TSMC

Index

For Information Purposes Only – Not an investment recommendation. Please see important disclosures at the end of the report.

Taiwan Semiconductor Manufacturing Company (TSMC)

	Total Returns		Annualized Returns	
	TSMC	S&P 500	TSMC	S&P 500
2-Year	103%	45%	43%	20%
3-Year	742%	111%	103%	28%
5-Year	1,210%	218%	67%	26%
Lifetime	51,703%	2,161%	23%	11%

Notes:
1. Return data from Bloomberg and FactSet, in local currency.
2. Total returns include dividends reinvested.
3. The start date for the return data above is 9/5/1994, which was the day of TSMC's IPO.
4. Lifetime end date is as of 11/29/2024.

Mental Model Summary Derived from TSMC

1. **The global semiconductor market and its end-user markets have seen healthy growth over decades. From 1993, the year before TSMC's IPO, to 2023, the global semiconductor market grew from $77 billion to $527 billion, reflecting a CAGR of over 6%.**[1] Since TSMC was founded in 1987, the world's semiconductor market has grown from $26 billion to $527 billion in 2023,[2] an 8.4% CAGR, while the number of integrated circuit units shipped globally exhibited a similar trend, increasing from nearly 20 billion to over 420 billion during the same period.[3]

   A 1993 U.S. congressional report emphasized that semiconductor technology underpins most modern electronic products, including computers, consumer electronics, communications equipment, and industrial systems. In 1992, approximately 45% of global semiconductor sales were for computers, followed by consumer electronics 21%, communications 14%, and industrial applications 10%.[4] **By 2023, the landscape had shifted such that communications (e.g., smartphones) accounted for 32% of global semiconductor sales, with computers at 25%, automotive at 17%, industrial at 14%, and consumer electronics at 11%.[5] This reflects the expanding role of semiconductors across both consumer and industrial sectors.**

   Personal electronics and communication devices have significantly driven the development of semiconductors, as these components are essential for such devices to function effectively. Semiconductors enable key functionalities such as data processing, graphic rendering, internet connectivity, and device communication. Nearly all personal electronics depend on semiconductors, from devices as small as digital watches and smartphones to those as large as home appliances and HVAC systems, not to mention the underlying infrastructure that keeps many of these devices functioning properly, such as data centers and telecommunication towers.

   Between 1977 and 2021, the annual global shipments of personal computing devices such as PCs, Macintosh computers, smartphones, and tablets grew remarkably, with each product category starting in different years. **For instance, the number of personal computers shipped annually increased from an estimated 20,000 units in 1977 to over 340 million units in 2021, reflecting a nearly 25% CAGR.[6] Similarly, Apple sold approximately 1.4 million iPhones in 2007,[7] the year of its launch, and shipped 234.6 million units in 2023,[8] achieving a 37% CAGR.** Apple's iPhone 15, one of the company's latest models, is estimated to contain nearly 30 key chips that

[1] Historical Billings Report. World Semiconductor Trade Statistics (WSTS). https://www.wsts.org/67/Historical-Billings-Report
[2] Historical Billings Report. World Semiconductor Trade Statistics (WSTS). https://www.wsts.org/67/Historical-Billings-Report
[3] Total IC Unit Shipments Forecast to Climb 9% This Year. https://www.design-reuse.com/news/51764/2022-total-ic-unit-shipments-forecast.html
[4] Contributions of DOE Weapons Labs and NIST to Semiconductor Technology. Office of Technology Assessment, U.S. Congress.
[5] SIA Factbook 2024.
[6] Diffusion of Personal Computing Devices. The Geography of Transport Systems. https://transportgeography.org/contents/chapter1/the-setting-of-global-transportation-systems/personal-computing-devices/
[7] How the Apple iPhone Changed the World. CNBC. https://www.cnbc.com/2024/01/27/how-the-apple-iphone-changed-the-world.html
[8] Apple Grabs the Top Spot in the Smartphone Market in 2023 along with Record High Market Share. IDC Research. https://www.idc.com/getdoc.jsp?containerId=prUS51776424

handle various functions, including power management, audio processing, motion sensing, and radio frequency operations. Furthermore, global smartphone shipments exceeded 1.17 billion units in 2023.

The rising variety and increasing number of consumer and commercial products have driven and are driving greater demand for chips. As products become more complex and feature-rich, the number of chips within each product tends to grow, although the exact numbers of semiconductor chips used in different devices could vary significantly depending on manufacturers. Since their debut, smartphones have steadily evolved, incorporating more functions that demand greater computing power, and consequently, more semiconductor chips. **Today's smartphones not only handle basic calls and texts but also support advanced graphics processing, AI capabilities, advanced cameras, and even satellite communications. This trend underscores the increasing complexity and chip dependency of modern devices.** Furthermore, the rapid growth in global motor vehicle production, from over 30 million units in the 1970s to 76 million units in 2021 annually, coupled with the increasing complexity of vehicle technology, has led to a significant rise in the demand for semiconductors. With a CAGR of approximately 2%, the number of semiconductor chips per vehicle varies greatly depending on the type of vehicle and its features such as different kinds of sensors, lightings, and entertainment. A Deloitte study in China indicates that from 2012 to 2022, the number of chips per internal combustion engine vehicle was expected to grow from 438 to 934, an increase of nearly 2.1 times. During the same period, the number of chips in new energy vehicles grew from 567 to 1,459, a 2.6x increase.[9]

2. **Being the world's first pure-play integrated circuit (IC) foundry, dedicated to semiconductor manufacturing,[10] TSMC committed exclusively to custom products as Morris Chang pointed out that these products typically face little to no competition.**[11] **Dedicated foundries benefit customers, such as fabless companies and integrated device manufacturers (IDMs), by eliminating the need for heavy investment in fabrication plants, while enabling high factory utilization rates for themselves. This enables customers to focus more on chip design and remain more agile in responding to market trends, without being burdened by the significant capital expenses associated with owning and operating fabrication facilities.**

   A dedicated foundry exclusively manufactures integrated circuit devices for other companies (customers), usually fabless companies, which typically refer to a semiconductor design company without a production line, but also sometimes for integrated device manufacturers (IDM), without selling integrated circuit products independently. This business model eliminates competition with customers and tailors production to their needs,[12] thus lowering barriers for semiconductor companies to enter the market. By focusing solely on integrated circuit design and sales, customers can avoid the immense costs and complexities of establishing and maintaining wafer fabrication facilities, which are handled entirely by the foundry.

   In contrast to foundries within IDMs such as Intel and Samsung, TSMC positions itself as a pure manufacturing partner, earning the trust of customers who design integrated circuits. Unlike Intel and Samsung, which fabricate wafers for both their own products and third-party clients, TSMC's business model eliminates any concerns that customers might have about potential competition from it. This allows its customers to focus exclusively on circuit design without needing to invest heavily in their own manufacturing plants or R&D for production. As a result, clients can allocate more capital to chip design and functionality, leaving the complexities of manufacturing to TSMC.

   TSMC has built strong partnerships with its customers by adhering to its business philosophy of being a dedicated foundry and prioritizing customer feedback obsessively. The top 15 customers have always contributed nearly 75% of TSMC's sales.[13] Since 2000, the top 15 customers have been more stable, with nine of them remaining in the group going forward. By 2023, TSMC had grown to serve 528 customers and manufactured 11,895 products across a wide range of applications, including computing, smartphones, automotive, and other digital

---

[9] Fighting An Unprepared Battle – Rethinking Auto Semiconductor Strategy in An Uncertain Era. Deloitte. https://www2.deloitte.com/cn/en/pages/consumer-business/articles/automotive-semiconductors-strategic.html

[10] The term semiconductor refers to a material that can be altered to conduct electrical current or block its passage. However, it more commonly refers to an integrated circuit (IC), or computer chip. The most common semiconductor material is silicon. What are Semiconductors. https://www.intel.com/content/www/us/en/newsroom/tech101/semiconductors-101-how-chip-is-made.html#gs.iibfb9; TSMC Annual Report 1994; Company Profile – TSMC. https://web.archive.org/web/20171106025256/http://www.tsmc.com/english/aboutTSMC/company_profile.htm

[11] Translated or rephrased by the author on a best effort basis. Chapter 6. Morris Chang: An Autobiography. Part II.

[12] Everything to Know about Dedicated Foundries – TSMC. https://www.tsmc.com/english/aboutTSMC/dc_infographics_foundry

[13] Translated or rephrased by the author on a best effort basis. Chapter 26. Morris Chang: An Autobiography. Part II.

consumer electronics.[14] **To strengthen relationships with top customers and better understand their needs, during his tenure as TSMC's chairman and president, Morris Chang visited the company's top customers at least once a year, and sometimes even more frequently.**

TSMC has a wide range of customers from all over the world and carefully planned capacity expansion based on customer demand determined in advance to ensure a high utilization rate over the years. Prior to 2000, TSMC operated at nearly full capacity for many years.[15] Fast forward to 2024, and the company's production capacity for its most advanced 3nm process node has already been fully allocated until 2026.[16] The company's lower process nodes such as 5nm and 4nm have also remained at 100% utilization rate.[17] Meanwhile, TSMC continues to expand its production capabilities. **One key reason TSMC can consistently maintain a high utilization rate of its production capacity is that it builds capacity based on customer demand rather than speculation.** TSMC consolidates requests from multiple customers and asks them to collectively justify the proposed demand. If customers genuinely foresee high demand, TSMC requires them to prepay for the additional tooling needed to expand capacity.[18] **Depending on the customer, some sign contracts with TSMC to secure a guaranteed, predetermined capacity for a set number of years.[19] For example, in 2013, Apple and TSMC reportedly entered into a three-year agreement for Apple's A-series chips, including the A8, A9, and A9X.[20] As of 2024, while TSMC does not explicitly disclose its customer agreements, the company's 3nm process capacity is reportedly fully booked by Apple, Qualcomm, Nvidia, and AMD.** This high demand has resulted in a queue of customers extending into 2026,[21] driven by TSMC's undisputed technological leadership in advanced process nodes.

TSMC has invested heavily in its manufacturing process, therefore enhancing efficiency and flexibility for its clients so that customers can better use the capital to focus on circuit designs. Building a semiconductor fabrication plant is extremely costly and time-consuming. A 2021 McKinsey report highlights the sharp increase in both R&D and CAPEX as the semiconductor industry advances to smaller, more complex nodes.[22] The average design cost for a 5nm chip is approximately $540 million, compared to $297 million for 7nm, $174 million for 10nm, and $104 million for 16nm. Meanwhile, the cost of constructing and equipping a facility for 5nm production is around $5.4 billion, whereas 7nm fabs cost $2.9 billion, 10nm fabs cost $1.7 billion, and 16nm facilities cost $1.3 billion. In addition to the financial investment, fab construction typically takes between 12 and 24 months, with another 12 to 18 months needed to achieve full production capacity.

In 2010, when TSMC built Fab 15 – initially for 28nm production, considered advanced at the time – the project, including later expansions into more advanced nodes, was estimated to cost nearly $10 billion over several phases.[23] By 2024, although starting costs for fabs producing mature process technologies (such as 28nm and above) seem to lower – Beijing Yandong Microelectronics plans to invest $4.6 billion in a 300mm (12-inch) fab[24] – the costs of building facilities for advanced nodes have risen significantly over the years. TSMC's Fab 18, which began construction in 2018 and started volume production in 2020, was estimated to cost $17 billion.[25] Meanwhile, TSMC's three Arizona

---

[14] Company Info. TSMC. https://www.tsmc.com/english/aboutTSMC/company_profile#:~:text=In%202023%2C%20TSMC%20served%20528,automotive%2C%20and%20digital%20consumer%20electronics

[15] TSMC Q4 2000 Investor Presentation.

[16] Major Clients Reportedly Fully Allocate TSMC's Production Capacity Until 2026, 3nm Process in High Demand. https://www.trendforce.com/news/2024/06/11/news-major-clients-reportedly-fully-allocate-tsmcs-production-capacity-until-2026-3nm-process-in-high-demand/

[17] TSMC's 3nm Process at Full Capacity, Led by Intel's Lunar Lake and Apple's iPhone 16 Launch. https://www.digitimes.com/news/a20240904PD213/3nm-tsmc-intel-apple-launch.html

[18] Interview with A Former Director at TSMC. 9/17/2024.

[19] TSMC Annual Report 2006

[20] Apple Reportedly Reaches Deal with TSMC for Next-Gen Chips. https://www.cnet.com/tech/tech-industry/apple-reportedly-reaches-deal-with-tsmc-for-next-gen-chips/

[21] Apple, Qualcomm, Nvidia, AMD Fully Book TSMC's 3nm Capacity. https://technode.com/2024/06/12/apple-qualcomm-nvidia-amd-fully-book-tsmcs-3nm-capacity-until-2026/

[22] McKinsey on Semiconductors. McKinsey & Company. November 2021.

[23] TSMC Begins Construction on GigafabTM In Central Taiwan. https://pr.tsmc.com/english/news/1629

[24] China to Spend Billions on Another Fab Offering Mature Nodes. https://www.tomshardware.com/tech-industry/china-to-spend-billions-on-another-fab-offering-mature-nodes-ydme-formed-to-operate-new-usd4-6b-facility

[25] TSMC Starts to Build Fab 18 - 5 nm, Volume Production in Early 2020. https://www.anandtech.com/show/12377/tsmc-starts-to-build-fab-18-5nm-in-early-2020

plants, which will manufacture advanced nodes such as 4nm and below, are projected to cost over $65 billion in total, with each facility exceeding $20 billion.[26]

Over the past two decades, Intel, Nvidia, and AMD have each invested nearly 20% of their sales into R&D (Intel ~18%, Nvidia and AMD ~22%). However, Intel remains the only integrated device manufacturer among the three, while Nvidia and AMD (since 2009) have adopted a fabless model, outsourcing chip production to foundries like TSMC. As a result, integrated device manufacturers must divide their R&D budgets between chip design and manufacturing, whereas fabless companies can focus all their resources on design. This allows fabless firms to potentially develop better chips in relatively lower R&D expenditures over the long term. Intel's R&D expense as a percentage of revenue have increased from the low teens in the early 2000s to nearly 30% by 2023. In comparison, Nvidia and AMD's R&D spending has been relatively steady and ranged from the mid-teens to the mid-twenties over the same period.

The capital expenditure of these companies reflects similar trends to their R&D spending. Fabless companies invest significantly less in CAPEX compared to IDMs and foundries, allowing them to allocate more capital to areas critical for chip design, such as R&D. On average, fabless companies such as Nvidia and AMD allocate a mid-single-digit percentage of their sales to CAPEX. In contrast, Intel, an integrated device manufacturer, has historically invested a mid-teen percentage of its sales. However, starting in 2022, Intel began significantly increasing its CAPEX, reaching nearly 50% by 2023, as the company works to catch up with chipmakers that outsource advanced process node production to TSMC such as AMD and Nvidia in different segments of processors.

Meanwhile, dedicated foundries such as TSMC, UMC, and SMIC have consistently invested a substantial portion of their sales in CAPEX to expand production capacity for both new and existing process nodes. Over the past two decades, TSMC has averaged CAPEX investments of around 40% of sales, UMC around 30%, and SMIC approximately 70%. For decades, Intel maintained a leading edge in process nodes but gradually lost ground to competitors such as AMD and Nvidia, which outsource to TSMC for production.

3. **Morris Chang and TSMC were customer obsessed and partnered with top customers, prioritizing customer feedback.**

To monitor customer satisfaction and maintain strong relationships, TSMC began hiring external advisors since 1997 to conduct annual surveys of its customers.[27] These surveys evaluate every aspect of TSMC's services, including capacity availability, response times, pricing, on-time delivery, and more. **Each year, Morris Chang (until his retirement), along with the management team, personally reviews the customer feedback with the advisors and implements improvements accordingly.** A dedicated team oversees the progress to ensure that necessary changes are made. The goal of this program is to identify areas of customer dissatisfaction, address them effectively, and build greater trust with customers by continually improving the company's services.

To elevate its customer service to the next level, TSMC supports its clients in different business prospects such as inventory planning, new employee training, and sales, and grows alongside them during their early stages. For example, in 1997, Jensen Huang from Nvidia approached Morris Chang for TSMC's foundry services for its graphics chips and expressed a willingness to work exclusively with TSMC. **Recognizing this opportunity, TSMC agreed and even sent two engineers to Nvidia, then shorthanded, for over a month to assist with procurement, inventory, sales, and other operational tasks.**[28]

TSMC has built its reputation on its unwavering philosophy: "We do not make commitments lightly. Therefore, once we make a commitment, we devote ourselves completely to meeting that commitment."[29] This steadfast dedication to its customers has served TSMC well, helping the company win and retain significant clients over the long term. For example, in 2011, when Apple approached TSMC as a potential customer, it requested TSMC to fabricate chips at the 20nm process node. At the time, TSMC was producing at 28nm and actively developing 16nm, the next full process node. Shifting focus to the 20nm process, considered a "half-node" relative to 16nm, would have been a detour from TSMC's long-term R&D roadmap. However, recognizing the value of securing Apple as a customer, TSMC took on the challenge and invested over $10 billion to develop the 20nm process. As anticipated, by 2013, while TSMC was ready for mass production at 20nm, it fell behind on 16nm development. This delay caused TSMC to lose Apple's next order to Samsung, which had stayed focused on advancing its 16nm technology. Despite this setback, TSMC's earlier

[26] TSMC Arizona. https://www.tsmc.com/static/abouttsmcaz/index.htm
[27] Translated or rephrased by the author on a best effort basis. Chapter 24. Morris Chang: An Autobiography. Part II.
[28] Translated or rephrased by the author on a best effort basis. Chapter 26. Morris Chang: An Autobiography. Part II.
[29] Values and Business Philosophy. TSMC. https://www.tsmc.com/english/aboutTSMC/values

commitment to Apple built trust. Apple assured TSMC that once it could deliver at the 16nm node, Apple would return as a customer. True to its word, Apple resumed its partnership with TSMC, which has since become one of Apple's largest and most trusted suppliers. Jeff Williams, Apple's Chief Operating Officer, once described the relationship to Morris Chang privately by saying, "TSMC is one of the few best partners to Apple."[30]

4. **TSMC has sustained its technological leadership since entering the 2000s. Morris Chang, TSMC's founder, emphasizes the importance of a first-mover advantage, which is evident in both the company's business model and its manufacturing technology.**

   The company has established a "virtuous cycle", where its dominance in advanced chipmaking attracts more customers, further strengthening its market position and gradually edging out competitors, especially in the more advanced market segment. TSMC essentially has limited competition on advanced process nodes during different time periods and has produced approximately 90% of the world's most advanced semiconductor chips.[31] By 2023, TrendForce, a technology-focused market research firm, estimated that TSMC held a dominant 59% share, with a gradual upward trend,[32] of the $117.5 billion global semiconductor foundry market.

   In 1987, TSMC's fabrication technology lagged two to three generations behind leading semiconductor companies like IBM, which were capable of mass-producing chips at 1.25μm to 1.0μm nodes, compared to TSMC's 2.0μm. However, by 1999, TSMC had risen to become a tier-1 semiconductor company, producing 0.18μm nodes with superior yield performance. In 2018, TSMC became the first foundry to achieve mass production of the 7nm process node, marking the first time it led the industry in advancing to a new generation of technology nodes that uses Extreme Ultraviolet (EUV) technology.[33] This milestone not only solidified TSMC's determination to become technology-independent but also strengthened its position as a global technology leader.[34] By 2023, TSMC achieved mass production of semiconductors at the 3nm node, with plans to begin volume production of 2nm chips by 2025.[35] This progress is closely followed by Samsung. In contrast, Intel, which was several generations ahead when TSMC was founded, now trails TSMC significantly in process node advancements. As of 2024, many of Intel's flagship chips are still produced at the 7nm node,[36] some of which have been outsourced to TSMC since 2021, while TSMC has already fabricated 3nm chips for its customers.

   Over the years, TSMC has consistently led the industry, being one of the first companies to bring various process nodes into production, from 90nm and 65nm in the early 2000s to 20nm, 16/12nm, and most recently 3nm.[37] Currently, TSMC and Samsung are the only two companies capable of manufacturing 3nm chips. When TSMC's 3nm process entered production in 2022, yield rates reportedly ranged from 60% to 80%, while Samsung's 3nm production saw yields estimated between 10% and 20%.[38] By Q3 2024, Taiwanese media reported that TSMC's N3E, an enhanced version of its 3nm process, had achieved a yield rate approaching 90%.[39] In contrast, Samsung's first-generation 3nm process reportedly improved to yield rates between 50% and 60%, but its second-generation process saw yields at around only 20%, leaving many customers no choice but to choose TSMC. Samsung has reportedly even considered outsourcing production of some of its flagship Exynos chips to TSMC.

---

[30] Translated or rephrased by the author on a best effort basis. Chapter 33. Morris Chang: An Autobiography. Part II.

[31] There is no strict definition for "advanced chips." Generally, the term refers to the smallest process nodes available at a given time. For example, while other IDMs and foundries have struggled with 14nm nodes in recent years, TSMC has progressed to 7nm and smaller, reaching as far as 2nm by 2024.

[32] Taiwan And The Global Semiconductor Supply Chain: 2023 in Review. Taipei Representative Office in Singapore.

[33] EUV technology is essential for process nodes below 7nm. TSMC Leads in Adoption of EUV. https://www.eetimes.com/tsmc-leads-in-adoption-of-euv/

[34] TSMC's Industry-First and Leading 7nm Technology Enters Volume Production. TSMC. https://esg.tsmc.com/en-US/articles/237; Translated or rephrased by the author on a best effort basis. Chapter 22. Morris Chang: An Autobiography. Part II.

[35] TSMC Annual Report 2023

[36] U.S. Chipmaker Intel Was Once Dominant, Now Struggles to Stay Relevant. CNBC. https://www.cnbc.com/2024/04/26/intel-dominated-us-chip-industry-now-struggling-to-stay-relevant.html#:~:text=Processors%20get%20faster%20with%20more,1%2C000%20times%20smaller%20than%20micrometers.

[37] 5nm Technology. TSMC. https://www.tsmc.com/english/dedicatedFoundry/technology/logic/l_90nm

[38] Analysts Estimate TSMC's 3nm Yields Between 60% and 80%. https://www.tomshardware.com/news/analysts-estimate-tsmc-n3-yields-between-60-and-80-percent

[39] Samsung May Outsource Exynos Production to TSMC Due to Low 3nm Yield Rate. https://www.trendforce.com/news/2024/11/14/news-samsung-may-outsource-exynos-production-to-tsmc-due-to-low-3nm-yield-rate/#:~:text=On%20the%20other%20hand%2C%20TSMC's,%25%2C%20as%20the%20report%20noted; TSMC N3E Yield Rate Approach 90%. https://www.moneydj.com/kmdj/news/newsviewer.aspx?a=c0628954-6020-40af-946d-7e497e8f9814&c=MB010000

The high cost of building new fabs deters many potential entrants from competing, and even established players hesitate to pursue advanced nodes. For example, in 2010, when TSMC built Fab 15 was estimated to cost nearly $10 billion over several phases.[40] By 2024, although starting costs for fabs producing mature process technologies (such as 28nm and above) seem to lower – Beijing Yandong Microelectronics plans to invest $4.6 billion in a 300mm (12-inch) fab[41] – the costs of building facilities for advanced nodes have risen significantly over the years. TSMC's Fab 18, which began construction in 2018 and started volume production in 2020, was estimated to cost $17 billion.[42] Meanwhile, TSMC's three Arizona plants, which will manufacture advanced nodes such as 4nm and below, are projected to cost over $65 billion in total, with each facility exceeding $20 billion.[43] This cost barrier, combined with the technological expertise TSMC has accumulated over decades, makes it challenging for competitors to keep pace.

5. **At the time of TSMC's IPO, its valuation appeared attractive, with a P/E of 17x and a P/FCF of 31x for the last fiscal year[44] given incredible growth and strong prospects. We believe the P/FCF ratio was a particularly important valuation metric given TSMC's high level of CAPEX.** Valuation numbers were supported by the company's strong sales growth, with a 1-year CAGR of 89% and a 3-year CAGR of 78%. Net income had grown significantly, achieving a 1-year CAGR of 268%, having just turned profitable in 1991. However, free cash flow data prior to the IPO is unavailable, [45] which is critical given TSMC's regular, heavy reliance on CAPEX.

