021). Instead of losing traction due to geopolitical events, TSMC's recently announced $100 billion expansion is on the horizon (Yang & Jie, 2021).

The outlook for Foxconn appears more complex. Foxconn's aspiration to shift from decelerating mass-market products to the fast-growing and more advanced AI-driven products is well-placed. However, new AI-driven market segments are still too small and too technologically demanding to allow Foxconn to quickly replace revenue and profits from their current mass-market products (Hille, 2019b). The global venture fund, recently proposed by Foxconn founder Terry Gou presumably to help propel Foxconn's transition, has also raised some eyebrows given the mounting problems facing Softbank's Vision Fund, which Gou is trying to emulate (Ihara & Nakamura, 2020).

This implies that at least in the short run, Foxconn must still rely on mega-factories making mass-market products. However, there are challenges in that space as well. As labor costs continue to rise in China and US–China technology decouples, Foxconn will be forced to diversify into other countries where it may not enjoy the cultural advantage and investment incentives that have enabled it to rapidly establish a profitable beachhead and beat out competitors as it did in China. Furthermore, these other countries may lack the scale, infrastructure, and efficient supplier networks that Foxconn enjoys in China, complicating logistics and fundamentally increasing the costs of operating in such environments (Burnson, 2016).

Further complicating the outlook for Foxconn, competition from mainland China is on the rise. In July 2020, Luxshare, an internationally little known Chinese electronics manufacturer, spent US$500 million to acquire two China-based iPhone factories from Taiwanese iPhone manufacturer Wistron—the smallest of the trio of Taiwanese iPhone manufacturers, the other two being Foxconn and Pegatron. Given that the acquisition took place with Apple CEO Tim Cook's blessing, it is clear that Luxshare will become the first Chinese-owned firm to assemble iPhones (Li & Cheng, 2020a). Luxshare has also won orders from global giants such as Microsoft, Google, Amazon, HP, and Dell. While Luxshare made only 5% of Foxconn's revenues in 2020, some analysts believe that the newcomer could capture up to 30% of global iPhone production within the next 5 years (Lee & Horwitz, 2020). Furthermore, amidst trade tension with the United States, Luxshare is an ideal candidate for Chinese government support in nurturing local tech firms that are globally competitive. In early 2021, Luxshare's market capitalization rose to approximately US$38 billion, only around US$20 billion shy of Foxconn's US$59 billion. In fact, this amazingly nimble Chinese copycat has earned the accolade as the "little Foxconn" (Li & Cheng, 2020a). To Foxconn, this must be flattering and threatening at the same time. At Terry Gou's direction, a task force was reportedly established in Foxconn in late 2020 with a dedicated focus to fend off Luxshare (Lee & Horwitz, 2020).

Beyond the two focal firms of TSMC and Foxconn, Taiwanese firms have not only established themselves as key cogs in the entire span of the global electronics supply chain, but have also played a vital role in the propagation of electronics factories throughout the Asia-Pacific region though their investment in China as well as other Asia-Pacific countries, including Malaysia, Vietnam, Thailand, and Philippines. According to the Ministry of Economic Affairs of Taiwan, 29.6% of Taiwan's non-financial outward FDI flows in 2017 were in the electronics manufacturing/IT sector, and 61.4% of total outward FDI was directed to Asia-Pacific countries (Kuo & Kao, 2018). As a result of this investment, Taiwanese electronics firms have helped stick together a global production supply chain, a great portion of which resides in Asia.

The greatest challenges now facing Taiwanese electronics firms are pressure from geopolitical forces that may lead to the U.S.-China economic decoupling of the United States. and the Chinese economies, the shifting tides of demand towards more advanced products, and a drastically changing China in its roles as an efficient production base, an eager consumer, and a relentless competitor. These challenges just as easily represent opportunities. Taiwanese firms are now pushed to explore production opportunities more broadly throughout the rest of the Asia-Pacific region, to better position themselves to capitalize upon the thriving demand from China while continue to serve the rest of the world, to expand technological leadership, and to fortify themselves for the looming competitive threat from China. The future of the Taiwanese electronics industry will ultimately depend on how these opportunities translate to reality.

Taiwanese electronics industry has distinguished itself by beating the odds. Few would have bet that an industry born on such a small island with little natural resources would survive in the global economy, much less thrive and lead in it. It has done this through clever play and an unrelenting, yet pragmatic will. No doubt its impact will continue to outsize the geography it calls home.

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