



How a handful of chip companies came to control the fate of the world

By Brinton Johns and Jon Bathgate, June 28th 2020

At the risk of sounding like hyperbolic doom mongers, let's grab your attention from the outset: Because of a series of complex and unexpected global developments over the past several decades, the fate of the world now lies in the hands of fewer than a dozen semiconductor companies.

A good exercise in assessing a potential investment is to ask "could the world get by without this company?". The answer is usually, "in time, probably just fine." But should we wake up tomorrow to find that any among Taiwan Semiconductor Manufacturing Co. (TSMC), ASML Holding, Lam Research, Cadence, Synopsys and KLA-Tencor have suddenly ceased to exist, the answer at best is "well, yes, but global progress will suffer a setback of several decades at least." The loss of a handful of critical chipmakers that depend on these companies – such as NVIDIA, Samsung, Intel, AMD, Texas Instruments, Xilinx, Broadcom and Microchip Technology – would dramatically impede the digital transition of the economy still further.

Why? Because these companies are at the core of a half a trillion-dollar industry that enables us to do pretty much everything, from flying across oceans to booking a ride and ordering a pizza when we get there; from diagnosing and treating a disease to boosting agricultural yields; from supporting the military to powering our cities.

ENGINE ROOM

No critical system can function without semiconductors and chip companies provide the wherewithal necessary to design, build and test ever-faster and more powerful sensors, microcontrollers, CPUs, GPUs, FPGAs, network switches, modems, memory, and all the other components that power our devices and, by extension, the entire digital economy.

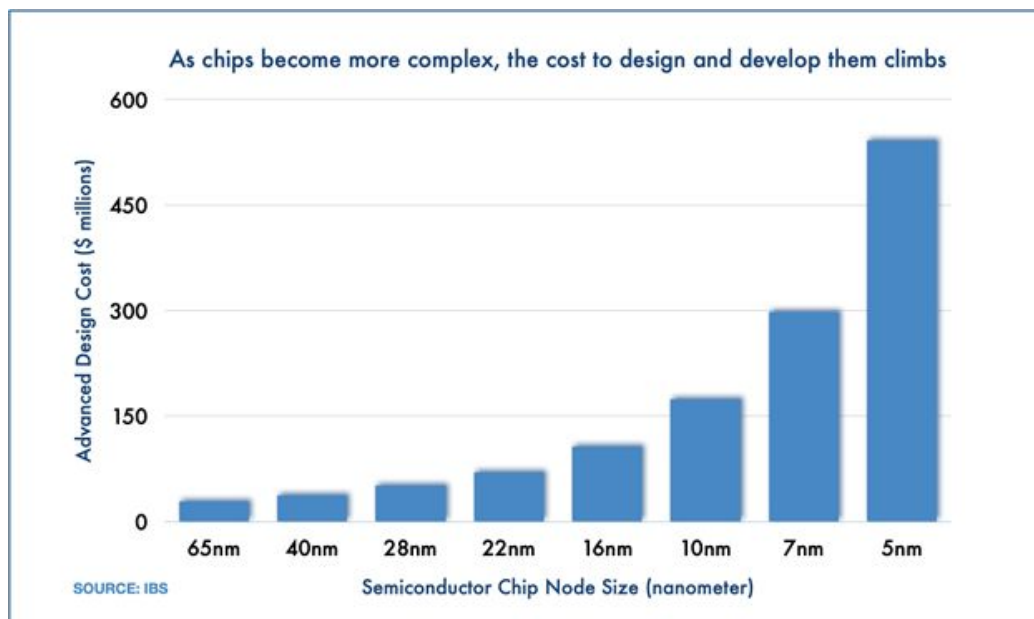
Marc Andreessen famously proclaimed in 2011 that "software is eating the world," and evidence of this truth can be seen more and more every day. But without the semiconductors that allow the machines to run the software, there would be no Information Age.

Chips are the engine driving the digital transformation of the world.

But how did we get to a place where more than half of all contract semiconductor manufacturing is handled by one company on an island whose sovereignty is in dispute; where a single organization holds what looks like an unassailable lead in photolithography; where virtually all memory is made by just three companies; and where it's well-nigh impossible to even design a chip without software that only a couple of companies provide?