   In addition, at the time of the IPO, the global semiconductor industry was booming, having grown at a CAGR of over 16% from 1986 (a year before TSMC's founding) to 1993, just prior to the IPO. Growth expectations remained high. **In early 1994, before TSMC's IPO, the Semiconductor Industry Association projected global semiconductor sales to rise from $77 billion in 1993 to nearly $133 billion by 1997,[46] a CAGR of over 14%.**

   If investors assumed a 5-year sales CAGR of 22%, above the overall industry given Foundry model, with a slight gross margin expansion and stable operating expenses, net income could grow at a 25% CAGR by 1998, potentially reducing TSMC's P/E to 5x and its P/FCF to 10x five years out.

---

[40] TSMC Begins Construction on GigafabTM In Central Taiwan. https://pr.tsmc.com/english/news/1629

[41] China to Spend Billions on Another Fab Offering Mature Nodes. https://www.tomshardware.com/tech-industry/china-to-spend-billions-on-another-fab-offering-mature-nodes-ydme-formed-to-operate-new-usd4-6b-facility

[42] TSMC Starts to Build Fab 18 - 5 nm, Volume Production in Early 2020. https://www.anandtech.com/show/12377/tsmc-starts-to-build-fab-18-5nm-in-early-2020

[43] TSMC Arizona. https://www.tsmc.com/static/abouttsmcaz/index.htm

[44] Based on our discussions with TSMC, financial data referenced herein, sourced from the 1994 annual report, represents the earliest publicly available information.

[45] We derived TSMC's 1993 financial data (the last fiscal year before its IPO) from the company's 1994 annual report. Despite reaching out to multiple sources, we were unable to obtain TSMC's IPO documents from its 1994 offering at the time of this analysis. Based on our discussions with TSMC, financial data referenced herein, sourced from the 1994 annual report, represents the earliest publicly available information.

[46] Global Semiconductor Market Size 1994. Los Angeles Times. https://www.latimes.com/archives/la-xpm-1994-05-18-fi-59254-story.html

Figure 1: Valuation Metrics

Metric	Amount (NTD Million)		Multiple / Ratio Analysis
Market Cap	NTD	70,200	-
Enterprise Value	NTD	70,954	5.8x EV/Sales LFY; 4.4x EV/Sales LTM
Cash	NTD	2,082	3.0% of Market Cap
LTD, STD, & Current Portion of LTD	NTD	2,837	NTD 754 Net Debt
-			0.11x Net Debt/EBITDA
Working Capital (inc. Cash)	NTD	3,065	4.4% of Market Cap
Net Working Capital (ex-Cash and STD)	NTD	1,273	1.8% of Market Cap
Total Equity Value	NTD	11,101	6.3x Price/Book Value
Tangible Book Value	NTD	11,101	6.3x Price/Tangible BV
Gross Profit	NTD	5,718	46.4% Gross Margin
Selling Expenses	NTD	305	2.5% Selling Expenses/Revenue
G&A Expenses	NTD	682	5.5% G&A Expenses/Revenue
R&D Expenses	NTD	313	2.5% R&D Expenses/Revenue
EBIT	NTD	4,419	35.8% Operating Margin
EBITDA	NTD	6,566	10.8x EV/EBITDA
Capex	NTD	3,856	26.2x EV/(EBITDA-CAPEX)
Net Income	NTD	4,245	16.5x P/E LFY[47]; NTD 6,499, 10.8x P/E LTM
Levered FCF	NTD	2,279	30.8x Price/Levered FCF
Unlevered FCF	NTD	2,404	29.5x EV/Unlevered FCF
Owner's Earnings	NTD	2,105	33.4x Price/OE
-			33.7x EV/OE
ROIC		36.3%	
ROTCE		37.7%	
1-Yr. Sales CAGR		89.4%	-
1-Yr. CAGR of Net Income		268.2%	-
3-Yr. Sales CAGR		77.6%	-
3-Yr. CAGR of Net Income		N/A	Net Loss in FY1990

Notes:

1. At the time this report was written, TSMC's IPO documents from Q3 1994 were not publicly available. Most of the financial information in the table above was sourced from the company's 1994 annual report. Based on our discussions with TSMC, financial data referenced herein, sourced from the 1994 annual report, represents the earliest publicly available information. Unless otherwise noted, the financial data presented in the table reflects the last fiscal year (FY1993) at the time of IPO rather than the last twelve months ending in the first half of 1994 (June 1994).
2. New Taiwan dollars (NTD, or NT$) are the lawful currency of the Republic of China (Taiwan).[48]
3. The market capitalization at the time of TSMC's IPO was calculated as the issuing price multiplied by the total number of shares outstanding immediately after the IPO, estimated using the number of shares at the end of FY1994. TSMC's common stock was issued at a price of NT$90 per share on September 5, 1994, on the Taiwan Stock Exchange.[49] According to the 1994 annual report, published after the IPO, TSMC had 780,000 shares of capital stock issued at the end of FY1994. Additionally, a Bloomberg news report from August 1994, prior to the IPO, stated that the company sold 5.2% of its stock at NT$90 per share, raising about NT$3.6 billion. This implied a total market capitalization of nearly NT$70 billion at the time of the IPO, aligning closely with our estimation.
4. EV = market cap on 9/5/1994 + STD (as of 12/31/1993) + LTD (as of 12/31/1993) – Cash (as of 12/31/1993)
5. Unless otherwise noted, sales and profit data are last-fiscal-year as of 12/31/1993.
6. The last-twelve-months sales and profit data are as of 6/30/1994, estimated from Bloomberg news report at the time of IPO and the company's 1994 annual report issued later.
7. Sales and Net Income CAGR is calculated from FY1990 to FY1993.
8. Levered FCF is calculated as CFO-CAPEX. Unlevered FCF is calculated as Levered FCF+Net Interest Expense.
9. Cash flow data prior to 1993 are not provided in the company's 1994 annual report.

[47] Last-Fiscal-Year.
[48] TSMC 20-F 2023.
[49] FAQ – TSMC. https://investor.tsmc.com/english/faq; Taiwan's Biggest Semiconductor Maker to List Shares 8/01/1994. Bloomberg.

10. ROIC is calculated EBIT*(1-Effective Tax Rate) divided by Total Asset – Cash – Non-interest Bearing Current Liabilities. Capital lease is not considered an interest-bearing liability. TSMC was granted tax-exempt status by the Taiwanese government at the time of its IPO.
11. Components of ROTCE (as of 12/31/1993) are EBIT=NTD 4,419; Current Asset (ex. Cash) = NTD 5,111 – NTD 2,082 = NTD 3,029; Current Liabilities (ex. STD) = NTD 2,046 – NTD 290 = NTD 1,756; NFA = NTD 10,436.

Company Overview

Taiwan Semiconductor Manufacturing Company (TSMC), headquartered in Taiwan, was founded in 1987 by Morris Chang (Chung-Mou Chang) as a joint venture between the government of the Republic of China (Taiwan),[50] Philips Electronics N.V., and other private investors.[51] At its inception, the company received 48.3% of its funding from the National Development Fund (NDF), the government fund, 27.6% from Philips, and the remainder from private investors, including prominent local manufacturing families and 4.1% from the Kuomintang (Chinese Nationalist Party).[52] The total initial funding amounted to $145 million. TSMC is the world's first pure-play integrated circuit (IC) foundry, dedicated to semiconductor manufacturing.[53]

As the pioneer of the dedicated integrated circuit foundry business model, which Morris Chang considers the most important innovation of TSMC,[54] it has earned a reputation for its advanced and "More-than-Moore" wafer production processes,[55] and unparalleled manufacturing efficiency. Since its establishment, the company has remained committed to manufacturing services for advanced integrated circuits, adhering to a strict promise not to design or market its own branded integrated circuit products. This approach has positioned TSMC as a trusted partner rather than a competitor to its customers in the semiconductor industry.

A dedicated foundry exclusively manufactures integrated circuit devices for other companies (customers), usually fabless companies, which typically refer to a semiconductor design company without a production line, but also sometimes for integrated device manufacturers (IDM), without selling integrated circuit products independently. This business model eliminates competition with customers and tailors production to their needs,[56] thus lowering barriers for semiconductor companies to enter the market. By focusing solely on integrated circuit design and sales, customers can avoid the immense costs and complexities of establishing and maintaining wafer fabrication facilities, which are handled entirely by the foundry.

Depending on customer orders, TSMC's advanced integrated circuits serve diverse applications, including computers, communication systems, industrial products, and consumer goods such as smartphones.

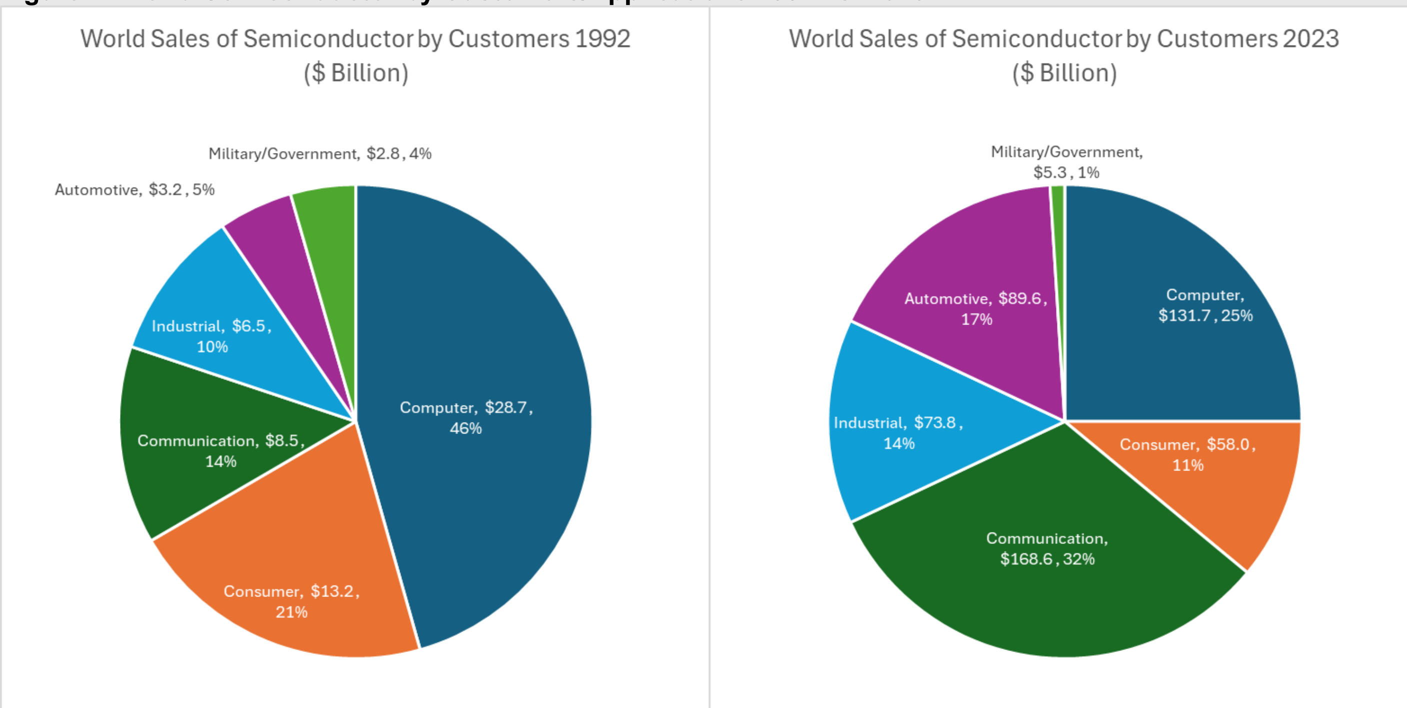
---

[50] TSMC Annual Report 1994; About Taiwan. Government Portal of the Republic of China (Taiwan). https://www.taiwan.gov.tw/about.php
[51] TSMC Annual Report 1994
[52] Translated or rephrased by the author on a best effort basis. Chapter 17. Morris Chang: An Autobiography. Part II.
[53] The term semiconductor refers to a material that can be altered to conduct electrical current or block its passage. However, it more commonly refers to an integrated circuit (IC), or computer chip. The most common semiconductor material is silicon. What are Semiconductors. https://www.intel.com/content/www/us/en/newsroom/tech101/semiconductors-101-how-chip-is-made.html#gs.iibfb9; TSMC Annual Report 1994; Company Profile – TSMC. https://web.archive.org/web/20171106025256/http://www.tsmc.com/english/aboutTSMC/company_profile.htm
[54] Morris Chang's Master Plan for 50 Years. Commonwealth Magazine. https://english.cw.com.tw/article/article.action?id=3114
[55] A wafer is a thin disc sliced from a silicon rod, primarily made from silicon extracted from sand. Thinner wafers reduce manufacturing costs, while larger diameters allow for the production of more semiconductor chips per wafer. Creating The Wafer – Samsung. https://semiconductor.samsung.com/us/support/tools-resources/fabrication-process/eight-essential-semiconductor-fabrication-processes-part-1-what-is-a-wafer/
[56] Everything to Know about Dedicated Foundries – TSMC. https://www.tsmc.com/english/aboutTSMC/dc_infographics_foundry

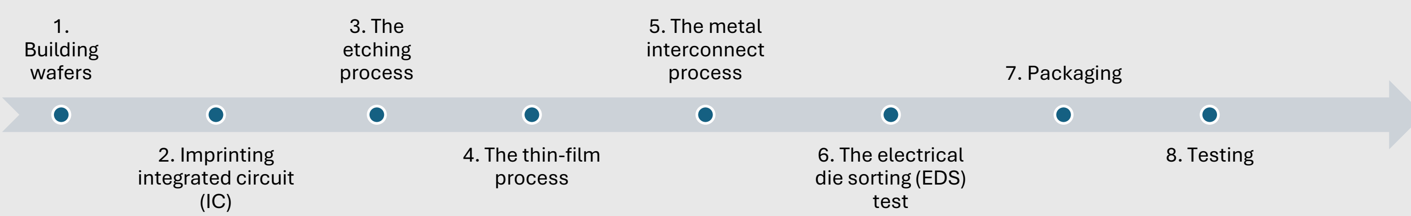
How Are Chips Fabricated? [57]

The term *semiconductor* originally refers to materials with electrical properties between conductors and insulators, as well as a wide range of electronic products made from these materials, such as memory devices, microprocessors, and integrated circuits. Today, semiconductors typically refer to the silicon 'chips' that house the electronic circuits at the core of nearly every electronic device, from the smallest calculator to the largest data centers. Integrated circuits (IC), depending on the context, nowadays are used interchangeably with other terms such as “semiconductors”, “microprocessors”, and “chips”, are essential components in nearly every modern electronic device, performing a variety of processing and storage functions.

Figure 2: World Semiconductor by Customers/Applications 1992 vs. 2023[58]



The process of manufacturing these chips involves creating many identical circuits on a wafer, a thin disc-shaped substrate. This is the process that TSMC’s core business focuses on along the value chain of semiconductor industry.[59] Below is a simplified explanation of the process, mapping out the major steps involved in the production of integrated circuits. For this overview, we will not delve into the technical specifics of each step.



TSMC participates in all steps of this manufacturing process except for the production of raw wafers. Typically, dedicated foundries such as TSMC manufacture semiconductor chips based on integrated circuit designs provided by

---

[57] A Short Introduction to Semiconductor Fabrication. Samsung Semiconductor. https://semiconductor.samsung.com/emea/news-events/tech-blog/a-short-introduction-to-semiconductor-fabrication/; Creating The Wafer – Samsung. https://semiconductor.samsung.com/us/support/tools-resources/fabrication-process/eight-essential-semiconductor-fabrication-processes-part-1-what-is-a-wafer/ ;Packaging Process That Protects Semiconductors. Samsung Semiconductor USA. https://semiconductor.samsung.com/us/support/tools-resources/fabrication-process/eight-essential-semiconductor-fabrication-processes-part-9-packaging-to-protect-the-chips-from-external-elements/

[58] Contributions of DOE Weapons Labs and NIST to Semiconductor Technology. Office of Technology Assessment, U.S. Congress.; SIA Factbook 2024.

[59] TSMC Annual Report 1994

customers, usually fabless semiconductor companies such as NVIDIA and Apple but sometimes also integrated device manufacturers (IDM) companies such as Intel and Samsung, which develop custom integrated circuits to meet their specific needs.

1. Building Wafers

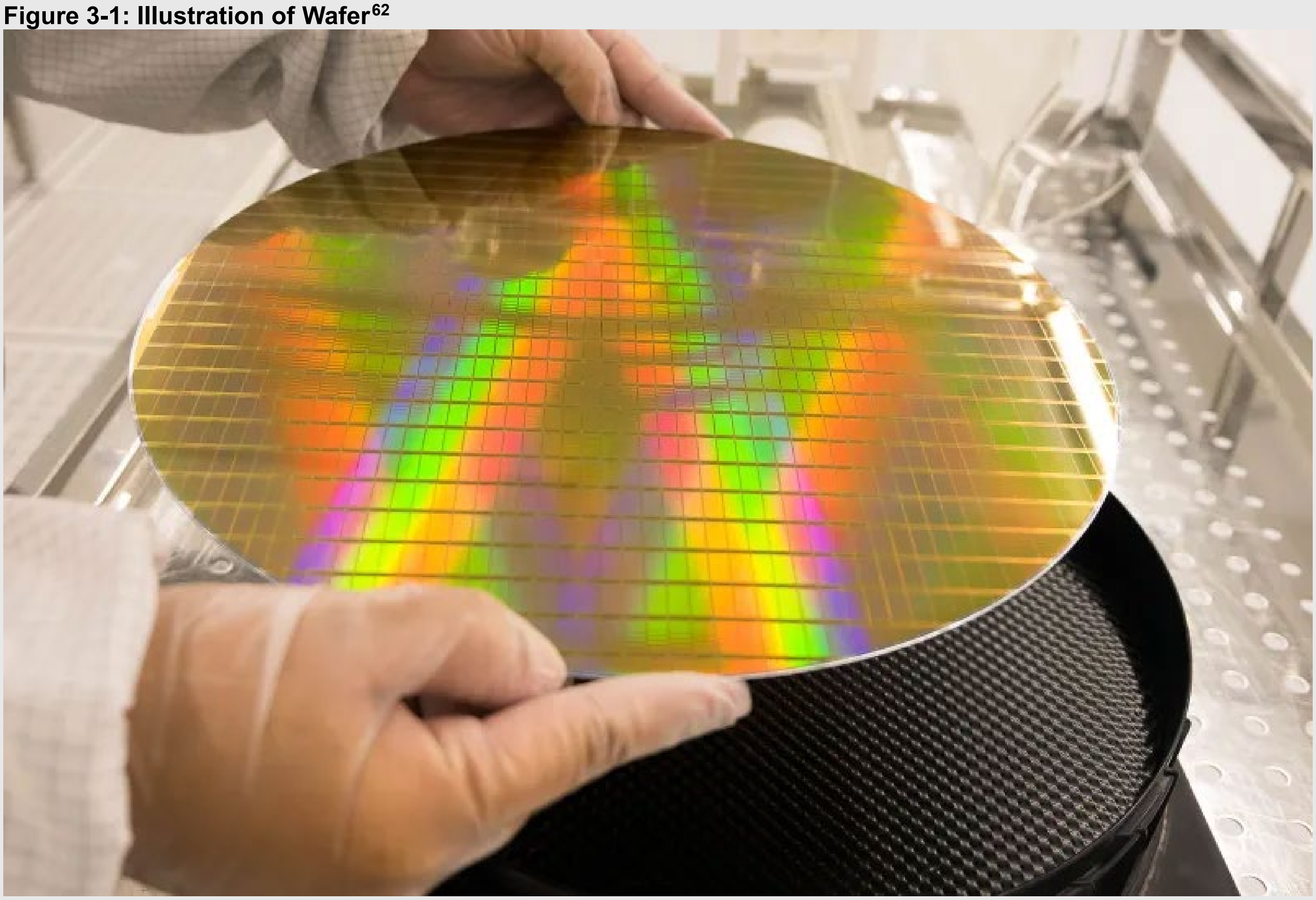
The process begins with the production of wafers, which are the foundation of semiconductors. Silicon is extracted from sand and purified before being melted into a high-purity liquid. Through a crystallization process, the liquid silicon is solidified into cylindrical ingots (blocks of pure silicon). These ingots are then sliced into thin, uniform discs using sharp diamond saw blades.

The diameter of an ingot determines the size of the wafer, which commonly comes in diameters of 150 mm (6 inches), 200 mm (8 inches), and 300 mm (12 inches). Larger diameters yield more semiconductor chips per wafer, while thinner wafers reduce manufacturing costs.[60]

It is important to note that TSMC does not produce raw wafers. Instead, they procure them from six major suppliers – FST, GlobalWafers, SHE, Siltronic, SK Siltron, and SUMCO – which collectively provide over 90% of the global raw wafer supply as of 2023.[61]

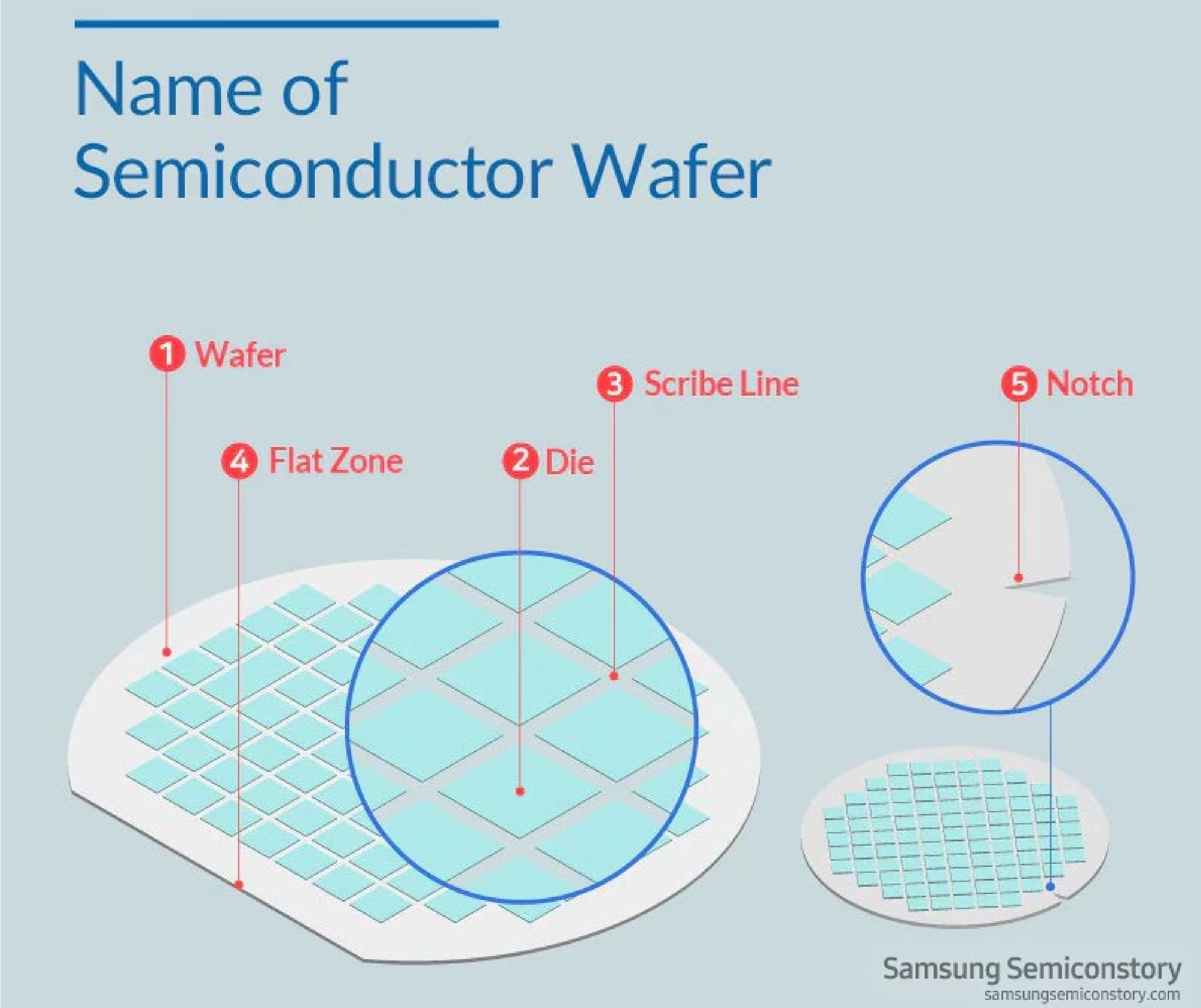
Each wafer contains numerous small squares called dies. Each die will eventually become an individual semiconductor chip after undergoing various manufacturing processes.

