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TSMC: Chip manufacturing in the era of AI

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With a market capitalization of around $820 billion in the spring of 2025, the Taiwan Semiconductor Manufacturing Company (TSMC), alongside Tesla, was the most valuable manufacturing company in the world, and it was, overall, the tenth most valuable publicly traded firm.[1] However, these facts alone did not capture the technological, economic, and geopolitical significance of this somewhat obscure Taiwan-based company.

TSMC was a leader in semiconductor manufacturing, particularly in leading-edge process nodes such as 3 nm, 5 nm, and 7 nm, which were essential for producing the latest high-performance computing chips used in AI applications. TSMC was the largest semiconductor foundry in the world, commanding over 60% of the global revenue in semiconductor manufacturing services.[2] This dominant position gave it significant influence over the semiconductor supply chain, and turned TSMC into a key supplier for many of the world's leading technology companies, including Apple, Nvidia, Broadcom, Qualcomm, and AMD, as well as a supplier of custom-made chips for Google, Amazon, and Meta.

By providing access to state-of-the-art technologies and manufacturing processes, TSMC enabled its customers to innovate and develop new products across various sectors, including AI, cloud services, consumer electronics, automotive, and national defense and security. It is not an exaggeration to say that a nontrivial percentage of the global GDP growth could be attributed to products or services that used chips manufactured by TSMC.

[1] Marketcap. "Largest Companies by Market Cap." Companies Ranked by Market Cap. Last modified 2025. https://companiesmarketcap.com/.

[2] Statista. "Top Semiconductor Foundries Market Share 2023." Statista. Last modified September 5, 2023. https://www.statista.com/statistics/867223/worldwide-semiconductor-foundries-by-market-share/.

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The company's position as a leading player in an industry of critical importance also made it a factor in global geopolitics. Rising tensions between the United States and China, on the one hand, and the complicated history between China and Taiwan, on the other, put TSMC at the center of discussions of trade policies and technology security. In fact, TSMC was touted by some as Taiwan's "silicon shield" against external threats, as presumably no one would risk disrupting access to leading-edge chips—for many of which TSMC was the sole supplier.

TSMC's dominance in the semiconductor industry was accompanied by excellent financial performance: over 30 years since listing in 1994, it had delivered a compound annual growth rate (CAGR) of 17.7% on revenues and 17.2% earnings; it had built a "fortress balance sheet" that endowed it with the highest credit rating in the semiconductor industry; its net income was around 40% of revenue, which was extraordinary for a manufacturing company; and its cash flows were strong enough for it to rely only on internally generated funds to finance organic growth.[3] For the company's 2024 consolidated financial statements and its historical operating data, see Exhibits 1–4.

Yet, the geopolitical tension between the United States and China, the global supply chain disruption caused by the COVID-19 pandemic, and the tariff-centric economic agenda of the recently elected Trump administration in 2025 had accelerated a movement of re-shoring or near-shoring manufacturing capacity in critical industry sectors, including semiconductors. Furthermore, the dawn of the era of AI with the release of OpenAI's ChatGPT had triggered an "arms race" among big technology firms for procuring leading-edge high-performance computing chips. These forced TSMC, really for the first time, to invest in a massive capacity expansion outside of Taiwan—facing operational, organizational, and cultural challenges along the way. Could TSMC maintain its technological dominance, robust growth, and excellent financial performance in this rapidly changing world?

The pervasiveness of advanced chips

Chips were critical to numerous advanced technology applications across various industries. Consumer electronics, particularly mobile devices such as smartphones, tablets, and smartwatches, used leading-edge chips in central processing units (CPUs) and graphics processing units (GPUs) to enable high-performance computing, enhanced graphics, and efficient power consumption. Similarly, laptops and desktops required advanced CPUs and GPUs to provide adequate performance for tasks ranging from everyday use to gaming and professional applications.

Leading-edge chips also constituted the core piece of hardware behind data centers and cloud computing services, the IT backbone of modern society, where high-performance CPUs and GPUs were essential for handling large-scale data processing and storage. Many applications of AI, e.g., training Large Language Models, the technology behind chatbots such as ChatGPT, Gemini, Claude, and DeepSeek, required data centers based on custom-made GPUs or accelerator chips like tensor processing units and neural processing units.

The automotive industry employed advanced chips for real-time processing of data from sensors and cameras, enabling features such as self-driving and advanced driver assistance, as well as in infotainment systems, designed to provide better user experience and connectivity.

[3] TSMC. "Investors." TSMC. Last modified 2025. https://investor.tsmc.com/english.

Advanced chips were also essential for the development and deployment of 5G cellular networks, providing faster data rates, lower latency, and enhanced connectivity to mobile devices such as smartphones and tablets.

Industry 4.0, the leading paradigm for the future of manufacturing, was another big "consumer" of advanced chips. High-performance processors and sensors were used in industrial robots and automation systems to enhance precision, efficiency, and reliability. They were also part of smart sensors and Internet-of-Things devices employed in smart factories, agriculture, and smart cities.

Finally, a critical, albeit less often discussed, application of advanced chips was in military technology: Leading-edge semiconductors were integrated into national security and defense, including fighter jets, missile and drone guidance, and electronic warfare systems. It was no coincidence that many breakthroughs in science and technology that paved the way for advanced chips of modern times were funded by the US government's Defense Advanced Research Projects Agency (DARPA).

The value chain of advanced chips

The value chain of advanced chips encompassed several key stages, the most important of which were as follows:

- Electronic design automation: Companies such as Cadence, Synopsys, and Mentor Graphics provided specialized software tools for designing, simulating, and verifying chips.
- Intellectual property (IP): Companies such as ARM and Imagination Technologies provided predesigned IP cores and design services that design companies could integrate into their chips.
- Integrated circuit design: Companies such as Apple, Nvidia, Broadcom, Qualcomm, AMD, Intel, Samsung, Google, Amazon, and Meta, using the aforementioned software tools and IP, designed the architecture and layout of the chips they needed for their products and services, specifying how millions or billions of transistors were arranged and interconnected. Design accounted for 53% of industry-wide R&D expenses, 13% of capital expenditure (CAPEX), and 50% of the total value added.[4]
- Fabrication equipment suppliers: Companies such as ASML, Nikon, Cannon, Applied Materials, and Lam Research supplied the advanced machinery and equipment needed for wafer fabrication, including lithography machines, etching equipment, and deposition systems. Equipment accounted for 9% of industry-wide R&D expenses, 3% of CAPEX, and 11% of the total value added.
- Wafer fabrication: In this stage of the value chain, the "front end" of chip manufacturing, the integrated circuit design was fabricated in silicon wafers using specialized fabrication equipment. Fabrication accounted for 13% of industry-wide R&D expenses, 64% of CAPEX, and 24% of the total value added.
    - Logic: Companies such as TSMC, Samsung, and Intel manufactured leading-edge chips designed for processors (e.g., CPUs and GPUs). The state of the art in logic chips in early 2025 was 3 nm process nodes.

[4] SIA. "Strengthening the Global Semiconductor Supply Chain in an Uncertain Era." SIA. Last modified April 1, 2021. https://www.semiconductors.org/strengthening-the-global-semiconductor-supply-chain-in-an-uncertain-era.