Taiwan Semiconductor

In 2020, I made our first semiconductor industry investment in a company called Taiwan Semiconductor Manufacturing Company Limited (TSMC). TSMC, based in Taiwan, is the largest semiconductor contract manufacturing company in the world.

TSMC is a special business. It is likely both one of the strongest and the most important companies globally. It is not an exaggeration to say that numerous industries would come to a standstill if this company were to disappear. Very few companies hold this kind of power. As you will see, it has brought tremendous value to the world, creating incredible value for its entire ecosystem, while erecting formidable competitive barriers. We were offered the rare opportunity to own TSMC at a reasonable price in 2020.

Business Model

TSMC operates a "pure-play integrated circuit (IC) foundry" with no products of its own. The company's mission is to serve solely its customers. It serves as an outsourced product manufacturer for them. The alternative to the pure-play foundry model is the vertically-integrated one employed by Intel where the "integrated device manufacturers" (IDM) design, fabricate, and market their own products.

Counter-Positioning, Process Power and Platform Business Model:

One of the most difficult challenges for a foundry is manufacturing chips at a very high yield (the percentage of working chips from a silicon wafer). Customers are most interested in getting to volume production with high yield rather quickly, as the newest designs often command a price premium in the first two years with a sharp drop-off thereafter (Moore's Law). However, each new design is unique and has a different "recipe." In addition, these recipes are extremely complex requiring thousands of steps. Yet, each step needs error rates very near to zero to be able to reach a high yield.

In order to achieve high yield performance, TSMC works collaboratively with its customers right from the design phase. Should yield problems arise, TSMC will partner with its customers' process engineers to identify and rectify any manufacturing defects. TSMC also recognizes the importance of close coordination with the entire chip value chain. It fosters this partnership between customers and its ecosystem via its "Open Innovation Platform" (OIP) and "Design Center Alliance" (DCA). Lastly, TSMC holds quarterly reviews with all its customers, and conducts an annual customer survey on key performance indicators. The survey results are compared to the previous year's results, as well as to competitors, and are closely watched by TSMC management.

Morris Chang, founder of TSMC, has often said to customers: "We will jump through hoops to help you succeed." For instance, when Apple signed a contract to have its A8 chip fabricated by TSMC, TSMC had more than 6000 people working around the clock to get things up and running, while committing $9B in capital expenditure all to support one new customer! TSMC delivered half a billion chips for Apple in the first year of the contract. Not surprisingly, Apple has fabricated all its chips at TSMC since then, and TSMC has never missed a single delivery commitment to date.

Prior to contracting with TSMC, Apple fabricated its chips at Samsung. However, this relationship went sour when Samsung decided to compete with Apple in the smartphone business. Subsequently, Apple sued Samsung for IP infringement and pulled out of the contract. TSMC is in a unique counterposition of

earning the customer's trust from day one by promising not to make any products of its own. No other foundry has earned such a strong reputation of trust to date.

TSMC's strong customer service orientation has created a powerful self-reinforcing flywheel that leads to more customers choosing TSMC, which in turn results in incrementally improved process knowledge for TSMC, which then further reinforces its manufacturing leadership. Morris Chang had the foresight to recognize that TSMC's technology and manufacturing were intrinsically tied to being client-driven. He formulated the TSMC vision, by which TSMC continues to be led today:

> *Our vision is to be the most advanced and largest technology and foundry services provider to fabless companies and IDMs, and in partnership with them, to forge a powerful competitive force in the semiconductor industry. To realize our vision, we must have the following strengths:*
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> - *Be a technology leader, competitive with the leading IDMs*
> - *Be the manufacturing leader*
> - *Be the most reputable, service-oriented, and maximum-total-benefits silicon foundry*

At the time of its founding in 1985, TSMC's pure-play model was viewed with skepticism by nearly everyone in the industry. For the first fifteen years, TSMC's manufacturing process (process technology) was consistently two to three generations behind industry leaders, all of whom were IDMs. It seemed inconceivable that TSMC could catch up to the IDMs on process technology without being vertically integrated with the design process. However, by 2000, despite the initial disadvantage, TSMC was able to close the gap with all foundries, including that of Intel. Today, TSMC now possesses process technology leadership that has become increasingly hard for even a juggernaut such as Intel to catch up to.

TSMC process leadership has benefitted from the need to coevolve alongside its most cutting-edge customer's technology roadmap. As an example, consider the case of TSMC and Apple again. Apple became a fabless company when it acquired P.A. Semi in 2008 to design chips for all its future mobile devices. Apple's business model of having a new product launched annually, which included a new Apple chip fabricated by TSMC beginning in 2014, left TSMC with no choice but to quickly reach high yield performance to stay in lockstep with Apple's product roadmap. As a result, TSMC has consistently advanced its process technology since 2014—from 20 nm node in 2014, to 16 nm node in 2015, to 10 nm node in 2016, to 7nm node in 2017, and to 5 nm node in 2019. In contrast, Intel has been stuck on its 14 nm node since 2014 and has been having trouble getting its 10 nm node, equivalent to TSMC's 7nm node, to volume production for several years now.

At this point, replicating TSMC's process leadership is extremely difficult. This is a result of a long period of sustained evolutionary advance that only comes through bottom-up trial-and-error on differing designs across a large number of customers. No other foundry, including Intel, has had the benefit of such experience. Furthermore, the fundamental tenets of the process are not even formally codified but are part of tacit organizational knowledge at TSMC. It is fair to say that even TSMC does not have a full, top-down understanding of what they have created.