Figure 3-1: Illustration of Wafer[62]



[60] Creating The Wafer – Samsung. https://semiconductor.samsung.com/us/support/tools-resources/fabrication-process/eight-essential-semiconductor-fabrication-processes-part-1-what-is-a-wafer/
[61] TSMC Annual Report 2023.
[62] TSMC's Long Path From Round To Square Silicon Wafers. https://hackaday.com/2024/06/23/tsmcs-long-path-from-round-to-square-silicon-wafers/

Figure 3-2: Illustration of Wafer[63]



Notes:

1. Wafer: A wafer is a circular disc that serves as the core raw material for manufacturing semiconductor integrated circuits (ICs).
2. Die: On the wafer surface, there are numerous small squares. Each square is called a die and represents an integrated circuit chip where electronic circuits are integrated.
3. Scribe Line: While the dies may appear to be seamlessly attached to one another, there are actually small gaps between them known as scribe lines. These gaps allow for precise cutting of the wafer into individual dies using a diamond saw. The separated dies are then assembled into integrated circuit chips after wafer processing.
4. Flat Zone: The flat zone is a specific feature of the wafer used to identify its orientation and serve as a reference during processing. Since the internal structure of the wafer is too small to discern with the naked eye, the flat zone provides a visual guide for alignment.
5. Modern wafers often feature a notch instead of a flat zone. Notched wafers are more efficient because they allow for the production of a greater number of dies compared to wafers with a flat zone.
6. Notch: Wafers with a notch have recently become available instead of a flat zone. Notched wafers are more efficient than wafers with a flat zone in that a greater number of dies can be produced from notched wafers.

[63] Creating The Wafer – Samsung. https://semiconductor.samsung.com/us/support/tools-resources/fabrication-process/eight-essential-semiconductor-fabrication-processes-part-1-what-is-a-wafer/

2. Imprinting The Integrated Circuit

In this step, the intricate patterns of an integrated circuit, which consist of components such as transistors, diodes, resistors, and capacitors, are transferred onto the wafer. Each component plays different roles in processing and storing electrical signals. This step is achieved through a process called photolithography, where photomasks containing miniaturized versions of the circuit patterns are used to imprint the designs onto the wafer's surface.

3. The Etching Process

Etching removes unnecessary material from the wafer's surface to define the circuit patterns. This is achieved using liquid or gas etchants that selectively eliminate unwanted areas, leaving behind the desired structures.

4. The Thin-Film Process

To achieve the desired electrical properties, materials are deposited in extremely thin layers on the wafer. These films, fabricated at the atomic or molecular level, are categorized into two types, 1) metal layers, which are conductive layers that establish electrical connections between circuits; and 2) dielectric layers, which insulate layers that electrically isolate the internal structures and protect them from contaminants.

5. The Metal Interconnect Process

Metal interconnects are created to link the electronic components of the chip, allowing signals to travel efficiently between different parts of the circuit.

6. The Electrical Die Sorting (EDS) Test

Before proceeding further, manufacturers test the wafer to evaluate the yield, the percentage of functional chips out of the total produced. The EDS process checks whether each chip meets performance standards. Defective chips are marked and discarded.

Higher yields translate into better productivity, making this a critical step in the fabrication process. While these rates depend on various factors such as process nodes and technological maturity, they typically improve over time as foundries climb the learning curve. Although TSMC does not publicly disclose yield rates for any of its process nodes, from mature to advanced, industry participants estimated that its initial 3nm production in 2022 achieved yields of 60% to 80%. In contrast, Samsung's 3nm yields were reportedly around 10% to 20%, with minimal improvement and significant variability in chip quality.[64] By Q3 2024, TSMC was estimated to have achieved a 90% yield rate on its enhanced 3nm process node,[65] while Samsung has reportedly considered outsourcing production of some of its flagship Exynos chips to TSMC, as it continues to struggle with yield issues. Samsung's first-generation 3nm process is said to have yielded between 50% and 60%, with the second generation dropping to around 20%.

7. Packaging

Packaging serves several purposes, including providing electrical connections, ensuring heat resistance, and protecting the integrated circuit from external factors such as humidity, chemicals, impact, and vibration.

During this step, wafers are cut into individual dies, becoming individual chips.[66] Functional dies are mounted onto a lead frame or printed circuit board and connected with tiny metal balls or wires to facilitate electrical connections. The packaging process protects the chip and prepares it for integration into electronic devices.

---

[64] Analysts Estimate TSMC's 3nm Yields Between 60% and 80%. https://www.tomshardware.com/news/analysts-estimate-tsmc-n3-yields-between-60-and-80-percent

[65] Samsung May Outsource Exynos Production to TSMC Due to Low 3nm Yield Rate. https://www.trendforce.com/news/2024/11/14/news-samsung-may-outsource-exynos-production-to-tsmc-due-to-low-3nm-yield-rate/#:~:text=On%20the%20other%20hand%2C%20TSMC's,%25%2C%20as%20the%20report%20noted; TSMC N3E Yield Rate Approach 90%. https://www.moneydj.com/kmdj/news/newsviewer.aspx?a=c0628954-6020-40af-946d-7e497e8f9814&c=MB010000

[66] Packaging Process That Protects Semiconductors. Samsung Semiconductor USA. https://semiconductor.samsung.com/us/support/tools-resources/fabrication-process/eight-essential-semiconductor-fabrication-processes-part-9-packaging-to-protect-the-chips-from-external-elements/

8. Testing

Once packaged, chips undergo testing to ensure proper functionality under various conditions, including different voltages, electrical signals, and temperatures. Defective chips are discarded.

Sometimes, chips that do not meet specific performance standards are still functional but are repurposed through a process called down-binning.[67] For instance, a chip designed by Intel to be a high-performance Core i5 CPU might fail to meet all requirements but could still function as a Core i3 CPU. In such cases, manufacturers may disable certain features, such as cores,[68] and sell the chip under a different classification.

Before founding TSMC at age 56, Morris Chang had nearly three decades of experience in the semiconductor industry, spanning engineering, marketing, and management.[69] Born in China, Chang spent his early years in various cities across the country, including Ningbo, Nanjing, Guangzhou, Shanghai, Chongqing, and Hong Kong, frequently relocating to escape the Japanese invasion and later the Chinese civil war.[70] At the age of 18, he moved to the United States, followed by his parents a year later. With a recommendation from his uncle, a professor at Northeastern University at that time, Chang enrolled at Harvard University but transferred to the Massachusetts Institute of Technology (MIT) when he was 19 to study engineering.[71]

After graduating from MIT, Morris Chang began his career at Sylvania Electric Products before joining Texas Instruments (TI) in 1958 at the age of 27. TI was at the forefront of the semiconductor industry, being the first to mass-produce silicon-based transistors in 1954,[72] a significant innovation that replaced germanium transistors and propelled TI to industry dominance for the next two decades. While at TI, Chang worked alongside Jack Kilby, who joined TI at the same time with Chang and invented the integrated circuit in 1958.[73] Kilby's invention sparked patent disputes with Robert Noyce, who later founded Intel with Gordon Moore in 1968,[74] of Fairchild Semiconductor, but the two companies ultimately agreed to cross-license their technologies.[75]

In 1961, TI sponsored Morris Chang's pursuit of a doctorate in electrical engineering at Stanford University, which he completed in 1964. Upon returning to TI, Chang quickly rose through the corporate ranks, managing various divisions, including germanium-based semiconductors, silicon-based semiconductors, and integrated circuits. By 1983, when he left TI a after 25 year tenure, Chang was the general manager of TI's global semiconductor business and a corporate vice president.[76] Disillusioned by TI's shift in focus from semiconductors to consumer electronics, he quit TI and briefly joined another U.S. company before being invited to Taiwan in 1985 to be the president of and lead the Industrial Technology Research Institute (ITRI),[77] a government-affiliated R&D organization. However, Chang quit his role as the president of ITRI after just three years due to difficulties implementing his initiatives in a quasi-government organization.

While serving as ITRI's president, Chang was tasked with addressing requests from three Chinese American integrated circuit design companies seeking government funding to build fabrication plants in Taiwan for each of them. Chang wanted to decline such unreasoned requests as it would cost the government at least $100 million for three plants. However, the government was hesitant to turn them down. For over a decade, Taiwan had been eager to establish its own integrated circuit industry and to position itself as a leader in semiconductor manufacturing, but little progress had been made.[78] At the time, many foreign manufacturers were drawn to Taiwan due to its low costs, especially since Mainland China had yet to open its markets. Taiwan saw this as an opportunity to attract investment.[79] One notable example was Philips, which later became one of TSMC's largest sources of funding, expressing interest in setting up a manufacturing base in Taiwan. Chang recalled that when Mainland China opened its markets in the mid-1990s, it quickly became the

---

67 What Is Binning. https://www.tomshardware.com/reviews/glossary-binning-definition,5892.html

68 A core is a single processing unit in a microprocessor that executes instructions. All else equal, a microprocessor with more cores is generally more powerful than one with fewer cores.

69 Translated or rephrased by the author on a best effort basis. Morris Chang: An Autobiography. Part I and Part II.

70 Translated or rephrased by the author on a best effort basis. Prologue. Morris Chang: An Autobiography. Part I.

71 Translated or rephrased by the author on a best effort basis. Chapter 1. Morris Chang: An Autobiography. Part I.

72 Translated or rephrased by the author on a best effort basis. Chapter 3. Morris Chang: An Autobiography. Part I.

73 Translated or rephrased by the author on a best effort basis. Chapter 4. Morris Chang: An Autobiography. Part I.

74 Explore Intel's History. https://timeline.intel.com/

75 Historic Figures - Kilby and Noyce (1923-2005). BBC. https://www.bbc.co.uk/history/historic_figures/kilby_and_noyce.shtml

76 Translated or rephrased by the author on a best effort basis. Preface. Morris Chang: An Autobiography. Part II.

77 Translated or rephrased by the author on a best effort basis. Chapter 15. Morris Chang: An Autobiography. Part II.

78 Translated or rephrased by the author on a best effort basis. Chapter 16. Morris Chang: An Autobiography. Part II.

79 Translated or rephrased by the author on a best effort basis. Chapter 17. Morris Chang: An Autobiography. Part II.

world's new low-cost manufacturing hub. As a result, many foreign companies, including Philips, shifted their production to China, leaving only marketing teams in Taiwan.

Recognizing the financial impracticality of the request, Chang proposed an alternative – a "Common Wafer Fab" model (there is a rumor that Morris Chang took the idea from Robert Hsing-Cheng Tsao, the founder of United Microelectronics Corporation and a former colleague at ITRI. Tsao reportedly proposed the idea to Chang three years before TSMC was founded, while Chang was serving as an advisor to ITRI. However, Chang rejected the idea at that time[80]). **This innovative business model, which was unprecedented and became the dedicated foundry model we know today, provided fabrication services for multiple clients without competing with them, addressing concerns about proprietary designs being exposed to competitors, a risk inherent in working with Integrated Device Manufacturers (IDMs).**

Foundry, Fabless, and Integrated Device Manufacturers

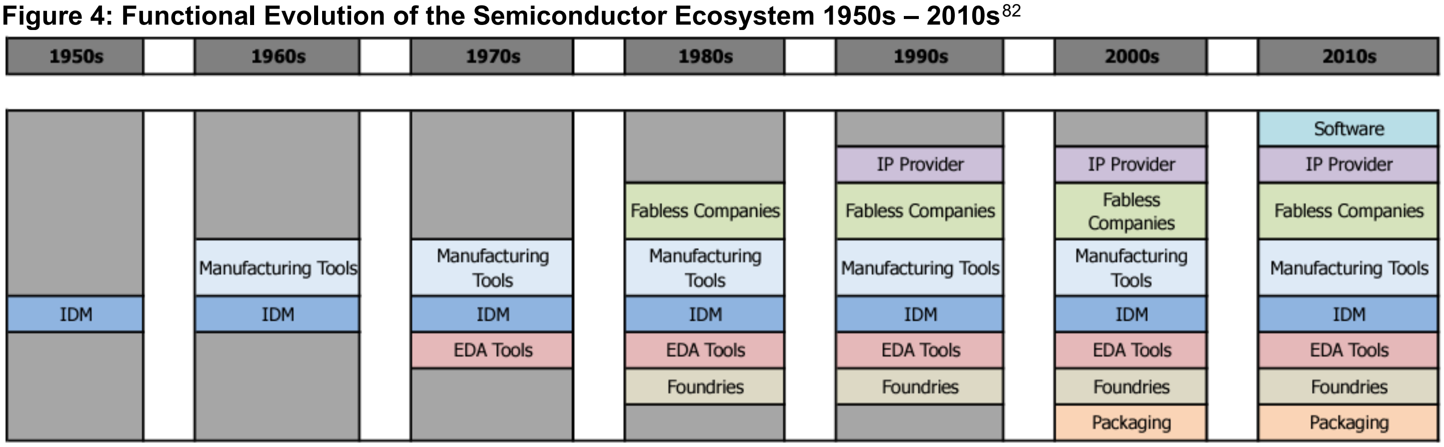
The primary difference between foundries, fabless companies, and IDMs lies in their distinct roles within the semiconductor industry. Dedicated foundries focus exclusively on manufacturing chips based on designs provided by customers, such as fabless companies and IDMs. They do not engage in chip design or sell products under their own brand. In contrast, fabless companies specialize in chip design but do not own or operate manufacturing facilities, instead of partnering with foundries to produce their designs. This allows fabless companies to select foundries based on the specific technology required for their products. By concentrating solely on manufacturing or design, both foundries and fabless companies can maximize efficiency and optimize their investments.

IDMs, on the other hand, manage the entire process, from chip design to in-house manufacturing. This vertical integration provides greater control over production and innovation, aligning chip development closely with the company's products and long-term goals. However, the IDM model can be more capital-intensive, requiring significant investment in both design capabilities and manufacturing infrastructure.

In addition, the IDM model carries inherent risks, as production capacity utilization depends primarily on the company's internal demand. In contrast, foundries mitigate the risk of underutilized capacity by serving a diverse customer base. This includes fabless companies and other IDMs across various sectors, such as consumer electronics and automotive industries, enabling more stable production levels and broader market reach.

Another reason for such a proposal, instead of building complete IDMs in the region, was that, although ITRI's yield on trial lines was excellent (without detailed numbers disclosed), it lagged behind foreign chip manufacturers in process node advancements.[81] Therefore, focusing on fabricating mature nodes not only leveraged Taiwan's strengths in yield but also allowed it to avoid direct competition with advanced technologies from foreign competitors. As these competitors allocated more production resources to new technologies, they often outsourced mature products to outside foundries, creating an opportunity for Morris Chang's new business idea.

Figure 4: Functional Evolution of the Semiconductor Ecosystem 1950s – 2010s[82]



Note:
1. Colored blocks are only for illustrative purposes and not indicative of their relative market sizes.

[80] Morris Chang and Robert Tsao. https://www.mirrormedia.mg/story/20170918fin023
[81] Translated or rephrased by the author on a best effort basis. Chapter 27. Morris Chang: An Autobiography. Part II.
[82] Beyond Borders The Global Semiconductor Value Chain. May 2016. SIA.

With government support and collaboration from Philips, Chang established TSMC in 1987, serving as its chairman and CEO from its inception until 2005 and again from 2009 to 2018. **TSMC adopted a customer-centric principle since its inception: "We have treated our customers as partners and have never competed against them,"[83] by not designing or marketing its own products but only fabricating integrated circuit based on customers' orders and providing services such as packaging and testing.[84] This philosophy has been key to its enduring success as being a dedicated foundry turns competitors into customers.**

In 1994, TSMC went public on the Taiwan Stock Exchange, followed by the listing of its American Depositary Shares (ADS) on the New York Stock Exchange in 1997.[85]

At the time of its IPO in 1994, TSMC focused on utilizing its 0.6μm and emerging 0.5μm processes to support clients in high-density and high-performance integrated circuit markets,[86] while Intel was already mature in 0.6μm and building facilities to produce the world's first microprocessors in 0.35μm to be launched in 1995.[87]

Over the decades, TSMC has significantly advanced its manufacturing processes, evolving from the 0.5μm node in 1994 to 7nm (0.007μm) and below, including 5nm and 3nm processes, which entered volume production in 2020 and 2022, respectively. The company plans to begin volume production of its 2nm process in 2025.[88]

Today, TSMC remains the global leader in semiconductor manufacturing, upholding its innovative business model and its commitment to supporting the integrated circuit industry's growth without directly competing with its customers**. In recent years, some market analysts have estimated that TSMC manufactures approximately 90% of the world's most advanced semiconductor chips,[89] which power everything from smartphones to AI applications.**[90] Some of the world's most advanced semiconductor chips can only be manufactured using TSMC's cutting-edge process nodes, attracting long-term, loyal customers such as Nvidia, Apple, and AMD.

From 1993 to 2023, TSMC's sales have grown from NTD 12.3 billion (approximately $0.5 billion) to NTD 2,161.7 billion (around $69 billion), reflecting a CAGR of nearly 19%. Throughout this period, the company maintained a gross margin of around 50% and an operating margin between 30% and 40%. The breakdown of regional sales has remained largely consistent, with sales to the U.S. increasing from around 57% to 65%. The remaining sales primarily come from Asia, followed by other regions. While the company does not disclose the exact percentage of organic growth in sales, excluding the effects of mergers, acquisitions, and currency fluctuations, we believe that growth has been driven primarily by increased customer demand, capacity expansion, and new product development. We will discuss these factors in more detail in the following section.

---

[83] Values and Business Philosophy. TSMC. https://www.tsmc.com/english/aboutTSMC/values

[84] Translated or rephrased by the author on a best effort basis. Chapter 17. Morris Chang: An Autobiography. Part II.

[85] FAQ – TSMC. https://investor.tsmc.com/english/faq

[86] TSMC Annual Report 1994

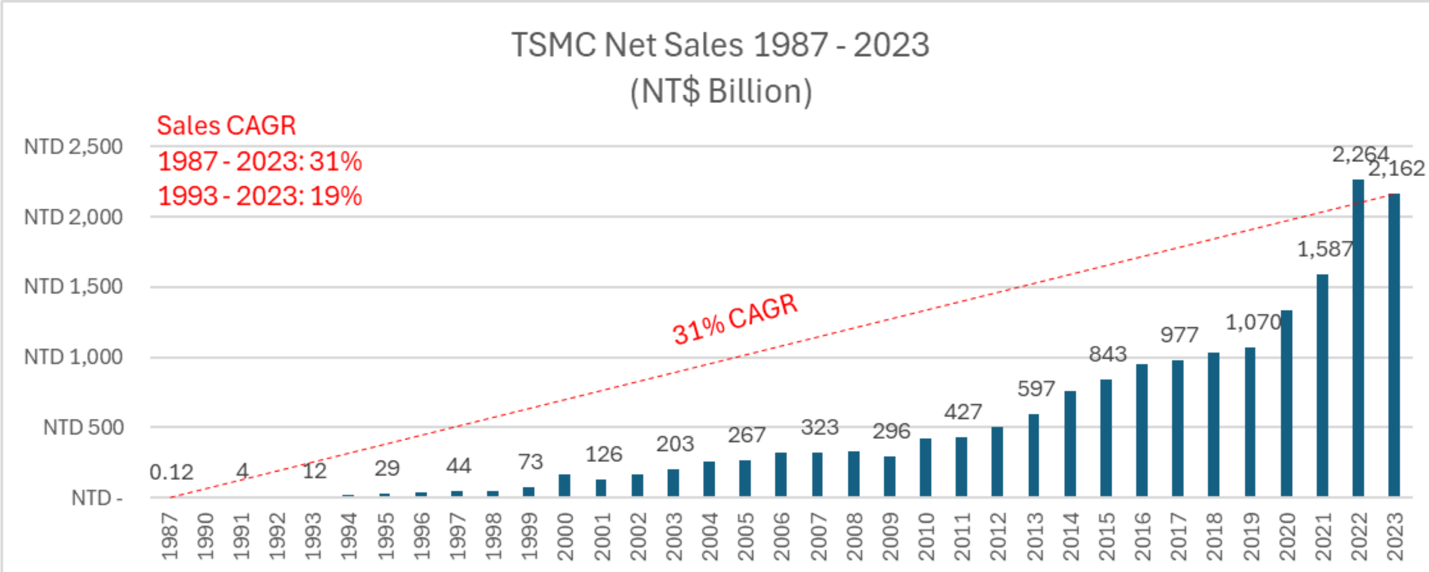
[87] Intel Annual Report 1994; Pentium Is First CPU to Reach 0.35 Micron. Linley Gwennap. Vol. 9, No. 4. 3/27/1995. Microprocessor Report.

[88] TSMC 20-F 2023.

[89] There is no strict definition for "advanced chips." Generally, the term refers to the smallest process nodes available at a given time. For example, while other IDMs and foundries have struggled with 14nm nodes in recent years, TSMC has progressed to 7nm and smaller, reaching as far as 2nm by 2024.

[90] How Taiwan Secured Semiconductor Supremacy. The Guardian. https://www.theguardian.com/world/article/2024/jul/19/taiwan-semiconductor-industry-booming

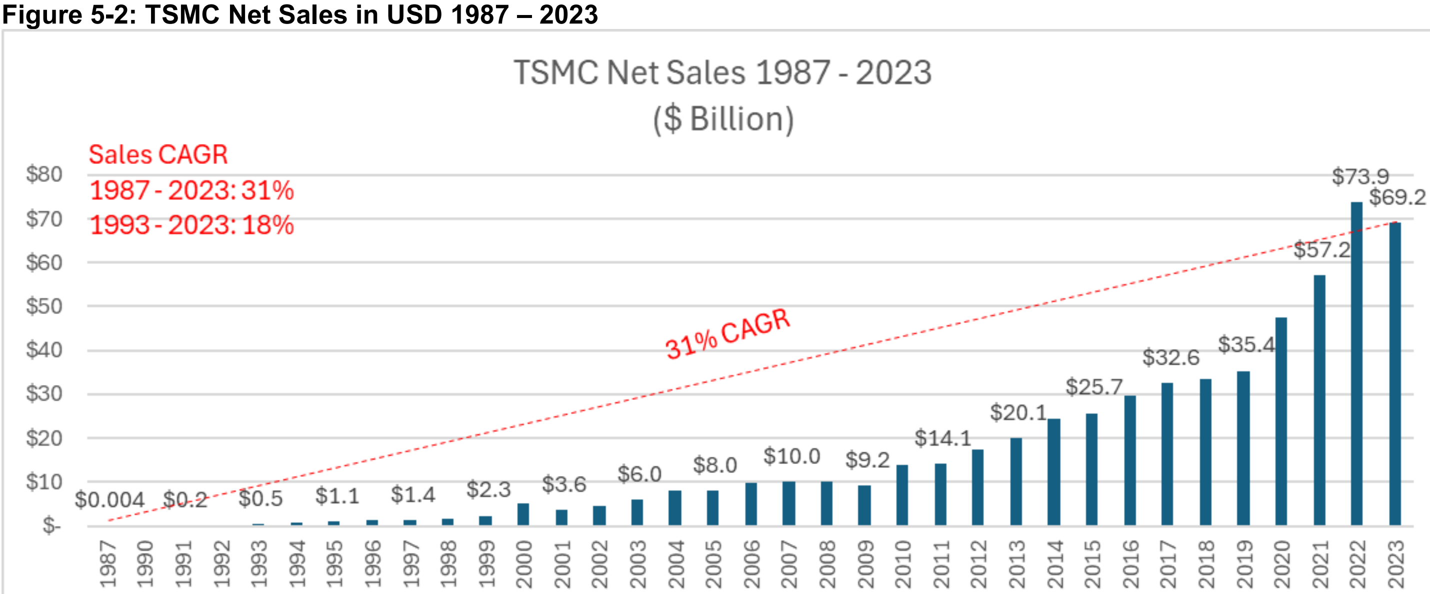
Figure 5-1: TSMC Net Sales in NTD 1987 – 2023



Note:

1. Sales in 1987 are provided in *Morris Chang: An Autobiography. Part II*. In the first year of TSMC's founding, it had sales of $4 million, with operating losses of $5.4 million, with 100% sales from Taiwan.[91]

Figure 5-2: TSMC Net Sales in USD 1987 – 2023



Notes:

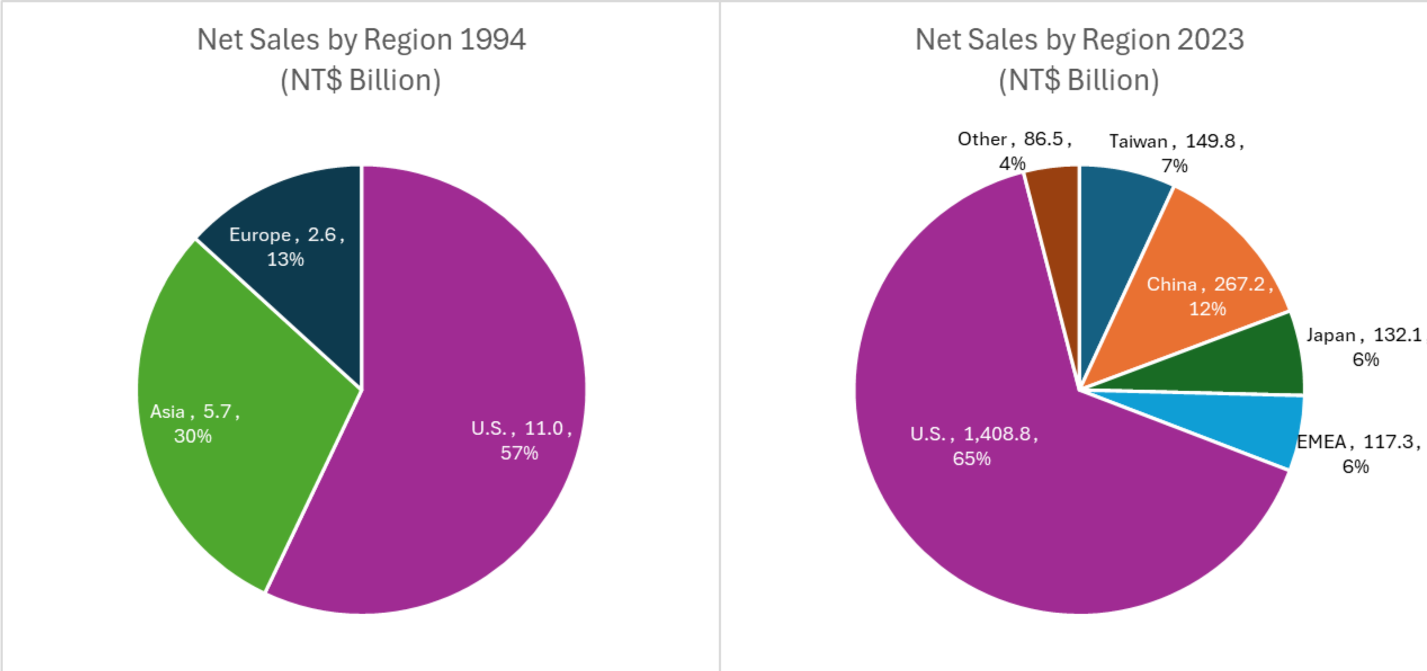
1. The exchange rates for NTD/USD used to convert net sales were based on the December rates of each year, as provided by the Federal Reserve Bank of St. Louis.[92]
2. Sales in 1987 are provided in *Morris Chang: An Autobiography. Part II*. In the first year of TSMC's founding, it had sales of $4 million, with operating losses of $5.4 million, with 100% sales from Taiwan.[93]

[91] Translated or rephrased by the author on a best effort basis. Chapter 19. Morris Chang: An Autobiography. Part II.