INCREASING COMPLEXITY

For one thing, as chips used in mobile phones, artificial intelligence and cloud computing applications become more complex, so too do the design, manufacturing and testing processes needed to produce them, making it impossible for all but a few of the most adaptable companies to keep pace. And as development becomes more complex, so does the cost to design, test and build an advanced chip, which has spiraled to as much as \$500 million, creating an additional barrier for wannabe disruptors.



MAGICAL PROCESS

Photolithography is a good example. In short, when the light source used in the process had to change from a wavelength of 193nm to 13.5nm to accommodate smaller, more intricate patterns on leading-edge chips of ever-decreasing geometry, only one company even tried to do it.

Extreme ultraviolet lithography (EUV) is an almost magical process. In a vacuum, 50,000 microscopic droplets of molten tin are fired every second in a stream as one laser strikes each one so precisely that they flatten into discs before another bombards them with so much power that they become balls of plasma shining with EUV light. The machines cost almost \$200 million, can be the size of a house and are contained within ultraclean environments to keep out even a single speck of dust. The scanners and lasers that power EUV lithography are so complex that a decade ago many scientists believed them to be an impossibility, and Nikon, ASML's key competitor, viewed the technology as so complicated that it didn't even attempt to develop an EUV tool.

Because of its unique mastery of EUV, ASML has built a de facto monopoly in manufacturing the machines that make the most advanced chips. The Dutch company expects to ship about 35 scanners this year, taking the total used by foundries around the world to around 100. TSMC and Samsung are already in high-volume manufacturing with EUV, while Intel will be using the process from 2021.

Without EUV, Moore's Law, which states that the density of transistors on a chip will double about every two years, would likely have reached its limitations. But because of the process, TSMC is building 7nm and 5nm fabs, and is investing another \$20 billion on a 3nm node foundry, while Samsung, South Korea's

biggest company, said in May 2020 it started building a 5nm facility near Seoul based on EUV as part of a \$116 billion plan outlined in April 2019 to compete with TSMC in contract chipmaking.

CLOSE COOPERATION

But even before you reach the manufacture and testing stages, intricate chips have to be designed, and as competition drives device makers to pack more performance, functionality and power efficiency into ever-smaller chips, the creation of semiconductors has become impossible without electronic design automation (EDA). A key provider is Cadence Design Systems, whose software is used to map advanced semiconductors. Cadence and its competitor Synopsys work in extremely tight partnership with chip designers and manufacturers (often TSMC) to ensure that those hundreds of millions of dollars invested into the next chip design will yield a functioning device. Initiatives such as TSMC's EDA Alliance and Digital Reference Flow – which have no equivalent at Samsung or Intel – increase the likelihood that designs will be compatible with TSMC's manufacturing processes, creating network effects by making it more likely that future projects will also be successful.

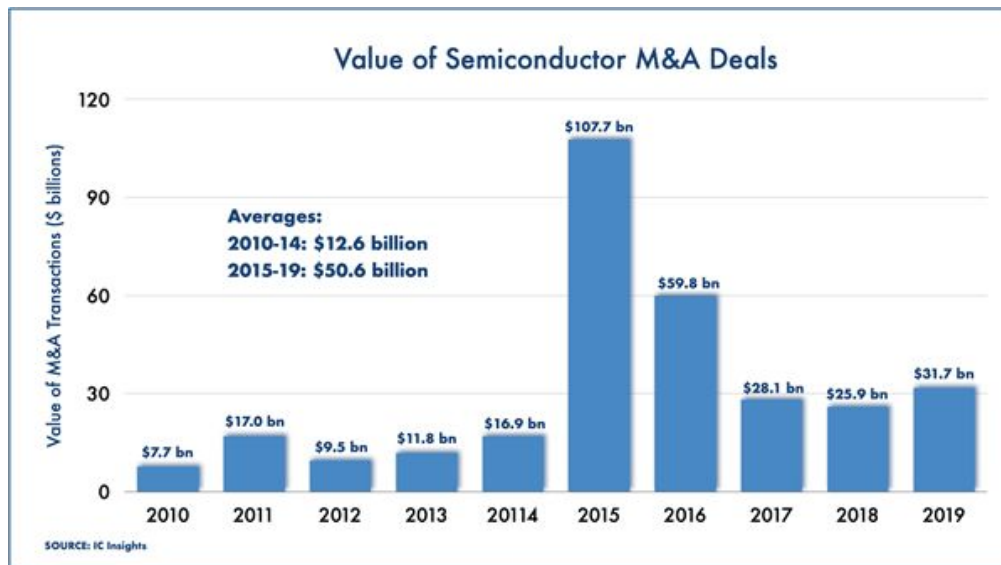
CONSOLIDATION EXPLOSION

While increasing complexity played a significant role in reducing the number of players, consolidation helped the process along. In 2009, there were 10 DRAM memory makers. Now, Samsung, SK Hynix and Micron Technology account for 95% of revenue in a roughly \$100 billion sector.