As a result of TSMC's process leadership, they have not only created a strong competitive barrier but also created enormous benefits for its customers by helping them shorten design time, shorten time-to-volume, shorten time-to-market, and ultimately shorten time-to-revenue. Over 500 fabless companies,

including companies such as Apple, Broadcom, Qualcomm, and Nvidia, rely on TSMC today. Fabless companies are asset light, generate high amounts of free cash flow, and command strong valuation multiples, as they outsource their capital expenditures to TSMC. The total value created by TSMC's customers on TSMC's "platform" is far higher than the value captured by TSMC itself. Even though the "platform" business model has only been recognized recently, TSMC, was the first hyper-scalar platform business

Pricing Power:

Historically, the semiconductor industry has been a cyclical one with major booms and busts. During an up-cycle customers face the challenge of being turned away from IDM contract manufacturers, as the IDM's would rather devote more of their scarce capacity for their own products.

In contrast, when customers choose TSMC as a sole-source contract manufacturer, TSMC guarantees capacity through the entire cycle. Taking it further, TSMC also offers capacity "flexibility" to its sole-source customers even if it comes at a high personal cost (to TSMC). Flexibility is defined as follows:

- The degree to which volume changes by customers are allowed.
- The ability to change the process recipe in the fabrication phase.
- The ability to change ship dates.
- The degree to which customers can make real time changes in production environment
- The ability to hold or cancel a job in process

In contrast to TSMC, many of its competitors "freeze" orders at a certain point in time beyond which no modifications are accepted in order to prevent uncertainties in their production system. As a result of being a sole-source vendor, TSMC has consistently been able to command pricing power.

Despite the advantages of flexible and guaranteed capacity, it may seem that a customer could gain a pricing advantage by choosing multiple foundries for a specific design. However, any such price advantage would be easily offset by the high engineering overhead to support another foundry and the resulting yield differences.

For the sake of argument, imagine AMD, a TSMC sole-source customer, split orders for its 7nm chips between TSMC and Samsung. Further, suppose that partway through the production, AMD discovers that Samsung's foundry is having yield problems. AMD would not be able to then move its orders to TSMC's foundry. Given that TSMC does not guarantee capacity for non-sole-source customers, TSMC is likely to give away the excess 7nm capacity (that AMD decided to dual-source) to another vendor. In this scenario, AMD would not only end up paying twice to have the 7nm chips designed, as the 7nm process for Samsung and TSMC differ significantly, but it would also end up with lower production. By the time it ramps up on TSMC, it could take years - by which point the price premium on the design may have completely eroded (Moore's Law).

The price premium for having TSMC as a sole-source is relatively small. Let's again consider Apple. They recently booked TSMC's entire 5nm production capacity for their chips for the next generation of iPhones, iPads, and Mac products. A 5nm wafer costs ~$17,000, and a typical wafer may yield 500-1000

chips, effectively costing TSMC $17-$35 per chip. This TSMC premium is a very reasonable price for Apple to pay relative to the total cost of manufacturing as well as the total price for Apple's products.

Thus, Apple uses TSMC as a sole-source provider. This was not always the case. In 2015, despite the initial souring of its relationship with Samsung, Apple dual-sourced the A9 chip from TSMC and Samsung. The TSMC chip proved to have significantly better battery life. This non-uniform customer experience was telling, and since then Apple has willingly paid the relatively small sole-source pricing premium to TSMC.

Scale Advantages

The cost of building a cutting-edge IC foundry is now greater than $10B and rising. The big driver of cost inflation is the cost of equipment. For instance, photolithography machines made by ASML, one of our other portfolio companies, are extremely expensive with each machine costing over $200M. Moreover, the useful life of the equipment is very short, possibly no more than 5 years. Thus, it becomes extremely critical to get a IC foundry running at maximum utilization, volume production, and high yield performance as quickly as possible.

Given TSMC's manufacturing/technology leadership and customer orientation, it has been able to attract long-term customers that are keen on absorbing any excess capacity. For instance, when TSMC lost Huawei as a customer after the U.S. Dept. of Commerce directed TSMC to sever the relationship, Apple snapped up the excess capacity that became available.

TSMC has also learned from the Apple playbook to use its scale to aggressively secure excess capacity from the supply chain. For example, in 2020, when Intel ramped down its demand for ASML machines due to the technical difficulties it was having with its 7nm node process, TSMC purchased all of ASML's excess capacity.

TSMC has 500 fabless companies in four key end markets: Smartphones; High Performance Computing, which includes the Cloud infrastructure companies that are now designing their own chips; Internet of Things; and Automotive. There is not a single device in the world today that does not have TSMC-made chips.

Earlier, I mentioned how the semiconductor industry has been a cyclical industry with major booms and busts. However, it is important to point out that these cycles were all tied to one end market—personal computers. As the world continues to undergo a digital transformation, the silicon content for all products is likely to continue going up. Thus, TSMC's revenue may be far less cyclical and benefit from secular tailwinds for decades to come. New fabless companies are likely to spawn, the way Qualcomm, Broadcom, Nvidia and Apple have in the last twenty years. The advantage of being a neutral customer-oriented "platform" is that the largest fabless companies that are not born yet are likely to be future TSMC customers.

TSMC recognizes the opportunities ahead. It has a $28B capital expenditure budget for 2021, far above previous analyst expectations of $20B to equal to 50% of TSMC's revenue. The last time TSMC ramped up its capital spending was at the start of the smartphone revolution. There are very few companies in the world, if any, that can match TSMC's capital spending. TSMC's scale will continue to beget scale.