[92] Taiwan Dollars to U.S. Dollar Spot Exchange Rate (EXTAUS). Federal Reserve Bank of St. Louis. https://fred.stlouisfed.org/series/EXTAUS

[93] Translated or rephrased by the author on a best effort basis. Chapter 19. Morris Chang: An Autobiography. Part II.

Figure 5-3: TSMC Net Sales by Region 1994 vs. 2023



Note:

1. TSMC did not disclose regional sales for 1993 in its 1994 annual report. Based on our discussions with TSMC, financial data referenced herein, sourced from the 1994 annual report, represents the earliest publicly available information.

Figure 5-4: TSMC Sales by Products/Services

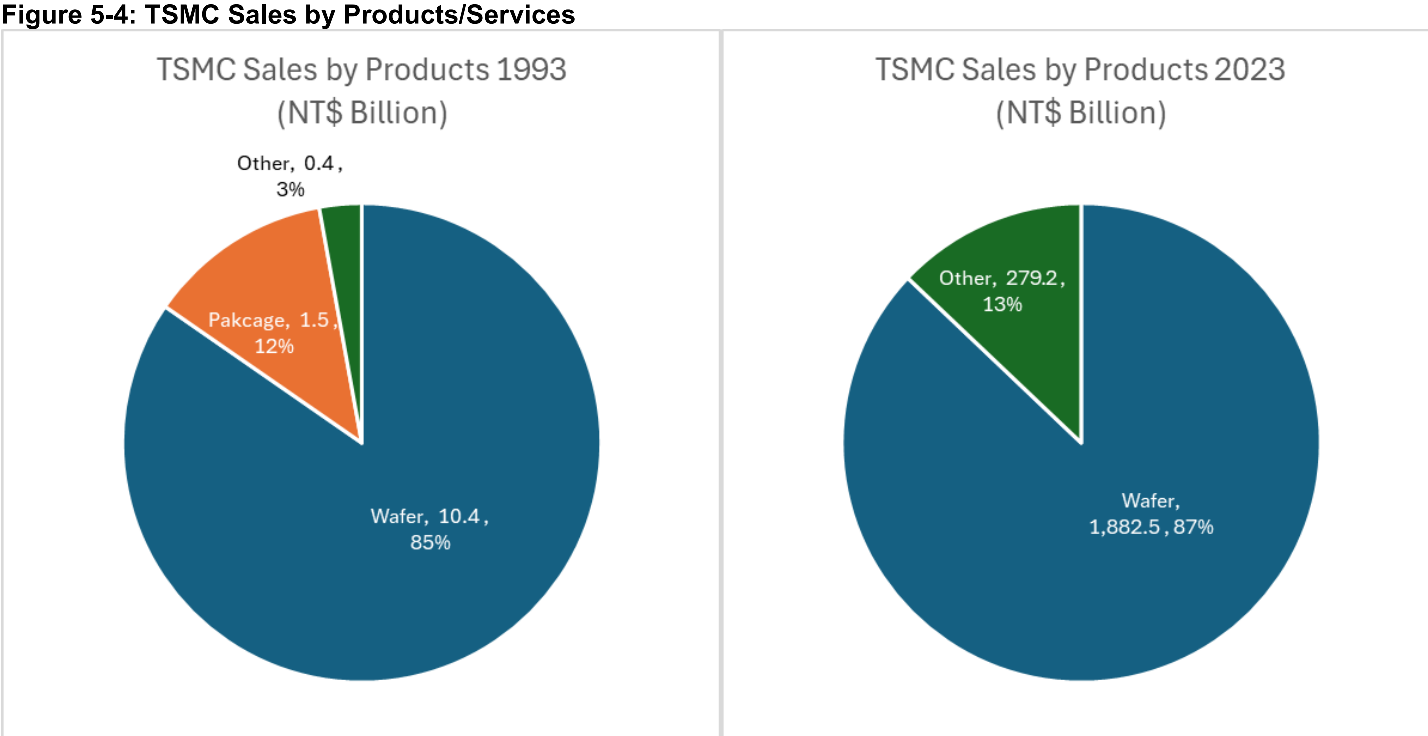
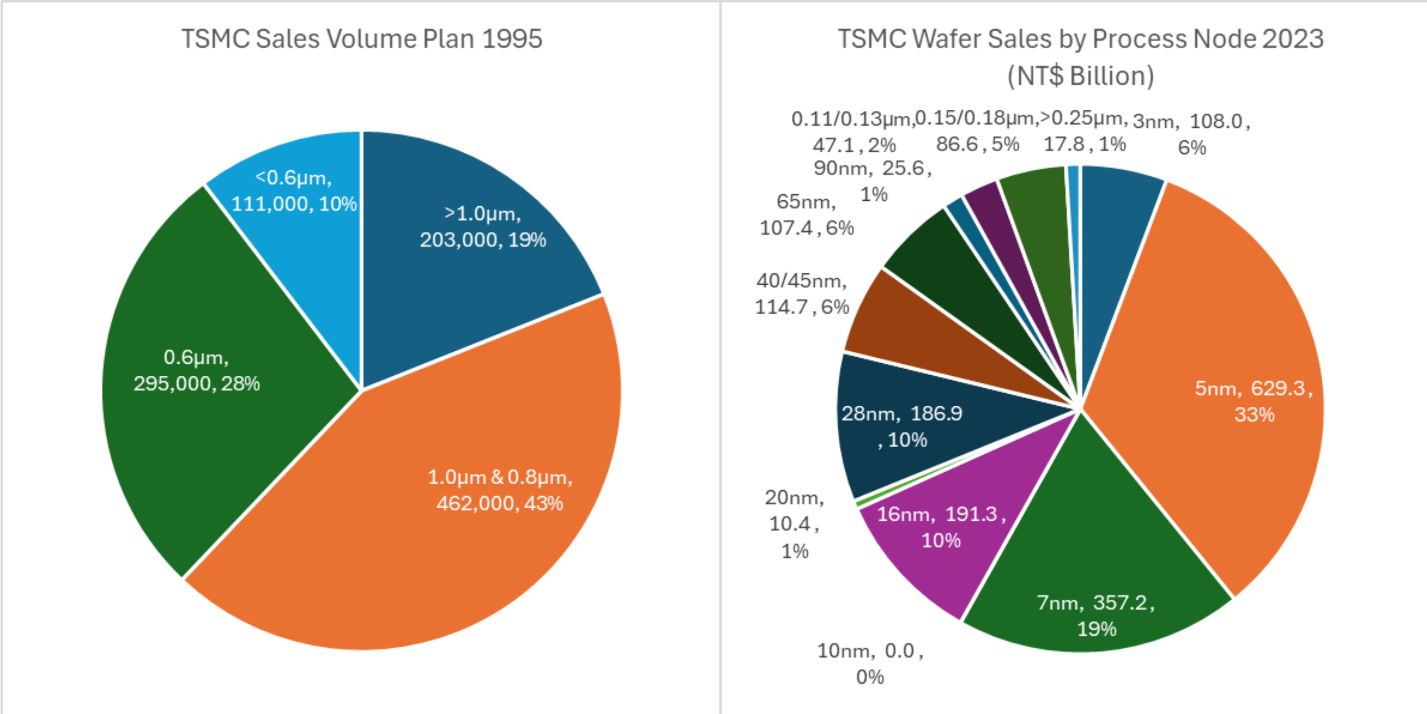
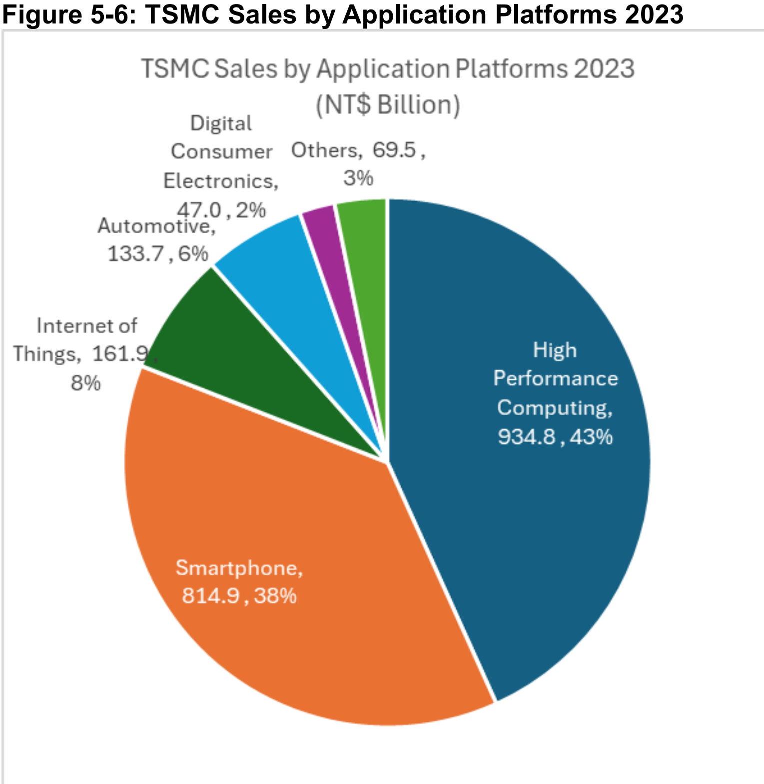


Figure 5-5: TSMC Wafer Sales (Volume) by Process Nodes 1995 vs. 2023



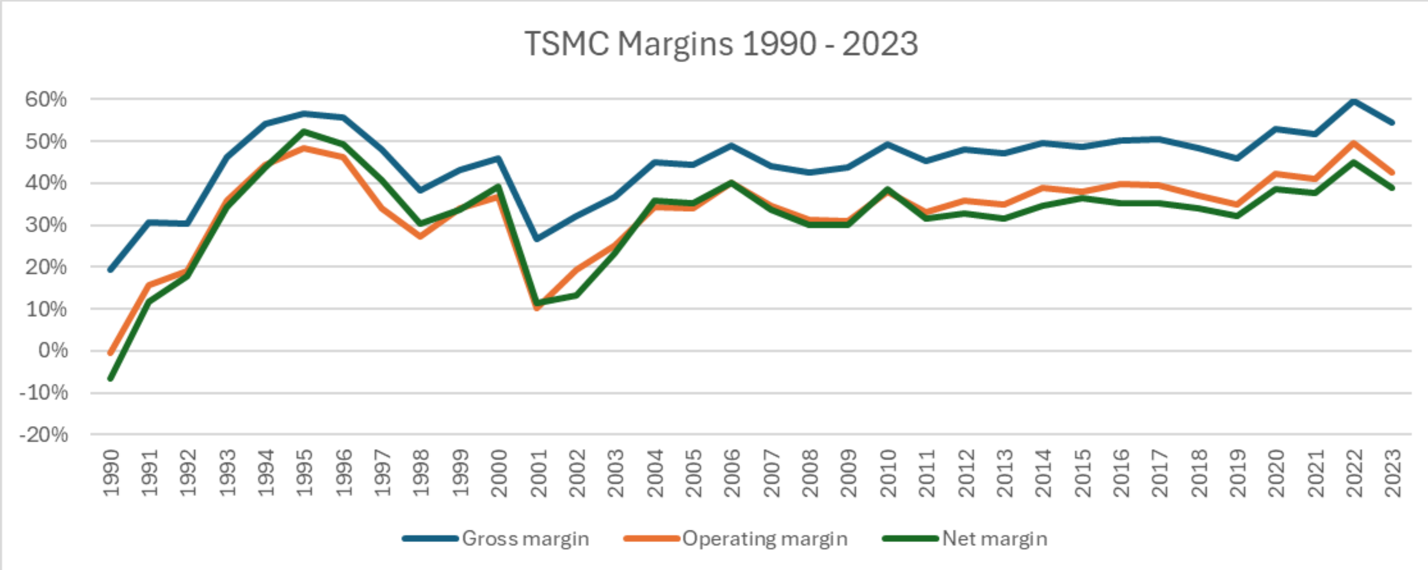
Notes:
1. TSMC did not disclose how much was actually sold by process type in 1994. We approximate it by its 1995 sales volume plan.[94]
2. The term "µm" stands for "micrometer." One micrometer is equal to one millionth of a meter (0.000001 m) or approximately 1/25,400 of an inch (0.00003937 inches).
3. The term "nm" stands for "nanometer." One nanometer is equal to 0.001µm.

Figure 5-6: TSMC Sales by Application Platforms 2023



[94] TSMC Annual Report 1994

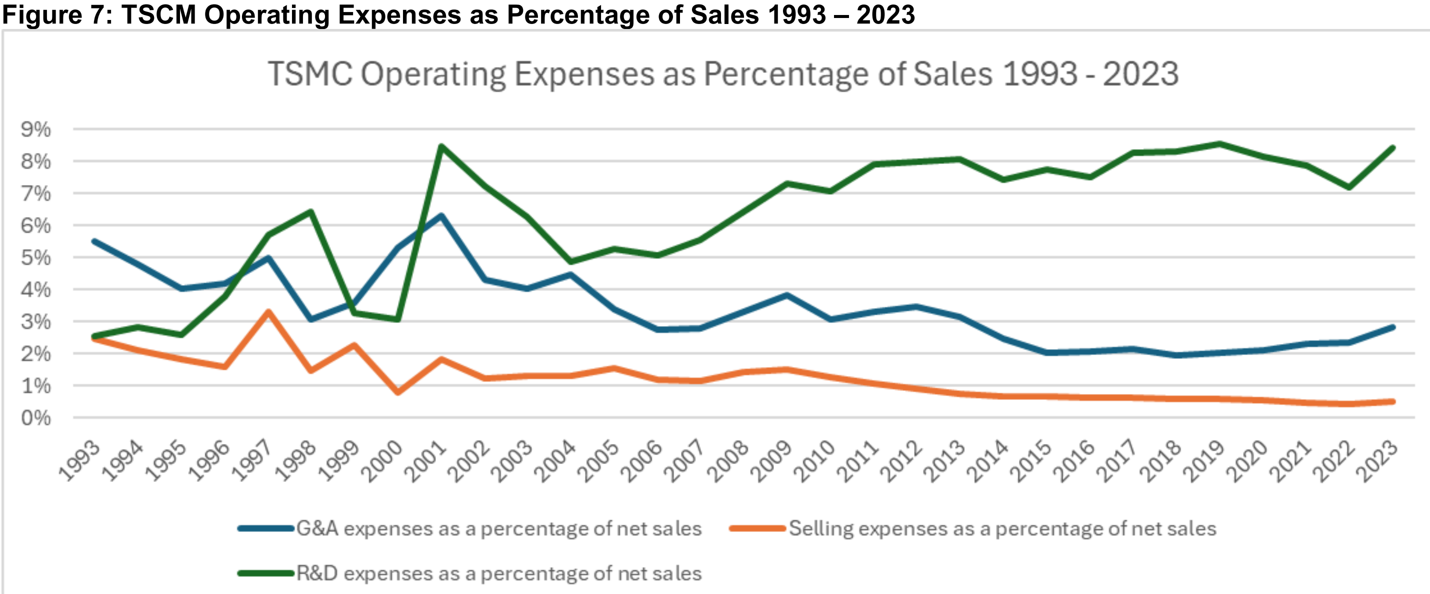
Figure 6: TSMC Profit Margins 1990 – 2023



Note:

1. The global semiconductor industry experienced a slowdown between 1996 and 1998, and again in 2001, following the burst of the dot-com bubble.

Figure 7: TSCM Operating Expenses as Percentage of Sales 1993 – 2023



Notes:

1. The data starts from 1993 due to the availability. Based on our discussions with TSMC, financial data referenced herein, sourced from the 1994 annual report, represents the earliest publicly available information.
2. The global semiconductor industry experienced a slowdown between 1996 and 1998, and again in 2001, following the burst of the dot-com bubble.

It typically takes TSMC about four to five months from receiving customer orders to deliver the final product.[95] The company's cash conversion cycle remained at 60 to 80 days for most years in the past but began to increase post-2017, reaching 103 days by 2023. This was primarily driven by lower inventory turnover, which declined from 8 times in 2017 to nearly 4 times in 2023.

Several factors contributed to this decrease. TSMC often stockpiles raw wafers and wafers for the current process node before transitioning to the next-generation process, converting some existing capacity to the newer node. For instance, in 2018, inventory turnover dropped from 7.9 times to 6.0 times, partly due to "an increase in raw wafer inventory and the 10-

[95] Translated or rephrased by the author on a best effort basis. Chapter 29. Morris Chang: An Autobiography. Part II.

nanometer wafer previewed before capacity was converted to 7-nanometer."[96] Similarly, in 2020, days of inventory rose "primarily due to the ramp-up of leading nodes."[97] **Depending on the customer, some sign contracts with TSMC to secure a guaranteed, predetermined capacity for a set number of years,**[98] allowing TSMC to plan its inventory in advance. This is particularly important because TSMC has consistently faced capacity constraints, especially for advanced nodes. Customers design their integrated circuits based on various process nodes aligned with TSMC's offerings and submit floorplans, typically created using Electronic Design Automation (EDA) tools,[99] to the foundry for fabrication.

In 2021 and 2022, TSMC pre-built wafers for the 5nm process and increased its raw material inventory.[100] Geopolitical tensions, such as the U.S.-China trade war and the Huawei ban,[101] along with supply chain disruptions during COVID-19, further contributed to the decline in inventory turnover. For example, in 2021, TSMC anticipated that its customers and the broader supply chain would maintain higher inventory levels compared to historical seasonal norms to ensure supply security.[102]

Despite short-term fluctuations, TSMC does not view this high industry-wide inventory level as a long-term concern. The company cites "the structural increase in long-term semiconductor demand underpinned by the industry megatrend of 5G and HPC-related (High Performance Computing) applications…the higher silicon content in many end devices, including automotive, PCs, servers, networking and smartphones."[103] TSMC believes its technology leadership positions it well to capture strong demand for advanced and specialty technologies.

Entering 2022, the global semiconductor industry faced headwinds from weakening end-user demand following the COVID surge.[104] TSMC expected customers to continue clearing inventory amid a softening global economy.[105]

---

[96] TSMC Q1 2018 Earnings Call. 4/19/2018.

[97] TSMC Q4 2020 Earnings Call. 1/14/2021.

[98] TSMC Annual Report 2006

[99] What is Electronic Design Automation (EDA). Synopsys. https://www.synopsys.com/glossary/what-is-electronic-design-automation.html

[100] TSMC Annual Report 2021; TSMC Q2 2022 Earnings Call. 7/14/2022

[101] Surge in Inventory - The Dark Clouds Gathering Over the Semiconductor Industry. https://medium.com/tej-can-help/tej-dictionary-surge-in-inventory-the-dark-clouds-gathering-over-the-semiconductor-indstury-eb8e32af3a08

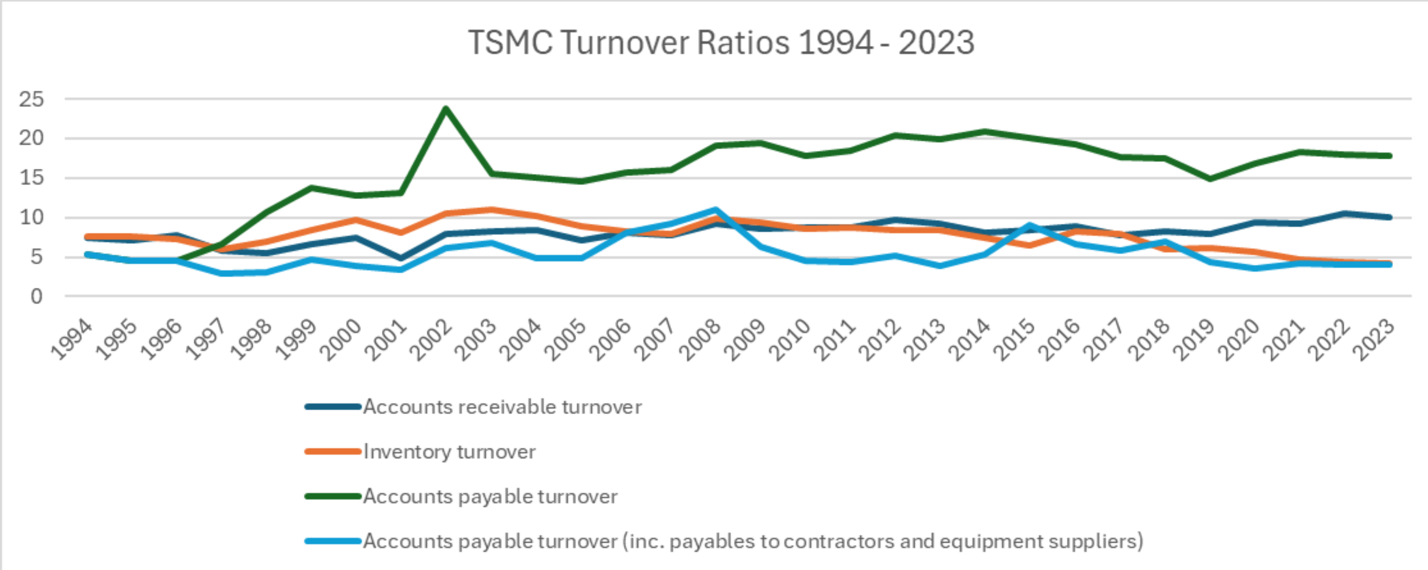
[102] TSMC Q3 2021 Earnings Call. 10/14/2021

[103] TSMC Q4 2021 Earnings Call. 1/13/2022

[104] Surge in Inventory - The Dark Clouds Gathering Over the Semiconductor Industry. https://medium.com/tej-can-help/tej-dictionary-surge-in-inventory-the-dark-clouds-gathering-over-the-semiconductor-indstury-eb8e32af3a08

[105] TSMC Expects Q2 Sales Drop as Clients Struggle to Clear Inventory. Reuters. https://www.reuters.com/technology/tsmc-q1-profit-rises-2-yy-beats-market-expectations-2023-04-20/