Consolidation elsewhere was triggered in large part by Hock Tan, the longtime CEO of Avago, now Broadcom, who saw an opportunity following the Great Financial Crisis to buy underpriced and under-appreciated assets using cheap money. In addition to noticing that semiconductor companies were undervalued, Hock's key insight was that they were often poorly managed -- chasing growth markets that promised low returns. Working more like a private equity executive than a technology CEO, Hock shuttered or sold off underperforming divisions of acquired companies, while investing in established highly profitable franchises. After the resounding success of Avago's 2014 acquisition of storage chipmaker LSI, rival CEOs saw the need to increase scale and returns to survive.

(As an aside, another more morbid reason for the quickening pace of consolidation was that many founders died, making it easier to build alliances that were previously unthinkable.)

So after lying dormant for a decade or so, semiconductor M&A exploded in 2015, surpassing \$100 billion in transaction value, more than six times any of the preceding five years, and remained elevated for the rest of the decade. Broadcom was the poster child of the consolidation wave. During this period, Tan spent \$50 billion on acquisitions, taking the company from a niche supplier of wireless technology to a powerhouse in wireless, networking and data center solutions at industry-leading profitability, a move that helped the stock to surge 1,800%, making it the best performer in the semis sector and one of the top-10 stocks in the S&P 500 in the decade.



DECLINING CYCLICALITY

Money poured into the space as Tan led others to realize that the industry's traditional cyclicality was ebbing. For decades, sales revolved around events such as upgrades to the Windows operating system and mobile phone releases. But as the number of use cases and potential profit pools widened due to mega themes such as artificial intelligence, cloud computing, mobility and the Internet of Things, along with expanding industrial and healthcare applications, those cyclical peaks and troughs became less pronounced, making chips even more appealing.

Inevitably, the M&A activity eventually drew the attention of the US government, whose Committee on Foreign Investment (CFIUS) became concerned that key American intellectual property was leaving the country through some consolidations. The most ambitious transaction in the industry's history, the \$120 billion planned acquisition of wireless giant Qualcomm by Broadcom, was blocked by CFIUS — even after Broadcom relocated to California from Singapore — over concerns that the target's key wireless technology, including 5G, were critical to national security.

THE MOMENT EVERYTHING CHANGED

This decision made it clear that the US government appreciated the lack of resilience in the supply chain while also signaling that it would act to protect America's strategic interests. That made it obvious that one key part of this critical supply chain would move directly into the crosshairs — fabrication.

And for that, we can blame Texas Instruments (TI).

In the early 1980s, Morris Chang was head of TI's semiconductor business. Despite being an exceptionally talented leader and technologist, he was passed over for CEO, many believe because he is not American. So Chang returned to his native Taiwan at the government's request to work on a way to build up the island's tech chops. With no history, infrastructure, obvious skills or other resources in any aspect of semiconductor design and manufacture, Chang hit on the idea of creating a fabrication only model.

Until then, semiconductor companies both designed and manufactured their chips, and constructing increasingly large factories was the biggest impediment to innovation as it was the most costly part of starting a company. Chang removed that barrier by undertaking to never compete with customers in chip design. TSMC grew over the proceeding decades into by far the biggest contract chipmaker, controlling 53% of the almost \$70 billion third-party fabrication market by January 2020, according to TrendForce, compared with 18% for Samsung and 8% for GlobalFoundries, the next two biggest producers.

In 2019, TSMC manufactured almost 11,000 products for around 500 customers, including AMD, Apple, Alphabet, Amazon, Microsoft, Facebook, NVIDIA and Qualcomm, while in a deliciously ironic twist, Texas Instruments, whose market cap is less than half TSMC's, now relies on the company to manufacture some of their advanced products.

TAIWAN'S STRATEGIC IMPORTANCE

What spooks the US government is that American companies account for about 60% of TSMC's revenue, according to analysts' estimates, with China bringing in a further 20%.