Figure 8-1: TSMC Turnover Ratios 1994 – 2023

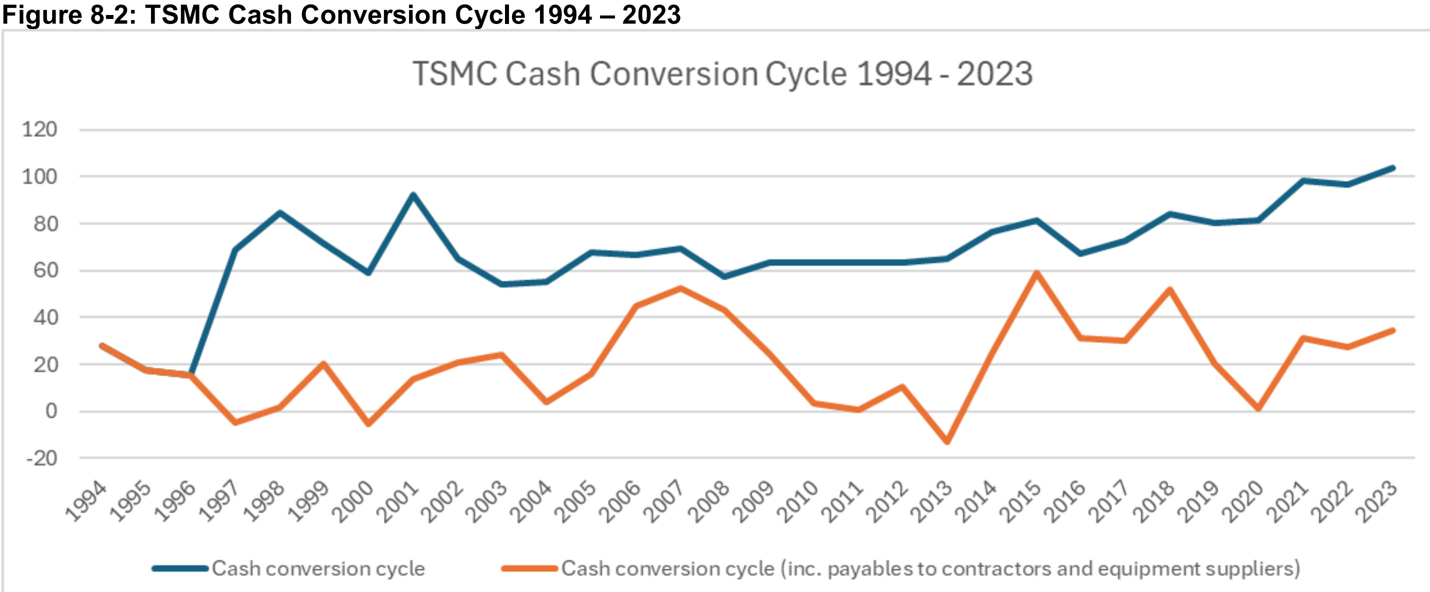


	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Accounts receivable turnover	7.5	7.3	8.0	5.9	5.6	6.7	7.4	4.9	8.0	8.2	8.4	7.0	8.0	7.8	9.2
Inventory turnover	7.7	7.6	7.2	6.0	7.0	8.4	9.6	8.2	10.5	11.0	10.2	8.9	8.3	8.0	9.9
Accounts payable turnover	5.3	4.4	4.5	6.6	10.7	13.8	12.8	13.2	23.8	15.5	15.1	14.6	15.8	16.0	19.1
Accounts payable turnover (inc. payables to contractors and equipment suppliers)	5.3	4.4	4.5	2.8	3.1	4.7	3.9	3.4	6.1	6.8	4.8	4.8	8.1	9.2	10.9

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Accounts receivable turnover	8.5	8.8	8.8	9.6	9.1	8.2	8.4	8.8	7.8	8.2	8.0	9.4	9.2	10.5	10.0
Inventory turnover	9.3	8.6	8.7	8.4	8.4	7.4	6.5	8.2	7.9	6.0	6.2	5.7	4.6	4.4	4.2
Accounts payable turnover	19.5	17.8	18.5	20.3	20.0	20.8	20.1	19.3	17.7	17.5	14.9	16.8	18.3	17.9	17.9
Accounts payable turnover (inc. payables to contractors and equipment suppliers)	6.3	4.5	4.4	5.1	3.8	5.3	9.0	6.7	5.8	6.9	4.3	3.6	4.2	4.1	4.1

Note:
1. The data starts from 1993 due to the availability.

Figure 8-2: TSMC Cash Conversion Cycle 1994 – 2023



	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Cash conversion cycle	27.3	16.1	14.4	67.5	83.5	71.3	58.7	92.0	65.0	54.3	55.2	67.7	66.5	69.6	57.4
Cash conversion cycle (inc. payables to contractors and equipment suppliers)	27.3	16.1	14.4	-6.3	0.9	19.6	-5.9	13.5	20.8	24.1	3.9	16.2	44.6	52.6	43.1

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Cash conversion cycle	63.5	63.5	63.6	63.5	65.1	76.4	81.5	67.1	72.7	84.2	80.3	81.2	98.2	96.9	103.5
Cash conversion cycle (inc. payables to contractors and equipment suppliers)	24.4	3.6	0.9	10.3	-12.7	24.9	59.2	31.3	30.0	52.1	20.1	1.4	31.0	27.4	34.4

Notes:
1. The data starts from 1993 due to the availability.
2. Cash conversion cycle = $\left(\frac{1}{Accounts\ receivable\ turnover} + \frac{1}{Inventory\ turnover} - \frac{1}{Accounts\ payable\ turnover} \right) * 365$

Figure 8-3: TSMC Technology Timeline[106]

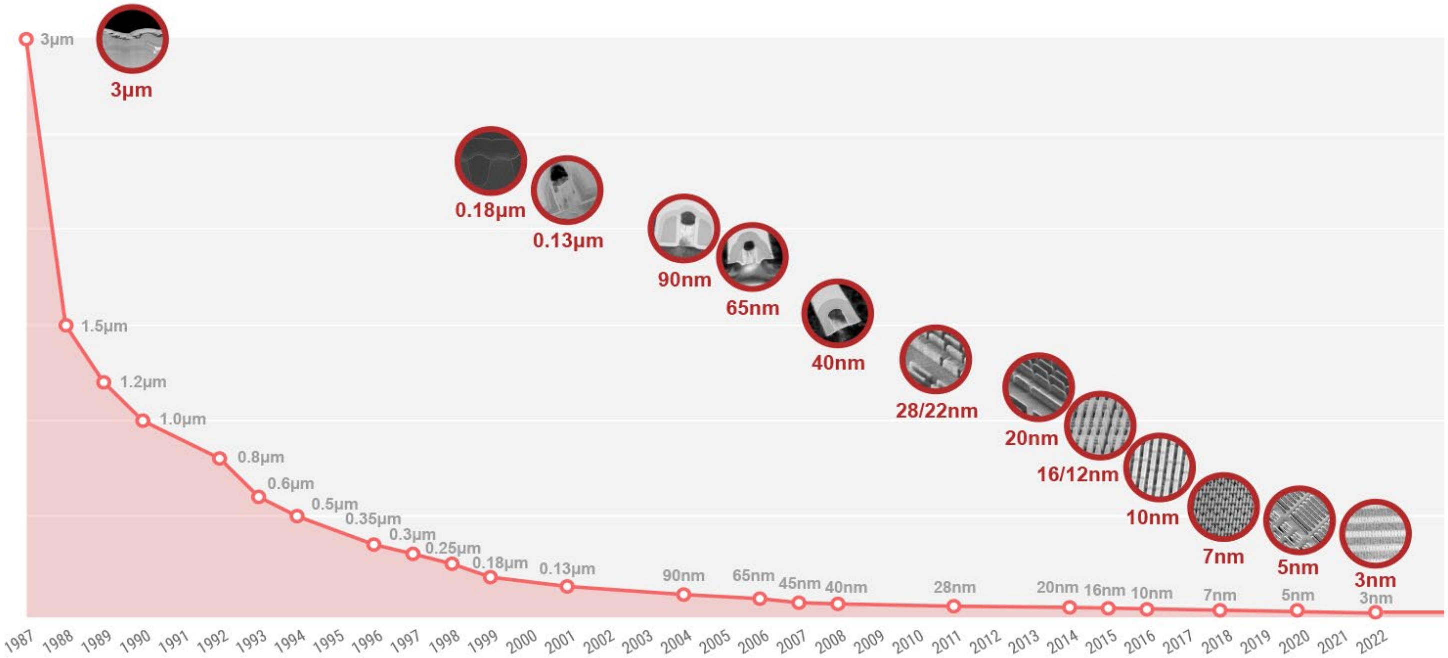
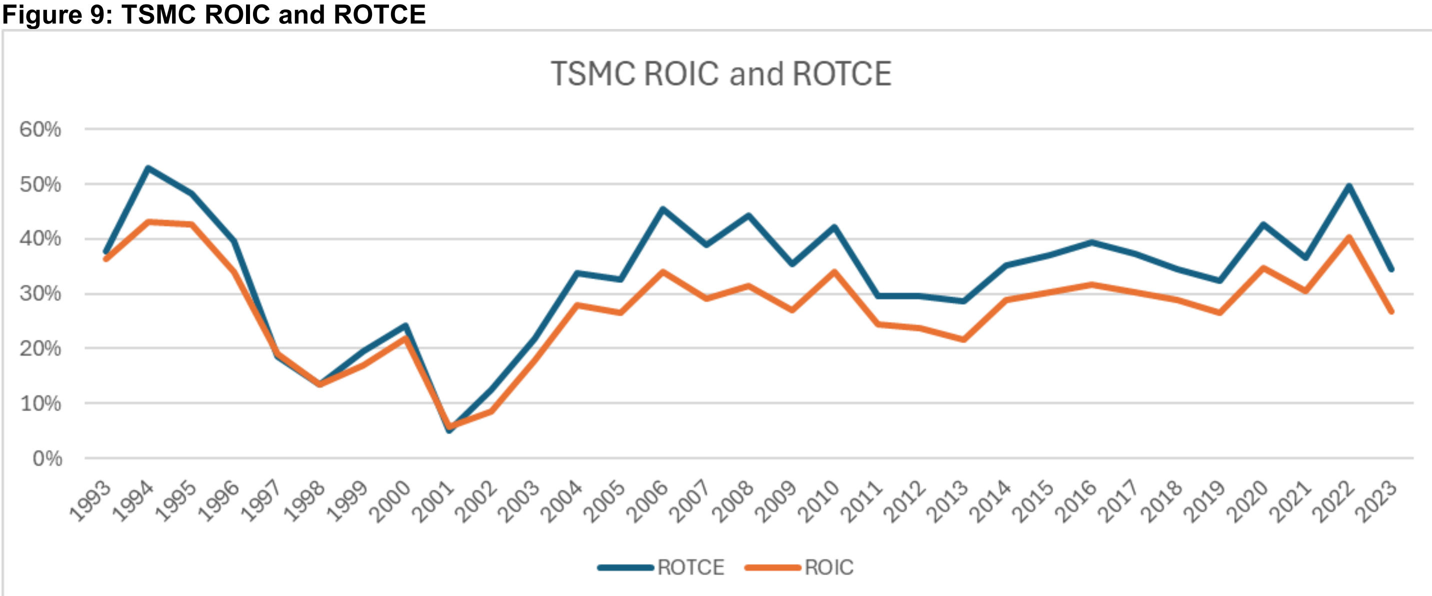


Figure 9: TSMC ROIC and ROTCE



Notes:
1. The data starts from 1993 due to the availability.
2. The global semiconductor industry experienced a slowdown between 1996 and 1998, and again in 2001, following the burst of the dot-com bubble.

[106] Logic Technology. https://www.tsmc.com/english/dedicatedFoundry/technology/logic

Figure 10-1: TSMC Income Statement

NTD Billion	1987	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Net Sales	NTD 0.1	NTD 2.2	NTD 4.5	NTD 6.5	NTD 12.3	NTD 19.3	NTD 28.8	NTD 39.4	NTD 43.9	NTD 50.4	NTD 73.1	NTD 166.2
YoY Growth			103.4%	45.3%	89.4%	56.8%	48.8%	37.0%	11.5%	14.8%	44.9%	127.5%
Gross profit	NTD -	NTD 0.4	NTD 1.4	NTD 2.0	NTD 5.7	NTD 10.5	NTD 16.3	NTD 22.0	NTD 21.1	NTD 19.3	NTD 31.5	NTD 76.5
Gross Margin		19.2%	30.7%	30.4%	46.4%	54.3%	56.8%	55.7%	48.0%	38.4%	43.1%	46.0%
YoY Growth			225.5%	44.0%	188.6%	83.6%	55.5%	34.5%	-4.0%	-8.3%	62.9%	142.9%
G&A expenses					NTD 0.7	NTD 0.9	NTD 1.2	NTD 1.6	NTD 2.2	NTD 1.6	NTD 2.6	NTD 8.8
G&A expenses as % of Sales					5.5%	4.8%	4.0%	4.2%	5.0%	3.1%	3.6%	5.3%
Selling expenses					NTD 0.3	NTD 0.4	NTD 0.5	NTD 0.6	NTD 1.5	NTD 0.7	NTD 1.7	NTD 1.3
Selling expenses as % of Sales					5.3%	3.9%	3.2%	2.9%	6.9%	3.8%	5.3%	1.7%
R&D expenses					NTD 0.3	NTD 0.5	NTD 0.7	NTD 1.5	NTD 2.5	NTD 3.2	NTD 2.4	NTD 5.1
R&D expenses as % of Sales					2.5%	2.8%	2.6%	3.8%	5.7%	6.4%	3.3%	3.1%
EBIT	NTD (0.2)	NTD (0.0)	NTD 0.7	NTD 1.2	NTD 4.4	NTD 8.6	NTD 13.9	NTD 18.2	NTD 14.9	NTD 13.8	NTD 24.8	NTD 61.3
EBIT Margin	-135.0%	-0.5%	15.8%	19.1%	35.8%	44.6%	48.3%	46.2%	34.0%	27.4%	34.0%	36.9%
YoY Growth				75.9%	255.6%	94.9%	61.3%	30.9%	-17.9%	-7.5%	79.8%	146.9%
Tax (Credit)					NTD -	NTD 0.1	NTD (0.8)	NTD (0.4)	NTD (2.6)	NTD (1.7)	NTD (0.4)	NTD (1.2)
Effective Tax Rate					0.0%	1.2%	-5.5%	-2.3%	-17.1%	-12.1%	-1.6%	-1.9%
Net income to shareholders	NTD -	NTD (0.1)	NTD 0.5	NTD 1.2	NTD 4.2	NTD 8.5	NTD 15.1	NTD 19.4	NTD 18.0	NTD 15.3	NTD 24.6	NTD 65.1
Net Margin		-6.7%	11.7%	17.7%	34.4%	43.8%	52.4%	49.2%	40.9%	30.4%	33.6%	39.2%
YoY Growth				119.8%	268.2%	99.6%	78.0%	28.6%	-7.4%	-14.6%	60.1%	165.1%
Split Adjusted EPS					$ 6.98	$ 10.86	$ 18.86	$ 23.68	$ 21.38	$ 17.90	$ 28.08	$ 63.35
YoY Growth						55.6%	73.7%	25.6%	-9.7%	-16.3%	56.9%	125.6%
Forward Split Adjusted P/E						8.3x	4.8x	3.8x	4.2x	5.0x	3.2x	1.4x
Split Adjusted IPO Price						$ 90						

NTD Billion	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Net Sales	NTD 125.9	NTD 162.3	NTD 203.0	NTD 257.2	NTD 266.6	NTD 317.4	NTD 322.6	NTD 333.2	NTD 295.7	NTD 419.5	NTD 427.1	NTD 506.2
YoY Growth	-24.3%	28.9%	25.1%	26.7%	3.6%	19.1%	1.6%	3.3%	-11.2%	41.9%	1.8%	18.5%
Gross profit	NTD 33.7	NTD 52.3	NTD 74.9	NTD 115.8	NTD 118.2	NTD 155.8	NTD 142.4	NTD 141.7	NTD 129.3	NTD 207.1	NTD 194.1	NTD 243.6
Gross Margin	26.7%	32.2%	36.9%	45.0%	44.3%	49.1%	44.1%	42.5%	43.7%	49.4%	45.4%	48.1%
YoY Growth	-56.0%	55.4%	43.1%	54.7%	2.1%	31.8%	-8.6%	-0.4%	-8.8%	60.1%	-6.3%	25.5%
G&A expenses	NTD 7.9	NTD 7.0	NTD 8.2	NTD 11.5	NTD 9.1	NTD 8.7	NTD 9.0	NTD 11.1	NTD 11.3	NTD 12.8	NTD 14.2	NTD 17.6
G&A expenses as % of Sales	6.3%	4.3%	4.0%	4.5%	3.4%	2.7%	2.8%	3.3%	3.8%	3.1%	3.3%	3.5%
Selling expenses	NTD 2.3	NTD 2.0	NTD 2.7	NTD 3.4	NTD 4.1	NTD 3.8	NTD 3.7	NTD 4.7	NTD 4.5	NTD 5.4	NTD 4.5	NTD 4.5
Selling expenses as % of Sales	6.8%	3.8%	3.6%	2.9%	3.5%	2.4%	2.6%	3.3%	3.5%	2.6%	2.3%	1.8%
R&D expenses	NTD 10.6	NTD 11.7	NTD 12.7	NTD 12.5	NTD 14.0	NTD 16.1	NTD 17.9	NTD 21.5	NTD 21.6	NTD 29.7	NTD 33.8	NTD 40.4
R&D expenses as % of Sales	8.5%	7.2%	6.3%	4.9%	5.3%	5.1%	5.6%	6.4%	7.3%	7.1%	7.9%	8.0%
EBIT	NTD 12.8	NTD 31.6	NTD 51.3	NTD 88.5	NTD 91.0	NTD 127.3	NTD 111.7	NTD 104.4	NTD 92.0	NTD 159.2	NTD 141.6	NTD 181.1
EBIT Margin	10.2%	19.5%	25.3%	34.4%	34.1%	40.1%	34.6%	31.3%	31.1%	37.9%	33.1%	35.8%
YoY Growth	-79.2%	147.2%	62.4%	72.5%	2.8%	39.9%	-12.2%	-6.5%	-11.9%	73.1%	-11.1%	27.9%
Tax (Credit)	NTD (3.7)	NTD 5.6	NTD 3.9	NTD (0.4)	NTD 0.6	NTD 7.8	NTD 11.7	NTD 10.9	NTD 6.0	NTD 8.0	NTD 10.7	NTD 15.6
Effective Tax Rate	-29.3%	17.8%	7.6%	-0.4%	0.7%	6.1%	10.5%	10.5%	6.5%	5.0%	7.6%	8.6%
Net income to shareholders	NTD 14.5	NTD 21.6	NTD 47.3	NTD 92.3	NTD 93.6	NTD 127.0	NTD 109.2	NTD 99.9	NTD 89.2	NTD 161.6	NTD 134.2	NTD 166.2
Net Margin	11.5%	13.3%	23.3%	35.9%	35.1%	40.0%	33.8%	30.0%	30.2%	38.5%	31.4%	32.8%
YoY Growth	-77.7%	49.1%	118.7%	95.3%	1.4%	35.7%	-14.0%	-8.5%	-10.7%	81.1%	-17.0%	23.8%
Split Adjusted EPS	$ 12.89	$ 19.48	$ 43.00	$ 83.58	$ 83.78	$ 112.24	$ 94.73	$ 88.08	$ 79.50	$ 143.99	$ 119.72	$ 148.15
YoY Growth	-79.6%	51.1%	120.7%	94.4%	0.2%	34.0%	-15.6%	-7.0%	-9.7%	81.1%	-16.9%	23.7%
Forward Split Adjusted P/E	7.0x	4.6x	2.1x	1.1x	1.1x	0.8x	1.0x	1.0x	1.1x	0.6x	0.8x	0.6x

NTD Billion	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Net Sales	NTD 597.0	NTD 762.8	NTD 843.5	NTD 947.9	NTD 977.4	NTD 1,031.5	NTD 1,070.0	NTD 1,339.3	NTD 1,587.4	NTD 2,263.9	NTD 2,161.7
YoY Growth	17.9%	27.8%	10.6%	12.4%	3.1%	5.5%	3.7%	25.2%	18.5%	42.6%	-4.5%
Gross profit	NTD 280.9	NTD 377.7	NTD 410.4	NTD 474.8	NTD 494.8	NTD 497.9	NTD 492.7	NTD 711.1	NTD 819.5	NTD 1,348.4	NTD 1,175.1
Gross Margin	47.1%	49.5%	48.7%	50.1%	50.6%	48.3%	46.0%	53.1%	51.6%	59.6%	54.4%
YoY Growth	15.3%	34.5%	8.6%	15.7%	4.2%	0.6%	-1.0%	44.3%	15.2%	64.5%	-12.8%
G&A expenses	NTD 18.9	NTD 18.9	NTD 17.3	NTD 19.8	NTD 21.2	NTD 20.3	NTD 21.7	NTD 28.5	NTD 36.9	NTD 53.5	NTD 60.9
G&A expenses as % of Sales	3.2%	2.5%	2.0%	2.1%	2.2%	2.0%	2.0%	2.1%	2.3%	2.4%	2.8%
Selling expenses	NTD 4.5	NTD 5.1	NTD 5.7	NTD 6.0	NTD 6.0	NTD 6.0	NTD 6.3	NTD 7.1	NTD 7.6	NTD 9.9	NTD 10.6
Selling expenses as % of Sales	1.6%	1.3%	1.4%	1.3%	1.2%	1.2%	1.3%	1.0%	0.9%	0.7%	0.9%
R&D expenses	NTD 48.1	NTD 56.8	NTD 65.5	NTD 71.2	NTD 80.7	NTD 85.9	NTD 91.4	NTD 109.5	NTD 124.7	NTD 163.3	NTD 182.4
R&D expenses as % of Sales	8.1%	7.4%	7.8%	7.5%	8.3%	8.3%	8.5%	8.2%	7.9%	7.2%	8.4%
EBIT	NTD 209.4	NTD 295.9	NTD 320.0	NTD 377.9	NTD 385.6	NTD 383.6	NTD 372.7	NTD 566.8	NTD 650.0	NTD 1,121.3	NTD 921.5
EBIT Margin	35.1%	38.8%	37.9%	39.9%	39.4%	37.2%	34.8%	42.3%	40.9%	49.5%	42.6%
YoY Growth	15.7%	41.3%	8.2%	18.1%	2.0%	-0.5%	-2.8%	52.1%	14.7%	72.5%	-17.8%
Tax (Credit)	NTD 27.5	NTD 38.3	NTD 43.9	NTD 51.6	NTD 53.0	NTD 46.3	NTD 44.5	NTD 66.6	NTD 66.1	NTD 127.3	NTD 141.4
Effective Tax Rate	13.1%	12.9%	13.7%	13.7%	13.7%	12.1%	11.9%	11.8%	10.2%	11.4%	15.3%
Net income to shareholders	NTD 188.1	NTD 263.9	NTD 306.6	NTD 334.2	NTD 343.1	NTD 351.1	NTD 345.3	NTD 517.9	NTD 596.5	NTD 1,016.5	NTD 838.5
Net Margin	31.5%	34.6%	36.3%	35.3%	35.1%	34.0%	32.3%	38.7%	37.6%	44.9%	38.8%
YoY Growth	13.2%	40.3%	16.2%	9.0%	2.7%	2.3%	-1.7%	50.0%	15.2%	70.4%	-17.5%
Split Adjusted EPS	$ 167.79	$ 235.28	$ 273.18	$ 297.91	$ 305.77	$ 312.94	$ 307.85	$ 461.54	$ 531.81	$ 905.99	$ 747.44
YoY Growth	13.3%	40.2%	16.1%	9.1%	2.6%	2.3%	-1.6%	49.9%	15.2%	70.4%	-17.5%
Forward Split Adjusted P/E	0.5x	0.4x	0.3x	0.3x	0.3x	0.3x	0.3x	0.2x	0.2x	0.1x	0.1x

Notes:

1. Sales in 1987 are provided in *Morris Chang: An Autobiography. Part II*. In the first year of TSMC's founding, it had sales of $4 million, with operating losses of $5.4 million, with 100% sales from Taiwan.[107]
2. TSMC issued stock dividends annually from fiscal years 1994 to 2008. During this period, the company distributed stock dividends for each common share as follows: 0.8 shares, 0.8 shares, 0.5 shares, 0.45 shares, 0.23 shares, 0.28

[107] Translated or rephrased by the author on a best effort basis. Chapter 19. Morris Chang: An Autobiography. Part II.

shares, 0.4 shares, 0.1 shares, 0.08 shares, 0.14 shares, 0.05 shares, 0.03 shares, 0.005 shares, 0.005 shares, and 0.005 shares, respectively.[108]

Figure 10-2: TSMC Balance Sheet

NTD Billion	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Cash and cash equivalents	NTD 2.1	NTD 3.5	NTD 8.7	NTD 18.7	NTD 17.9	NTD 15.6	NTD 18.6	NTD 41.2	NTD 39.0	NTD 68.0	NTD 116.6
Accounts receivable	NTD 2.1	NTD 3.1	NTD 5.0	NTD 5.2	NTD 10.1	NTD 8.2	NTD 13.8	NTD 31.4	NTD 20.6	NTD 20.0	NTD 29.6
Allowance	NTD (0.3)	NTD (0.4)	NTD (0.6)	NTD (0.6)	NTD (0.8)	NTD (0.7)	NTD (1.1)	NTD (3.4)	NTD (3.7)	NTD (3.3)	NTD (3.2)
Inventories	NTD 1.1	NTD 1.2	NTD 2.1	NTD 2.8	NTD 4.9	NTD 4.1	NTD 5.8	NTD 12.8	NTD 9.8	NTD 11.2	NTD 12.1
Prepayments and other current assets	NTD 0.1	NTD 0.2	NTD 0.9	NTD 0.7	NTD 2.3	NTD 1.4	NTD 4.7	NTD 11.2	NTD 5.1	NTD 6.7	NTD 11.4
Current Assets	**NTD 5.1**	**NTD 7.7**	**NTD 16.1**	**NTD 26.7**	**NTD 34.3**	**NTD 28.5**	**NTD 41.7**	**NTD 93.2**	**NTD 70.8**	**NTD 102.5**	**NTD 166.5**
Long-term investments	NTD 0.2	NTD 3.1	NTD 5.0	NTD 6.7	NTD 7.2	NTD 6.7	NTD 16.2	NTD 9.8	NTD 11.6	NTD 10.6	NTD 10.7
PP&E, net	NTD 10.4	NTD 15.0	NTD 26.6	NTD 43.6	NTD 79.1	NTD 98.7	NTD 120.7	NTD 244.7	NTD 251.3	NTD 246.5	NTD 211.9
Other assets	NTD 0.3	NTD 0.4	NTD 0.6	NTD 2.0	NTD 4.0	NTD 6.9	NTD 5.2	NTD 23.1	NTD 32.8	NTD 30.9	NTD 18.3
Total assets	**NTD 16.0**	**NTD 26.1**	**NTD 48.3**	**NTD 78.9**	**NTD 124.6**	**NTD 140.8**	**NTD 183.7**	**NTD 370.9**	**NTD 366.5**	**NTD 390.5**	**NTD 407.4**
Short-term debt	NTD 0.0	NTD -	NTD -	NTD -	NTD 0.3	NTD -	NTD -	NTD 3.8	NTD 6.3	NTD 0.7	NTD 0.4
Accounts payable	NTD 1.3	NTD 2.1	NTD 3.9	NTD 4.3	NTD 3.3	NTD 2.3	NTD 4.0	NTD 11.1	NTD 2.4	NTD 6.9	NTD 9.7
Payables to contractors and equipment suppliers					NTD 10.1	NTD 3.6	NTD 8.7	NTD 25.6	NTD 12.9	NTD 14.1	NTD 7.2
Current portion of long-term debt	NTD 0.2	NTD 0.1	NTD -	NTD -	NTD -	NTD 0.3	NTD -	NTD 0.1	NTD 5.0	NTD 12.1	NTD 5.0
Accrued expenses and other	NTD 0.5	NTD 0.7	NTD 1.2	NTD 1.3	NTD 1.6	NTD 2.6	NTD 3.6	NTD 6.9	NTD 6.7	NTD 6.5	NTD 8.8
Current liabilities	**NTD 2.0**	**NTD 2.9**	**NTD 5.1**	**NTD 5.6**	**NTD 15.3**	**NTD 8.8**	**NTD 16.2**	**NTD 47.4**	**NTD 33.3**	**NTD 40.4**	**NTD 31.1**
Long-term debt	NTD 2.5	NTD 3.3	NTD 5.6	NTD 5.7	NTD 20.0	NTD 31.3	NTD 33.0	NTD 52.3	NTD 46.4	NTD 46.1	NTD 38.8
Other liabilities	NTD 0.3	NTD 1.1	NTD 4.1	NTD 9.9	NTD 9.0	NTD 7.0	NTD 6.2	NTD 9.0	NTD 9.5	NTD 8.2	NTD 8.1
Total liabilities	**NTD 4.9**	**NTD 7.3**	**NTD 14.7**	**NTD 21.2**	**NTD 44.3**	**NTD 47.0**	**NTD 55.4**	**NTD 108.8**	**NTD 89.2**	**NTD 94.6**	**NTD 78.1**
Shareholders' equity	NTD 11.1	NTD 18.8	NTD 33.6	NTD 52.1	NTD 69.4	NTD 84.1	NTD 120.8	NTD 261.8	NTD 277.2	NTD 295.9	NTD 329.2
Minority interest	NTD -	NTD -	NTD -	NTD 5.6	NTD 10.8	NTD 9.7	NTD 7.5	NTD 0.3	NTD 0.1	NTD 0.1	NTD 0.1
Total liabilities and shareholders' equity	**NTD 16.0**	**NTD 26.1**	**NTD 48.3**	**NTD 78.9**	**NTD 124.6**	**NTD 140.8**	**NTD 183.7**	**NTD 370.9**	**NTD 366.5**	**NTD 390.5**	**NTD 407.4**

NTD Billion	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Cash and cash equivalents	NTD 128.4	NTD 143.9	NTD 195.1	NTD 174.8	NTD 211.5	NTD 195.8	NTD 181.6	NTD 150.6	NTD 150.9	NTD 245.3	NTD 436.9
Accounts receivable	NTD 31.9	NTD 43.8	NTD 35.2	NTD 47.2	NTD 25.0	NTD 44.7	NTD 51.0	NTD 46.5	NTD 58.6	NTD 71.9	NTD 115.0
Allowance	NTD (4.3)	NTD (5.3)	NTD (3.6)	NTD (4.8)	NTD (6.5)	NTD (9.3)	NTD (8.1)	NTD (5.6)	NTD (6.5)	NTD -	NTD -
Inventories	NTD 15.6	NTD 17.7	NTD 21.4	NTD 23.9	NTD 14.9	NTD 20.9	NTD 28.4	NTD 24.8	NTD 37.8	NTD 37.5	NTD 66.3
Prepayments and other current assets	NTD 12.9	NTD 12.2	NTD 12.2	NTD 8.7	NTD 7.8	NTD 7.7	NTD 8.6	NTD 8.8	NTD 11.4	NTD 3.7	NTD 8.3
Current Assets	**NTD 184.4**	**NTD 212.3**	**NTD 260.3**	**NTD 249.8**	**NTD 252.6**	**NTD 259.8**	**NTD 261.5**	**NTD 225.3**	**NTD 252.3**	**NTD 358.5**	**NTD 626.6**
Long-term investments	NTD 38.1	NTD 42.4	NTD 53.9	NTD 36.5	NTD 40.0	NTD 37.8	NTD 39.8	NTD 34.5	NTD 65.8	NTD 89.2	NTD 30.1
PP&E, net	NTD 258.9	NTD 244.8	NTD 254.1	NTD 260.3	NTD 243.6	NTD 273.7	NTD 388.4	NTD 490.4	NTD 617.5	NTD 792.7	NTD 818.2
Other assets	NTD 18.0	NTD 20.0	NTD 19.2	NTD 24.3	NTD 22.7	NTD 23.4	NTD 29.2	NTD 24.2	NTD 19.4	NTD 22.7	NTD 20.3
Total assets	**NTD 499.5**	**NTD 519.5**	**NTD 587.5**	**NTD 570.9**	**NTD 558.9**	**NTD 594.7**	**NTD 718.9**	**NTD 774.3**	**NTD 955.0**	**NTD 1,263.1**	**NTD 1,495.1**
Short-term debt	NTD 0.4	NTD 0.3	NTD -	NTD -	NTD -	NTD -	NTD 31.2	NTD 25.9	NTD 34.7	NTD 15.6	NTD 36.2
Accounts payable	NTD 9.5	NTD 11.2	NTD 9.8	NTD 13.1	NTD 6.0	NTD 11.7	NTD 13.0	NTD 11.9	NTD 15.2	NTD 16.4	NTD 23.4
Payables to contractors and equipment suppliers	NTD 33.4	NTD 9.1	NTD 10.8	NTD 6.3	NTD 8.0	NTD 28.9	NTD 43.3	NTD 35.5	NTD 44.8	NTD 89.8	NTD 27.0
Current portion of long-term debt	NTD 10.5	NTD 0.0	NTD 7.0	NTD 0.3	NTD 8.2	NTD 0.9	NTD 0.2	NTD 4.6	NTD 0.1	NTD -	NTD -
Accrued expenses and other	NTD 10.1	NTD 14.6	NTD 19.3	NTD 29.1	NTD 34.5	NTD 37.6	NTD 35.5	NTD 39.1	NTD 47.5	NTD 68.0	NTD 114.5
Current liabilities	**NTD 63.9**	**NTD 35.1**	**NTD 46.9**	**NTD 48.7**	**NTD 56.8**	**NTD 79.1**	**NTD 123.2**	**NTD 117.0**	**NTD 142.4**	**NTD 189.8**	**NTD 201.0**
Long-term debt	NTD 21.4	NTD 20.2	NTD 13.2	NTD 14.2	NTD 5.9	NTD 11.4	NTD 4.8	NTD 19.6	NTD 81.4	NTD 210.8	NTD 0.2
Other liabilities	NTD 15.1	NTD 18.0	NTD 18.3	NTD 17.3	NTD 15.8	NTD 5.1	NTD 12.2	NTD 5.6	NTD 5.5	NTD 14.7	NTD 248.2
Total liabilities	**NTD 100.4**	**NTD 73.3**	**NTD 78.3**	**NTD 80.2**	**NTD 78.5**	**NTD 95.6**	**NTD 140.2**	**NTD 142.2**	**NTD 229.3**	**NTD 415.3**	**NTD 449.5**
Shareholders' equity	NTD 399.0	NTD 445.6	NTD 508.0	NTD 487.1	NTD 476.4	NTD 495.1	NTD 574.1	NTD 629.6	NTD 723.2	NTD 847.5	NTD 1,045.5
Minority interest	NTD 0.1	NTD 0.6	NTD 1.2	NTD 3.6	NTD 4.0	NTD 4.0	NTD 4.6	NTD 2.5	NTD 2.6	NTD 0.3	NTD 0.1
Total liabilities and shareholders' equity	**NTD 499.5**	**NTD 519.5**	**NTD 587.5**	**NTD 570.9**	**NTD 558.9**	**NTD 594.7**	**NTD 718.9**	**NTD 774.3**	**NTD 955.0**	**NTD 1,263.1**	**NTD 1,495.1**

NTD Billion	2015	2016	2017	2018	2019	2020	2021	2022	2023
Cash and cash equivalents	NTD 586.2	NTD 632.1	NTD 649.3	NTD 695.2	NTD 583.4	NTD 791.5	NTD 1,188.4	NTD 1,561.5	NTD 1,687.6
Accounts receivable	NTD 85.6	NTD 129.3	NTD 122.3	NTD 129.2	NTD 139.8	NTD 146.0	NTD 198.3	NTD 231.3	NTD 201.9
Allowance	NTD -	NTD -	NTD -	NTD -	NTD -	NTD -	NTD -	NTD -	
Inventories	NTD 67.1	NTD 48.7	NTD 73.9	NTD 103.2	NTD 83.0	NTD 137.4	NTD 193.1	NTD 221.1	NTD 251.0
Prepayments and other current assets	NTD 8.0	NTD 7.6	NTD 11.7	NTD 24.1	NTD 16.4	NTD 17.3	NTD 27.2	NTD 38.9	NTD 53.5
Current Assets	**NTD 746.7**	**NTD 817.7**	**NTD 857.2**	**NTD 951.7**	**NTD 822.6**	**NTD 1,092.2**	**NTD 1,607.1**	**NTD 2,052.9**	**NTD 2,194.0**
Long-term investments	NTD 35.0	NTD 46.2	NTD 41.6	NTD 29.3	NTD 30.2	NTD 27.7	NTD 29.4	NTD 68.9	NTD 129.4
PP&E, net	NTD 853.5	NTD 997.8	NTD 1,062.5	NTD 1,072.1	NTD 1,352.4	NTD 1,555.6	NTD 1,975.1	NTD 2,693.8	NTD 3,064.5
Other assets	NTD 22.3	NTD 24.8	NTD 30.5	NTD 37.1	NTD 59.6	NTD 85.2	NTD 113.9	NTD 149.1	NTD 144.4
Total assets	**NTD 1,657.5**	**NTD 1,886.5**	**NTD 1,991.9**	**NTD 2,090.1**	**NTD 2,264.8**	**NTD 2,760.7**	**NTD 3,725.5**	**NTD 4,964.8**	**NTD 5,532.4**
Short-term debt	NTD 39.5	NTD 58.0	NTD 63.8	NTD 88.8	NTD 118.5	NTD 88.6	NTD 114.9	NTD -	NTD -
Accounts payable	NTD 19.7	NTD 27.3	NTD 30.1	NTD 34.4	NTD 40.2	NTD 41.1	NTD 48.7	NTD 56.5	NTD 57.3
Payables to contractors and equipment suppliers	NTD 26.0	NTD 63.2	NTD 55.7	NTD 43.1	NTD 140.8	NTD 157.8	NTD 145.7	NTD 213.5	NTD 171.5
Current portion of long-term debt	NTD 23.5	NTD 38.1	NTD 58.4	NTD 34.9	NTD 31.8	NTD 2.6	NTD 4.6	NTD 19.3	NTD 9.3
Accrued expenses and other	NTD 103.5	NTD 131.7	NTD 150.7	NTD 139.4	NTD 259.4	NTD 327.1	NTD 425.6	NTD 654.9	NTD 675.5
Current liabilities	**NTD 212.2**	**NTD 318.2**	**NTD 358.7**	**NTD 340.5**	**NTD 590.7**	**NTD 617.2**	**NTD 739.5**	**NTD 944.2**	**NTD 913.6**
Long-term debt	NTD 192.0	NTD 153.1	NTD 91.8	NTD 56.9	NTD 25.1	NTD 256.1	NTD 613.4	NTD 839.1	NTD 918.3
Other liabilities	NTD 30.7	NTD 25.0	NTD 18.6	NTD 15.2	NTD 26.9	NTD 36.9	NTD 201.9	NTD 221.0	NTD 217.2
Total liabilities	**NTD 434.9**	**NTD 496.4**	**NTD 469.1**	**NTD 412.6**	**NTD 642.7**	**NTD 910.1**	**NTD 1,554.8**	**NTD 2,004.3**	**NTD 2,049.1**
Shareholders' equity	NTD 1,221.7	NTD 1,389.2	NTD 1,522.1	NTD 1,676.8	NTD 1,621.4	NTD 1,849.7	NTD 2,168.3	NTD 2,945.7	NTD 3,458.9
Minority interest	NTD 1.0	NTD 0.8	NTD 0.7	NTD 0.7	NTD 0.7	NTD 1.0	NTD 2.4	NTD 14.8	NTD 24.3
Total liabilities and shareholders' equity	**NTD 1,657.5**	**NTD 1,886.5**	**NTD 1,991.9**	**NTD 2,090.1**	**NTD 2,264.8**	**NTD 2,760.7**	**NTD 3,725.5**	**NTD 4,964.8**	**NTD 5,532.4**

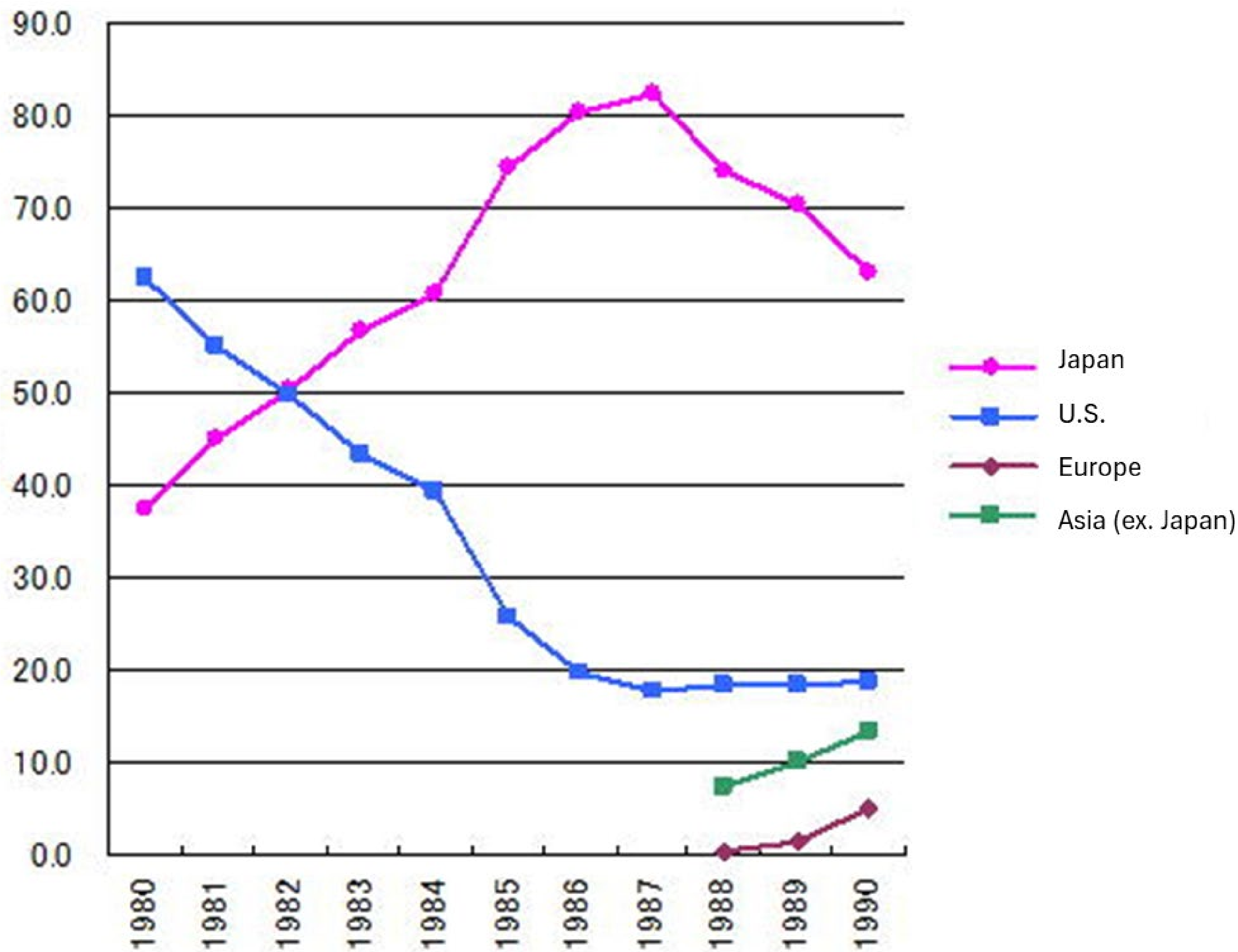
[108] Dividend History. https://investor.tsmc.com/english/dividends

Industry Overview

In the 1980s, Japan's semiconductor industry experienced rapid development, surpassing the U.S. in 1986 to become the world's largest supplier of semiconductors.[109] **Japanese manufacturers focused on quality, stable supplies, and competitive pricing achieved through active investment.** This approach significantly elevated the reputation of Japanese semiconductor products. Many U.S. electronics companies adopted Japanese semiconductors, particularly DRAMs. In consumer electronics, products such as VCRs, CDs, and video game machines gained widespread popularity. During this period, Japanese manufacturers led the global market in consumer electronics, fueling strong demand for its semiconductors.

As the U.S. computer industry's demand for DRAMs surged, American computer manufacturers increasingly turned to Japanese DRAMs, known for their superior quality. By 1981, Japanese manufacturers had captured the majority market share in 64K DRAMs, and **by 1987, they dominated 80% of the overall DRAM market**,[110] primarily with 256K DRAMs. Japanese DRAMs were acclaimed for their advancements in design and process technologies, as well as their high-quality, reliable delivery, and competitive pricing.

Figure 11: Global Market Share of DRAM Sales, Percentage, 1980 – 1990[111]



[109] Trends in The Semiconductor Industry 1980s. Semiconductor History Museum of Japan. https://www.shmj.or.jp/english/trends/trd80s.html
[110] Trends in The Semiconductor Industry 1980s. Semiconductor History Museum of Japan. https://www.shmj.or.jp/english/trends/trd80s.html
[111] Trends in The Semiconductor Industry 1980s. Semiconductor History Museum of Japan. https://www.shmj.or.jp/english/trends/trd80s.html

In 1977, U.S. corporate executives, who were principal stakeholders in the semiconductor industry, established the Semiconductor Industry Association (SIA) to lobby against Japan, citing issues of dumping and restricted market access to foreign companies.[112] This marked the beginning of the "semiconductor war" between the two nations. By 1985, most U.S. semiconductor producers, with the exception of Texas Instruments and Micron, had exited the DRAM market. Many companies abandoned DRAM production to focus on other product lines. Leading U.S. firms such as Micron, Intel, and AMD filed antidumping complaints against Japanese exporters. In December 1985, the U.S. Commerce Department initiated an antidumping investigation into 256K DRAMs and other future generations of DRAMs from Japan. In addition, the SIA filed a Section 301[113] petition with the U.S. Trade Representative, alleging unfair market barriers in Japan. Reports revealed that U.S. semiconductor producers accounted for over 83% of sales in the U.S., 55% in Europe, 47% in other global markets, but only 11% in Japan. In response, the U.S. – Japan Semiconductor Trade Agreement was signed in 1986. This five-year agreement (later extended to 1996[114]) aimed to end dumping practices and open Japan's semiconductor market to foreign companies, targeting a 20% foreign market share within five years. Despite this, Japan's compliance faced challenges. Entering the 1990s, while Japan continued its dispute with the U.S. with international trading authorities such as Gevena secretariat of the General Agreement on Tariffs and Trade,[115] the country started to enter into a recession. By 1991, foreign companies held only 14% to 15% of Japan's semiconductor market share, predominantly American firms. To avoid sanctions, Japan agreed in 1992 to purchase more semiconductors from the U.S. and to provide American and other foreign suppliers with advance information on semiconductor demand from its largest electronics companies, including Hitachi, Toshiba, and Sony.[116]

The Japanese semiconductor industry struggled under the constraints of the U.S. – Japan Semiconductor Trade Agreement until it expired in 1996.[117] Meanwhile, South Korean and Taiwanese manufacturers entered the global market, further eroding Japan's dominance. By 1993, the U.S. had reclaimed the top position in the global semiconductor market, holding a 43% share, while Japan's share fell to 40%, as Figures 12-1 and 12-2 show. Intel emerged as the leading manufacturer, achieving remarkable success with its CPUs. We estimated that with its $8.8 billion sales in 1993,[118] Intel occupied an 11% global market share of all semiconductors, or 74% of the microprocessor (MPU) segment.[119] Concurrently, South Korean and Taiwanese companies expanded their capabilities, securing a combined 10% share of the global market of semiconductor by 1994, matching Europe's share. By the late 1990s, Japan's market share had dropped to 28%, largely due to the success of U.S. firms and the rise of South Korean and Taiwanese manufacturers.

The advent of fabless semiconductor companies further disrupted the industry, particularly within the integrated circuit segment. U.S.-based companies such as Qualcomm and Broadcom outsourced chip manufacturing to foundries such as TSMC and UMC. This collaboration between design-focused firms and specialized manufacturers outperformed Japan's traditional integrated device manufacturer (IDM) model,[120] which encompassed all stages of production from design to fabrication.

Before TSMC's founding, nearly all integrated circuit (IC) companies operated as IDMs (Integrated Device Manufacturers), managing everything from IC design and wafer fabrication to process node development and marketing.[121] The

---

[112] The U.S. – Japan Semiconductor Trade Conflict. Douglas Irvin. University of Chicago.