US-based companies are responsible for about 45% of global semiconductor sales, according to the Semiconductor Industry Association, yet almost 70% of chips are made in Taiwan or pass through the island during the manufacturing process.

Given that China as recently as May 20, 2020, said that reunification "cannot be stopped by anyone or by any force," the US is keen to loosen the stranglehold of TSMC on the fabrication of leading-edge chips in Taiwan.

As a result, TSMC this year entered an accord to build a \$12 billion, 5nm fab in Arizona, which it plans to open in 2024, while at time of writing Congress is also debating a multibillion-dollar package of incentives designed to further boost third-party fabrication options in the US. While these moves aren't enough to significantly reduce the US's exposure to Taiwan, they signal intent.

UNASSAILABLE LEAD?

While the US has sought to deny China's Huawei access to the semiconductors needed to build 5G mobile networks, as a nation China remains several years behind its American and European counterparts, a gap that would likely be decades without access to western tools.

Moreover, China has little to no hope of closing the gap, since it's impossible to reverse engineer the complex processes, making traditional industrial espionage techniques pointless.

The \$100 billion “Made in China 2025” effort, which seeks to essentially replicate the global semiconductor industry to reduce the country’s dependence on US and European knowhow, is therefore likely to result in success in lower-end parts of the market and not achieve the goal of technology independence. While total Chinese output is rising, the chips are still designed with US-produced software and manufactured with American and European gear. China is in no position to go it alone and won’t be for the foreseeable future.

FINANCIAL RESILIENCE

We go into the geopolitics of semi fabrication in more detail in this [MarketWatch](#) op-ed, but the fragility inherent in the supply chain stands in stark contrast to the financial resilience created by the concentration of capabilities in a few privileged hands.

It may come as a surprise to many that the best-performing sector of the S&P 500 since the Great Financial Crisis is semiconductors. From a nadir in November 2008, the 30-member Philadelphia Semiconductor index doubled in value in a year and surged 377% in the decade through 2019, returning more than twice the 182% of the main S&P 500.

Semis are the best-performing sector of the S&P over the past decade



Another example is the stock of Lam Research, which increased in value 14 times since languishing around \$20 in February 2009. Lam’s tech is a key enabler of both NAND and DRAM memory, which are seeing rising demand as the world generates and analyzes more

data. Lam is the only provider of high aspect ratio etch tools, which are critical in the NAND market as the device architecture has started to scale vertically, leaving the latest chips looking more like skyscrapers than their one-story house antecedents. The magic in Lam's process allows its tool to etch more than a trillion perfectly uniform holes — each one-thousandth of the diameter of a human hair — on a wafer. Lam's leverage to the NAND market and a broader renaissance in memory helped the company to grow annual revenue by 16% on average from 2013 through 2019, double the rate of the semiconductor equipment sector. The company has also quietly built up about a third of its business to be a highly profitable recurring revenue stream of services, refurbishes and consumables that improves its ability to serve customers while adding a stabilizing force to the cyclicity from the rest of the business.

IMPROVING PROFITABILITY

Despite that perception of heightened cyclicity, the profitability of many semiconductor companies now compares with top tier software providers. By transforming from a pure-play chip company into one that produces software that is monetized through silicon, graphics processing leader NVIDIA -- which now employs more software than hardware engineers -- is this year expected to earn a 38% operating margin based on consensus estimates, slightly higher than Microsoft.

Such performance is not limited to the leading edge. While some NVIDIA products sell for hundreds or thousands of dollars each, companies such as Microchip Technology and TI are earning software-like margins by pushing billions of sub-\$5 embedded processing and analog chips a year to tens of thousands of customers. Both companies are earning higher margins at the current cyclical trough than at previous cyclical peaks seen earlier last decade. Moreover, the outlook for such products is brighter than ever as their market potential explodes in coming years to encompass trillions of connected devices as the mega themes lead to more chips being deployed across countless applications in healthcare, industrial, agriculture, automotive and other parts of the burgeoning digital economy.

WHAT NOW?

So having examined how we got here, the question now is what happens next?

While 2020 has shown us that forecasting can often be a futile pursuit, three broad predictions seems safe to make. China is in no position to go it alone, we'll continue to rely on the key ecosystem enablers named at the start of this article, and the semiconductor renaissance will keep gaining steam.

In the final [audio portion](#) of this look at the space, we'll talk about what's happening in individual parts of the chip market, while also touching on why we're excited about the absence of a Next Big Thing.