[113] Section 301 of the Trade Act of 1974 grants the Office of the United States Trade Representative (USTR) a range of responsibilities and authorities to investigate and take action to enforce U.S. rights under trade agreements and respond to certain foreign trade practices. Section 301 of the Trade Act of 1974

[114] The Japan-U.S. Semiconductor Agreement - Ministry of Foreign Affairs of Japan. https://www.mofa.go.jp/region/n-america/us/q&a/agree/1.html#:~:text=It%20has%20been%20almost%20a%20decade%20since%20the%20Japan%2DUnited%20States%20Semiconductor%20Arrangement%20was&text=expire%20at%20the%20end%20of%20July%201996.

[115] Japan Buys Too Few Chips, U.S. Finds. The New York Times. https://www.nytimes.com/1992/08/03/business/japan-buys-too-few-chips-us-finds.html

[116] New U.S.-Japan Accord on Semiconductors. The New York Times. https://www.nytimes.com/1992/06/05/business/new-us-japan-accord-on-semiconductors.html

[117] Trends in the Semiconductor Industry 1990s. Semiconductor History Museum of Japan. https://www.shmj.or.jp/english/trends/trd90s.html

[118] Intel Annual Report 1993.

[119] Intel Market Share Rises. The New York Times. https://web.archive.org/web/20210727131056/https://www.nytimes.com/1994/02/21/business/intel-market-share-rises.html

[120] In the semiconductor industry, companies are categorized based on their roles in the production process. An Integrated Device Manufacturer (IDM) manages every step, from planning and design to manufacturing and sales. A Foundry focuses solely on production, while a Fabless company specializes in designing semiconductors without owning production facilities.

[121] Translated or rephrased by the author on a best effort basis. Chapter 16. Morris Chang: An Autobiography. Part II.

emergence of the fabless model introduced greater flexibility, allowing companies to adapt more quickly to rapidly changing market trends.

Between 1992 and 1994, the global semiconductor market surged from $60 billion to $144 billion, driven largely by the booming Windows PC market.[122] As the 2000s began, the growing demand for mobile phones further accelerated semiconductor growth, even as personal computers continued their upward trajectory. IDMs, however, faced challenges transitioning from producing computer chips to smartphone chips or shifting focus from general-purpose processors to graphics processors. A notable example occurred in 2016, when Intel announced plans to lay off approximately 11% of its workforce – a move interpreted by the market as a struggle to adapt to the post-PC era. By that time, most mobile devices, including iPhones, iPads, and Android phones, relied on chips based on ARM architecture, known for its superior power efficiency – an essential trait for mobile devices.[123] While Intel's x86 architecture, which was created by Intel in 1981 and is still in use today,[124] remained dominant in PC world for power-intensive applications such as gaming and data analysis, it lagged in mobile applications due to higher power consumption. [125] By 2006, approximately 98% of mobile phones powered by ARM-designed processors.[126] Today, around 99% of premium smartphones are powered by ARM processors.[127]

In contrast to IDMs, fabless companies flourished by focusing exclusively on design, outsourcing manufacturing based on market demand, and leaving production complexities to foundries. This model allowed them to thrive in a fast-evolving technological landscape.

Japan's resistance to the fabless model, coupled with trade tensions with the U.S. and a prolonged economic recession, led to a decline in its competitive edge in the semiconductor industry. Morris Chang, the founder of TSMC, observed during a 2007 visit to Japan that the country lacked fabless companies and showed little interest in adopting the model.[128] Instead, Japanese firms sought government support to build their own foundries – an approach Chang deemed outdated and counterproductive. By 2023, Japan's global semiconductor market share had dwindled to 9%, while the U.S. maintained nearly 50% since the late 1990s.

---

[122] OECD Digital Economy Outlook 2015. OECD. Trends in the Semiconductor Industry 1990s. Semiconductor History Museum of Japan. https://www.shmj.or.jp/english/trends/trd90s.html

[123] ARM vs x86 - Understanding the Differences in Computer Architecture. https://blog.acer.com/en/discussion/1639/arm-vs-x86-understanding-the-differences-in-computer-architecture#:~:text=ARM's%20architecture%20offers%20excellent%20power,ARM%20Processors%20Pros

[124] U.S. Chipmaker Intel Was Once Dominant, Now Struggles to Stay Relevant. CNBC. https://www.cnbc.com/2024/04/26/intel-dominated-us-chip-industry-now-struggling-to-stay-relevant.html#:~:text=Processors%20get%20faster%20with%20more,1%2C000%20times%20smaller%20than%20micrometers

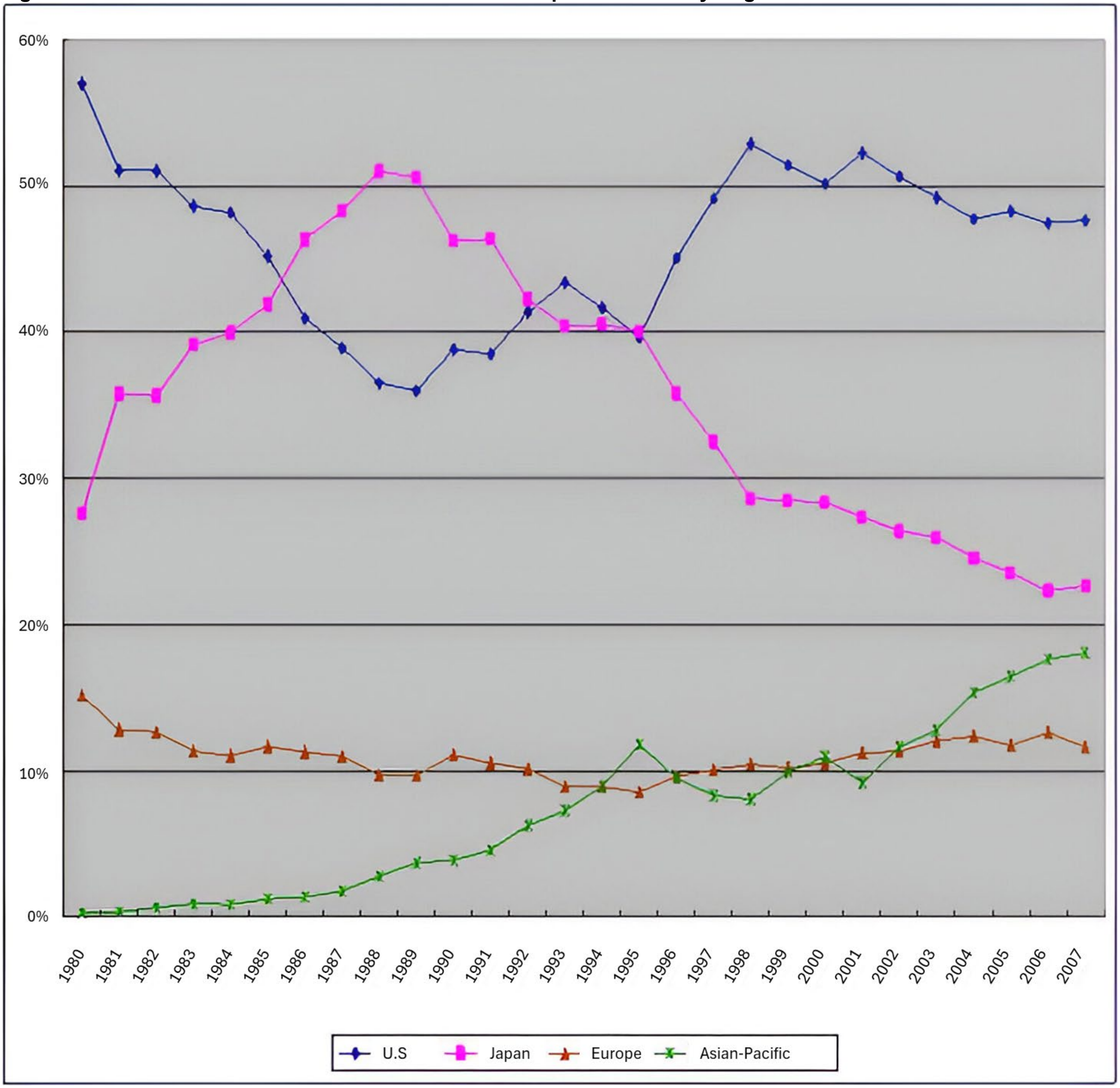
[125] ARM vs x86 - Understanding the Differences in Computer Architecture. https://blog.acer.com/en/discussion/1639/arm-vs-x86-understanding-the-differences-in-computer-architecture#:~:text=ARM's%20architecture%20offers%20excellent%20power,ARM%20Processors%20Pros

[126] ARMed for The Living Room. https://www.cnet.com/tech/tech-industry/armed-for-the-living-room/

[127] Smartphones – Arm. https://www.arm.com/markets/consumer-technologies/smartphones#:~:text=Arm%20CPUs%20are%20the%20leading,smartphones%20are%20powered%20by%20Arm.&text=Arm%20GPUs%20deliver%20first%2Drate%20performance%20and%20efficiency%20for%20smartphones.

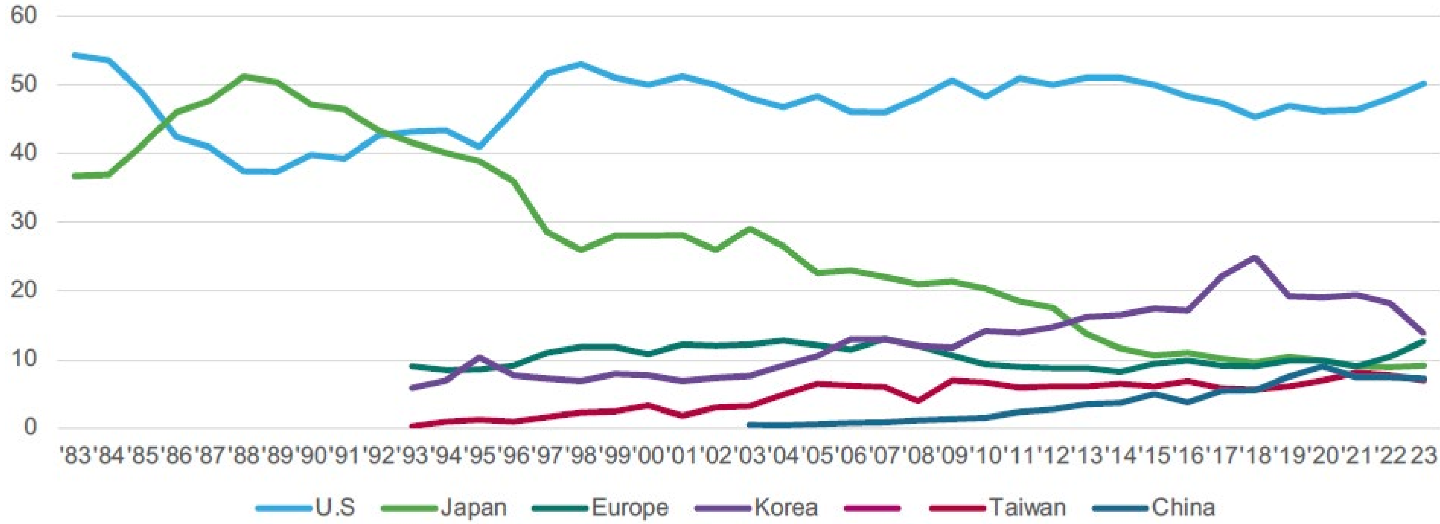
[128] Translated or rephrased by the author on a best effort basis. Chapter 20. Morris Chang: An Autobiography. Part II.

Figure 12-1: World Market Share of Semiconductor Companies' Sales by Region 1980 – 2007[129]



[129] Trends in the Semiconductor Industry 1970s. Semiconductor History Museum of Japan. https://www.shmj.or.jp/english/trends/trd70s.html

Figure 12-2: Global Market Share of Semiconductor Industry By Region 1983 – 2023[130]



In September 1993, a year before TSMC's IPO, the Office of Technology Assessment at the U.S. Congress published *Contributions of DOE Weapons Labs and NIST to Semiconductor*. The report stated that, as of 1992, worldwide semiconductor sales totaled nearly $60 billion, with Japan and the U.S. accounting for 44% and 43% of the market, respectively.[131] These figures encompassed all semiconductor-based electronic components, including integrated circuits (ICs) such as microprocessors and memory chips, discrete components like transistors and diodes, and other semiconducting devices such as solar cells and photodiodes. Within the U.S. economy, integrated circuits were the most significant category, comprising 73% of total U.S. semiconductor shipments in 1991, a proportion that remained consistent over the preceding decade. Beyond their financial impact, integrated circuits, which integrate thousands of interconnected circuits onto a single chip, enabled the creation of innovative electronic products previously unimaginable with discrete components. Integrated circuits also necessitated the development of advanced production machinery and processes, exerting a transformative influence on other sectors of the U.S. economy.

The congressional report further emphasized that semiconductor technology underpins most modern electronic products, including computers, consumer electronics, communications equipment, and industrial systems. In 1992, approximately 45% of global semiconductor sales were for computers, followed by consumer electronics 21%, communications 14%, and industrial applications 10%.[132] **By 2023, the landscape had shifted such that communications (e.g., smartphones) accounted for 32% of global semiconductor sales, with computers at 25%, automotive at 17%, industrial at 14%, and consumer electronics at 11%.[133] This reflects the expanding role of semiconductors across both consumer and industrial sectors.**

---

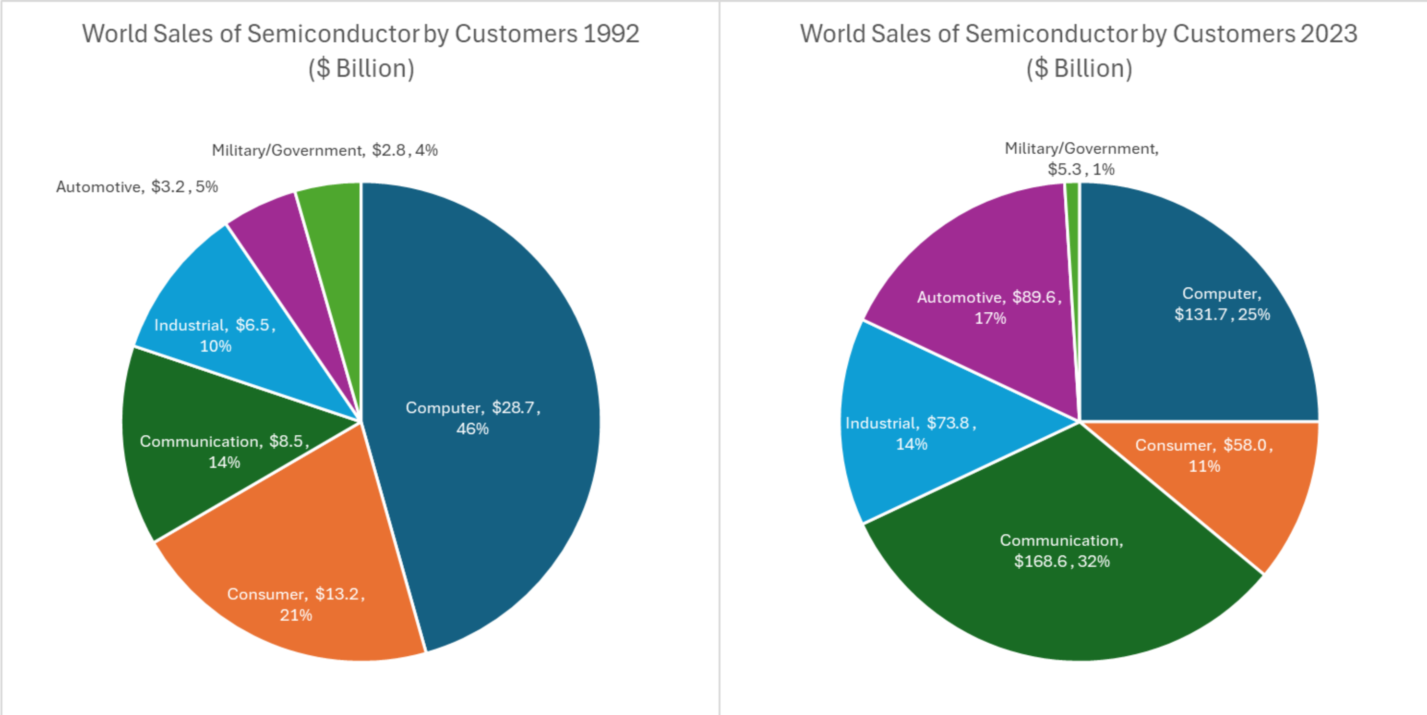
[130] SIA Factbook 2024.

[131] Contributions of DOE Weapons Labs and NIST to Semiconductor Technology. Office of Technology Assessment, U.S. Congress.

[132] Contributions of DOE Weapons Labs and NIST to Semiconductor Technology. Office of Technology Assessment, U.S. Congress.

[133] SIA Factbook 2024.

Figure 13: World Semiconductor by Customers/Applications 1992 vs. 2023[134]



Personal electronics and communication devices have significantly driven the development of semiconductors, as these components are essential for such devices to function effectively. Semiconductors enable key functionalities such as data processing, graphic rendering, internet connectivity, and device communication. Nearly all personal electronics depend on semiconductors, from devices as small as digital watches and smartphones to those as large as home appliances and HVAC systems, not to mention the underlying infrastructure that keeps many of these devices functioning properly, such as data centers and telecommunication towers.

Between 1977 and 2021, the annual global shipments of personal computing devices such as PCs, Macintosh computers, smartphones, and tablets grew remarkably, with each product category starting in different years. **For instance, the number of personal computers shipped annually increased from an estimated 20,000 units in 1977 to over 340 million units in 2021, reflecting a nearly 25% CAGR.**[135] **Similarly, Apple sold approximately 1.4 million iPhones in 2007,**[136] **the year of its launch, and shipped 234.6 million units in 2023,**[137] **achieving a 37% CAGR.** Apple's iPhone 15, one of the company's latest models, is estimated to contain nearly 30 key chips. These chips handle various functions, including power management, audio processing, motion sensing, and radio frequency operations. Furthermore, global smartphone shipments exceeded 1.17 billion units in 2023.

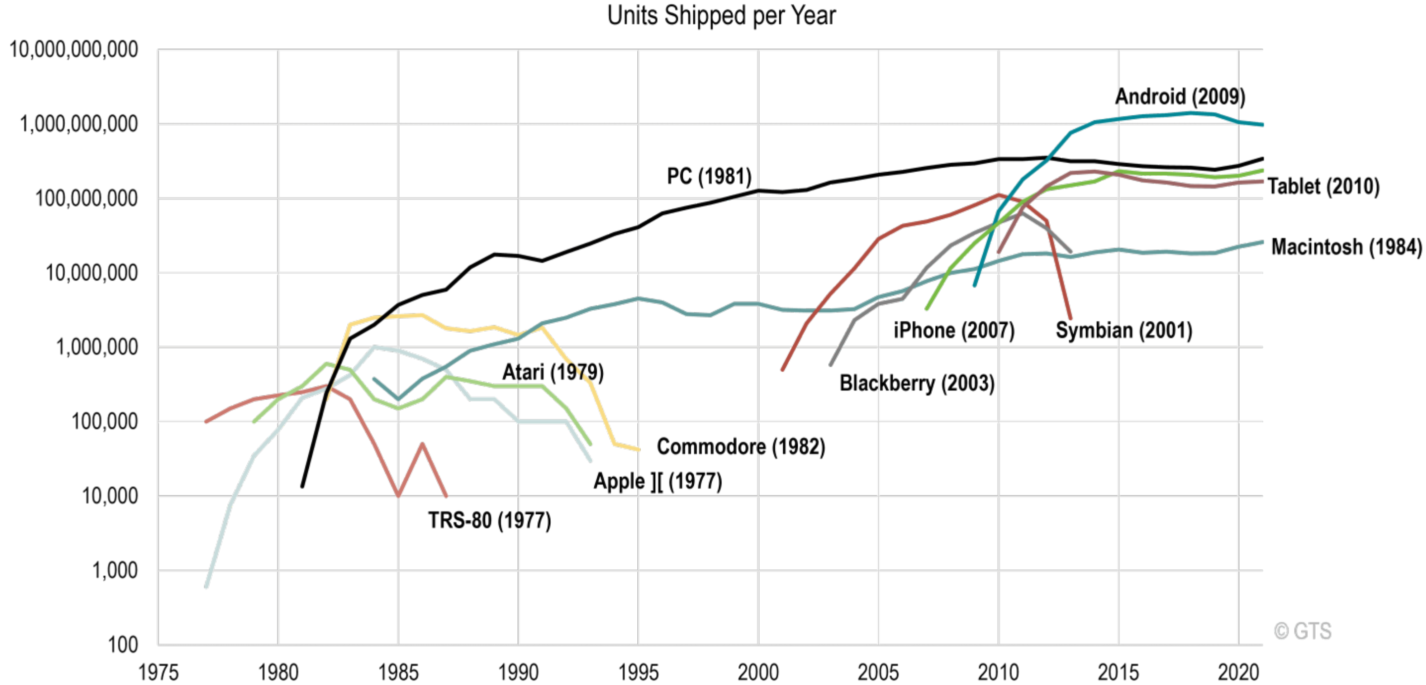
[134] Contributions of DOE Weapons Labs and NIST to Semiconductor Technology. Office of Technology Assessment, U.S. Congress.; SIA Factbook 2024.

[135] Diffusion of Personal Computing Devices. The Geography of Transport Systems. https://transportgeography.org/contents/chapter1/the-setting-of-global-transportation-systems/personal-computing-devices/

[136] How the Apple iPhone Changed the World. CNBC. https://www.cnbc.com/2024/01/27/how-the-apple-iphone-changed-the-world.html

[137] Apple Grabs the Top Spot in the Smartphone Market in 2023 along with Record High Market Share. IDC Research. https://www.idc.com/getdoc.jsp?containerId=prUS51776424

Figure 14: Diffusion of Personal Computing Devices 1977 – 2021[138]



Note:
1. The raw data of each item is not provided by the publisher.

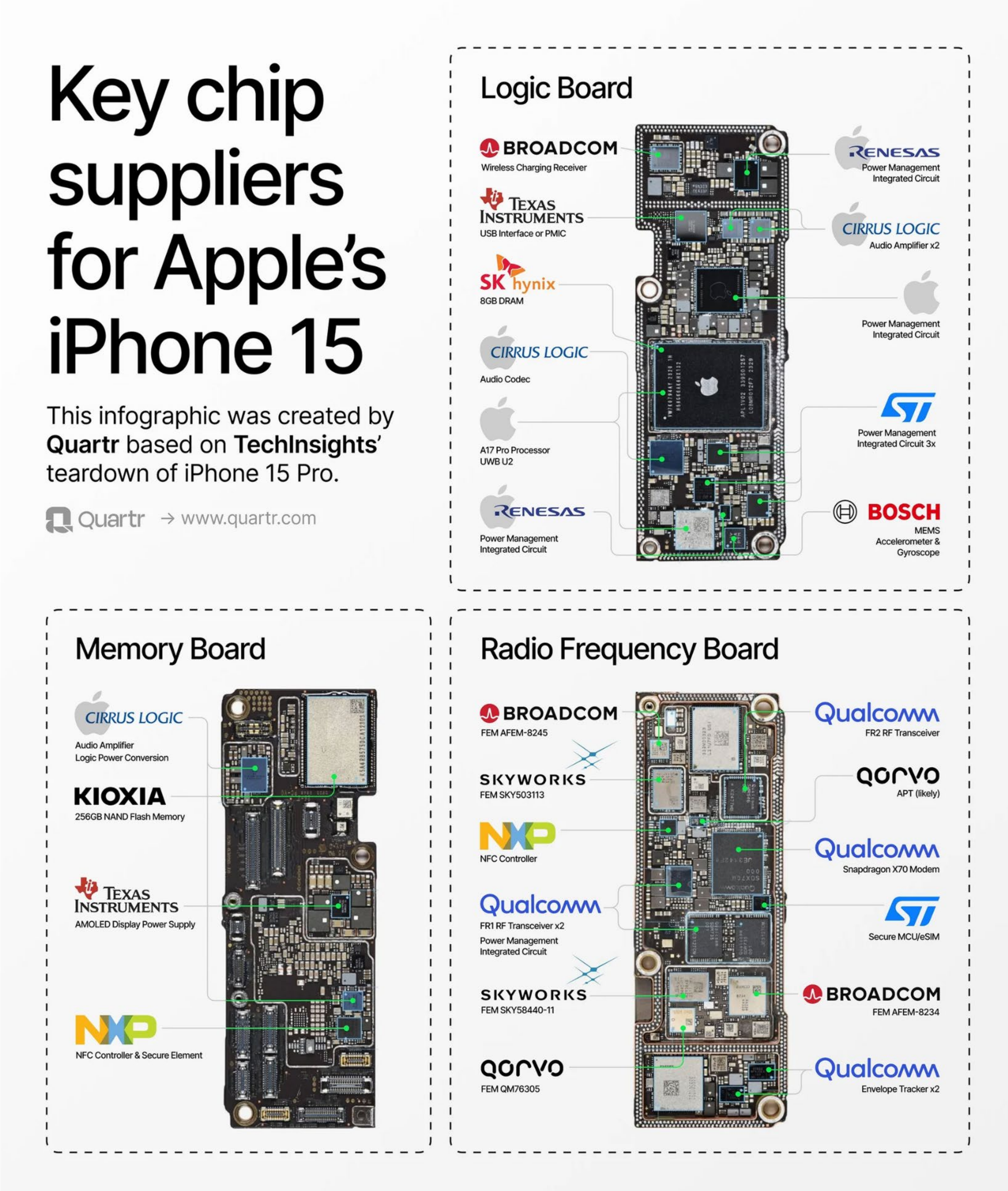
The rising variety and increasing number of consumer and commercial products are driving greater demand for chips. As products become more complex and feature-rich, the number of chips within each product tends to grow, although the exact numbers of semiconductor chips used in different devices could vary significantly depending on manufacturers. For example, a mobile phone from 20 years ago may have contained just a handful of chips to handle basic functions such as calling, texting, storage, and power management. While there is no universally agreed timeline, some point to the IBM Simon from 1994, featuring a touchscreen and the ability to fax, email, and manage a calendar, as an early smartphone.[139] Others highlight the BlackBerry, launched in 1999, which introduced a keyboard instead of traditional phone buttons. However, many also consider the modern smartphone era to have begun with the launch of the iPhone in 2007, soon followed by Android phones.

Since their debut, smartphones have steadily evolved, incorporating more functions that demand greater computing power, and consequently, more semiconductor chips. **Today's smartphones not only handle basic calls and texts but also support advanced graphics processing, AI capabilities, advanced cameras, and even satellite communications. This trend underscores the increasing complexity and chip dependency of modern devices.**

[138] Diffusion of Personal Computing Devices. The Geography of Transport Systems. https://transportgeography.org/contents/chapter1/the-setting-of-global-transportation-systems/personal-computing-devices/

[139] A History of Mobile Phones And Smartphones. BBC. https://www.bbc.co.uk/bitesize/articles/z62gjfr

Figure 15: Key Chips for iPhone 15[140]

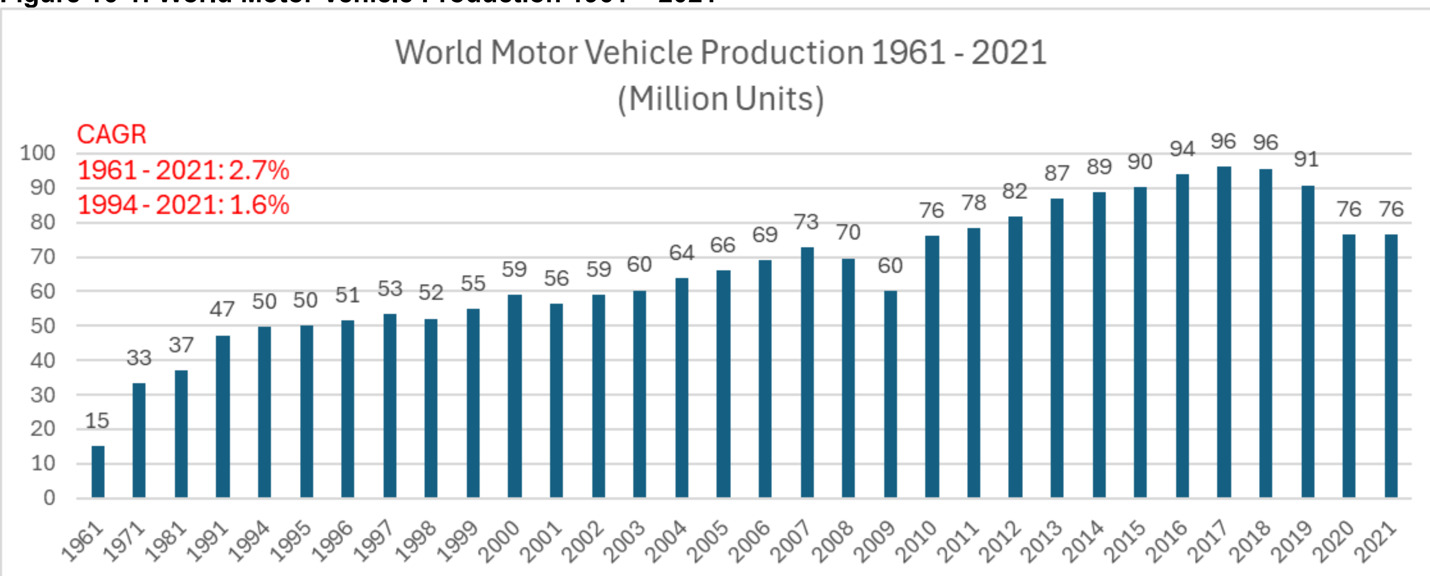


[140] The Suppliers Making the iPhone Possible. https://quartr.com/insights/company-research/the-suppliers-making-the-iphone-possible

In addition, the rapid growth in global motor vehicle production, from over 30 million units in the 1970s to 76 million units in 2021 annually, coupled with the increasing complexity of vehicle technology, has led to a significant rise in the demand for semiconductors. With a CAGR of approximately 2%, the number of semiconductor chips per vehicle varies greatly depending on the type of vehicle and its features such as different kinds of sensors, lightings, and entertainment.

Electric vehicles (EVs) are particularly chip-intensive. **As highlighted in a 2022 survey, EVs require more than twice as many semiconductor chips as traditional internal combustion engine vehicles, 1,300 chips in an EV versus 600 chips in a combustion engine vehicle.**[141] This difference can be attributed to the increased number of sensors, processors, and specialized electronic components needed for electric drivetrains, battery management systems, and advanced driver-assistance systems in EVs. Joe Biden's 2022 speech further emphasized the critical role of semiconductors, noting that modern vehicles can contain as many as 3,000 chips.[142] This highlights the growing importance of semiconductors in enabling the functionalities and advancements seen in today's vehicles, from enhanced safety features to advanced infotainment and connectivity systems. **A Deloitte study in China indicates that from 2012 to 2022, the number of chips per internal combustion engine vehicle was expected to grow from 438 to 934 – an increase of nearly 2.1 times. During the same period, the number of chips in new energy vehicles grew from 567 to 1,459, a 2.6x increase.**[143] These findings are generally consistent with other studies mentioned earlier, underscoring the increasing interdependence between the automotive industry and the semiconductor sector, especially as vehicles become more electrified and technologically sophisticated.

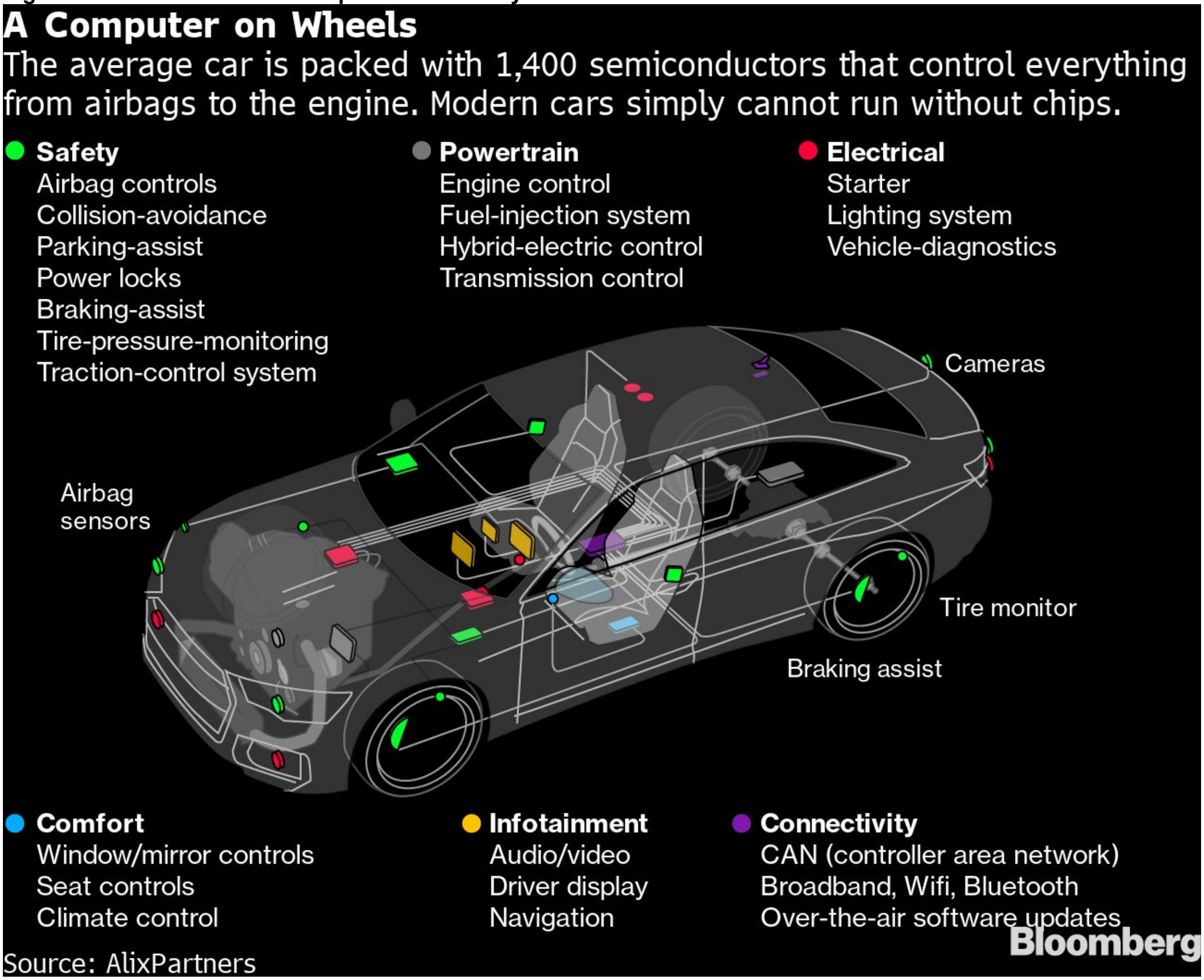
Figure 16-1: World Motor Vehicle Production 1961 – 2021[144]



Note:
1. The data provided above includes both passenger and commercial vehicles such as cars, minivans, pickups, sport utility vehicles, etc.

[141] Electric Vehicles Require Lots of Scarce Parts. WSJ. https://www.wsj.com/articles/electric-vehicles-scarce-parts-supply-chain-11668206037; Chips Are the New Oil and America Is Spending Billions to Safeguard Its Supply. WSJ. https://www.wsj.com/articles/chips-semiconductors-manufacturing-china-taiwan-11673650917
[142] Remarks by President Biden at Signing of H.R. 4346, "The CHIPS and Science Act of 2022". The White House. https://www.whitehouse.gov/briefing-room/speeches-remarks/2022/08/09/remarks-by-president-biden-at-signing-of-h-r-4346-the-chips-and-science-act-of-2022/
[143] Fighting An Unprepared Battle – Rethinking Auto Semiconductor Strategy in An Uncertain Era. Deloitte. https://www2.deloitte.com/cn/en/pages/consumer-business/articles/automotive-semiconductors-strategic.html
[144] World Motor Vehicle Production, Selected Countries. Bureau of Transportation Statistics. https://www.bts.gov/content/world-motor-vehicle-production-selected-countries

Figure 16-2: Semiconductor Chips in Modern Day Vehicles[145]



Market Size and Market Share

A Los Angeles Times article published before TSMC's IPO cited data from the World Semiconductor Trade Statistics, estimating that the global semiconductor market would grow to $93.8 billion in 1994.[146] At that time, TSMC's market share was approximately 0.5% of the global semiconductor industry, based on its 1993 net sales of NT$12.3 billion (around $0.5 billion). It is worth noting that because TSMC is a pure-play foundry, its market share in the overall semiconductor industry is not indicative of its market position in the foundry segment. Comparing with the foundry segment within the semiconductor industry would be more appropriate, which we will discuss in the section below.

A year earlier, in 1993, The Washington Post quoted an industry analyst predicting that the semiconductor market would more than double to over $200 billion in annual sales by the early 2000s,[147] implying a minimum 10% CAGR from nearly $70 billion. Data from the OECD and the Semiconductor Industry Association show that the global semiconductor market

[145] What Will Replace Silicon Chips in the Next Generation of EVs. https://www.supplychainbrain.com/articles/33836-what-will-replace-silicon-chips-in-the-next-generation-of-evs

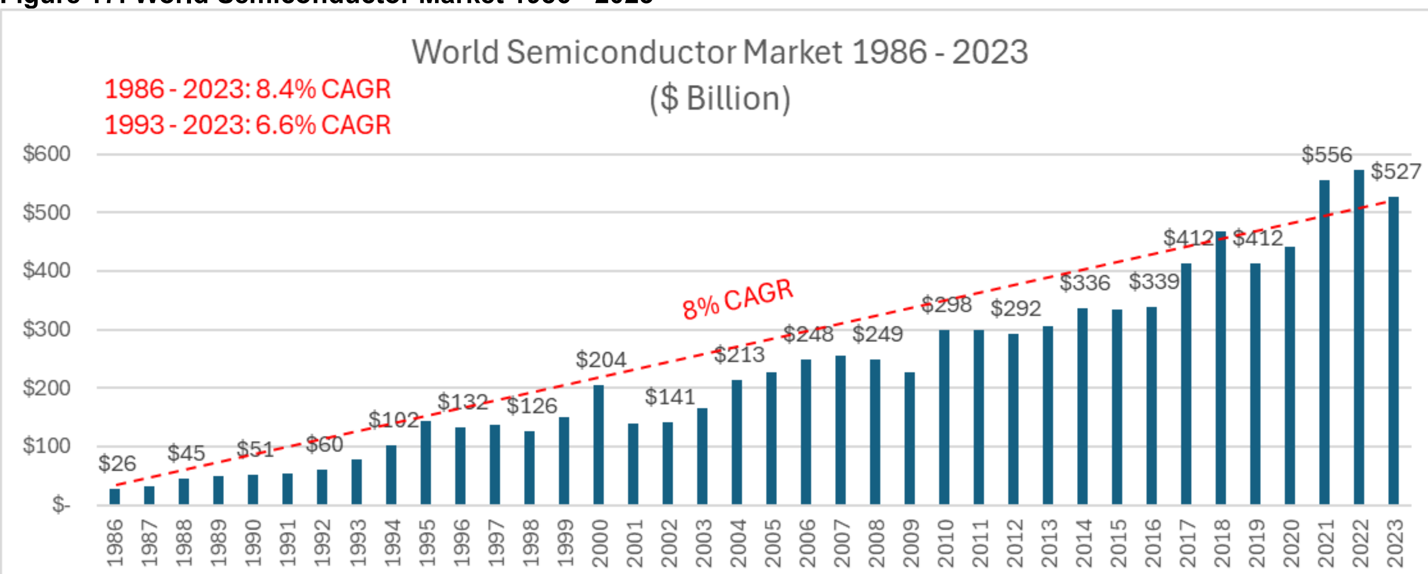
[146] Global Semiconductor Market Size 1994. Los Angeles Times. https://www.latimes.com/archives/la-xpm-1994-05-18-fi-59254-story.html

[147] Computer Chipmakers Race To Keep Up With Demand. https://www.washingtonpost.com/archive/business/1993/08/23/computer-chipmakers-race-to-keep-up-with-demand/3827206c-df90-4174-8759-9a6b536217f5/

grew from $26 billion in 1986, a year before TSMC's founding, to nearly $527 billion in 2023,[148] an 8% CAGR. **From 1993 to 2023, during the period when TSMC is public, the market expanded at a 6.6% CAGR.** At the time of its IPO, TSMC held less than 1% of the global semiconductor market share.

The Semiconductor Industry Association (SIA) reported that global semiconductor sales reached $526.8 billion in 2023, an 8.2% decline from the 2022 all-time-high of $574.1 billion.[149] Out of the $526.8 billion global semiconductor market, approximately $117.5 billion went to foundries, accounting for 22% of the total industry.[150] **Based on TSMC's 2023 net sales of NT$2.2 trillion (approximately $69 billion), its share of the global semiconductor market was less than 8%, and 59% of the foundry segment. The company essentially has limited competition on advanced process nodes during different time periods and has produced approximately 90% of the world's most advanced semiconductor chips.**[151] Over the years, TSMC has consistently led the industry, being the first to bring various process nodes into production, from 90nm and 65nm in the early 2000s to 20nm, 16/12nm, and most recently 3nm.[152] Currently, TSMC and Samsung are the only two companies capable of manufacturing 3nm chips. When TSMC's 3nm process entered production in 2022, yield rates reportedly ranged from 60% to 80%, while Samsung's 3nm production saw yields estimated between 10% and 20%.[153] By Q3 2024, Taiwanese media reported that TSMC's N3E, an enhanced version of its 3nm process, had achieved a yield rate approaching 90%.[154] In contrast, Samsung's first-generation 3nm process reportedly improved to yield rates between 50% and 60%, but its second-generation process saw yields at around only 20%, leaving many customers no choice but to choose TSMC. Samsung has reportedly even considered outsourcing production of some of its flagship Exynos chips to TSMC.

Figure 17: World Semiconductor Market 1986 - 2023[155]



Note:

---

[148] OECD Digital Economy Outlook 2015. OECD; SIA Factbook 2016 – 2024; Historical Billings Report. World Semiconductor Trade Statistics (WSTS). https://www.wsts.org/67/Historical-Billings-Report

[149] Global Semiconductor Sales Decrease 8.2% in 2023; Market Rebounds Late in Year. Semiconductor Industry Association. https://www.semiconductors.org/global-semiconductor-sales-decrease-8-2-in-2023-market-rebounds-late-in-year/

[150] Taiwan And The Global Semiconductor Supply Chain: 2023 in Review. Taipei Representative Office in Singapore.

[151] There is no strict definition for "advanced chips." Generally, the term refers to the smallest process nodes available at a given time. For example, while other IDMs and foundries have struggled with 14nm nodes in recent years, TSMC has progressed to 7nm and smaller, reaching as far as 2nm by 2024.

[152] 5nm Technology. TSMC. https://www.tsmc.com/english/dedicatedFoundry/technology/logic/l_90nm

[153] Analysts Estimate TSMC's 3nm Yields Between 60% and 80%. https://www.tomshardware.com/news/analysts-estimate-tsmc-n3-yields-between-60-and-80-percent

[154] Samsung May Outsource Exynos Production to TSMC Due to Low 3nm Yield Rate. https://www.trendforce.com/news/2024/11/14/news-samsung-may-outsource-exynos-production-to-tsmc-due-to-low-3nm-yield-rate/#:~:text=On%20the%20other%20hand%2C%20TSMC's,%25%2C%20as%20the%20report%20noted; TSMC N3E Yield Rate Approach 90%. https://www.moneydj.com/kmdj/news/newsviewer.aspx?a=c0628954-6020-40af-946d-7e497e8f9814&c=MB010000

[155] Historical Billings Report. World Semiconductor Trade Statistics (WSTS). https://www.wsts.org/67/Historical-Billings-Report

1. According to the World Semiconductor Trade Statistics (WSTS), the data above includes several sub-segments within the semiconductor industry – discrete semiconductors, optoelectronics, sensors, and integrated circuits.

Between 1980 and 2023, global shipments of integrated circuits (ICs), a segment of the semiconductor industry commonly known as chips (i.e., microprocessors), were estimated to have grown from 9.8 billion to nearly 428 billion units, reflecting a 9% CAGR. This growth was driven by the increasing adoption of electronic devices for both consumer and commercial use, including smartphones, computers, and automobiles, as mentioned above.

Figure 18-1: World Integrated Circuit (IC) Unit Shipment Growth 1980 – 2023[156]

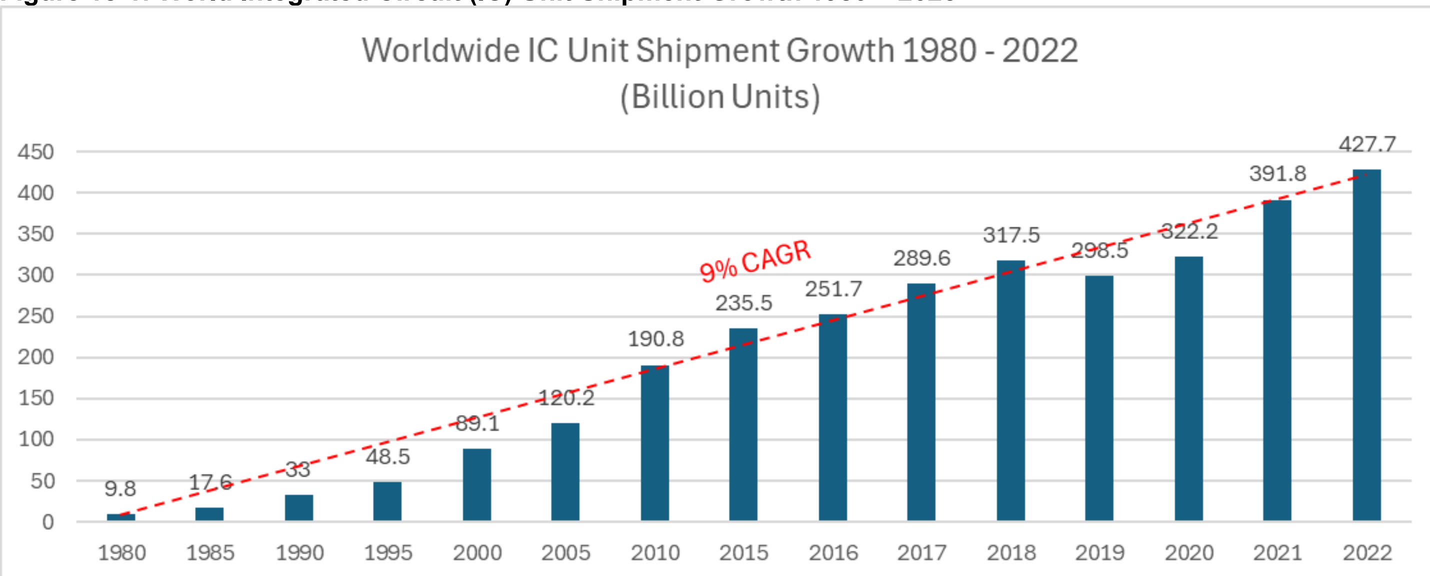
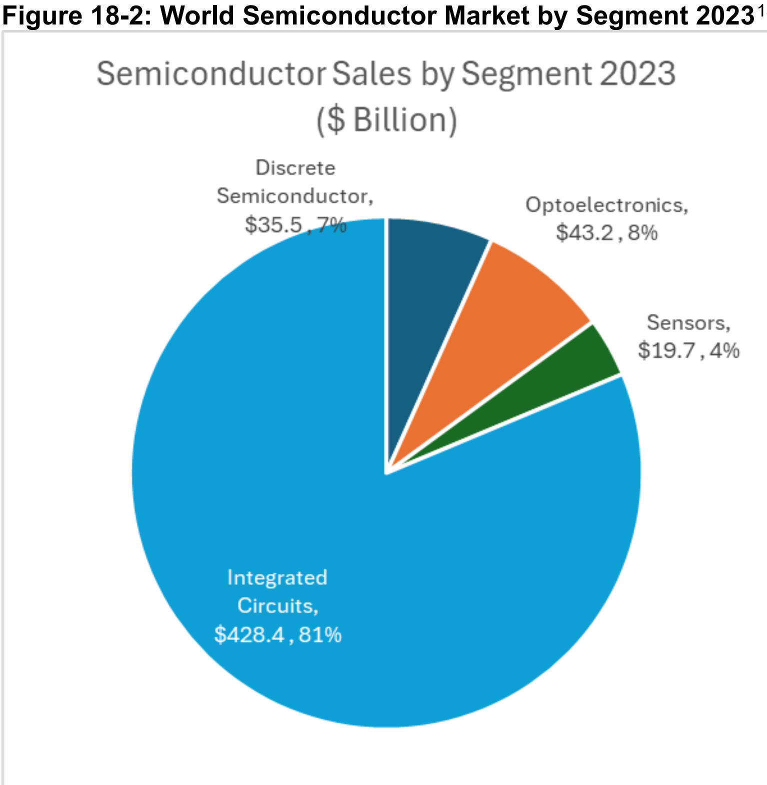


Figure 18-2: World Semiconductor Market by Segment 2023[157]



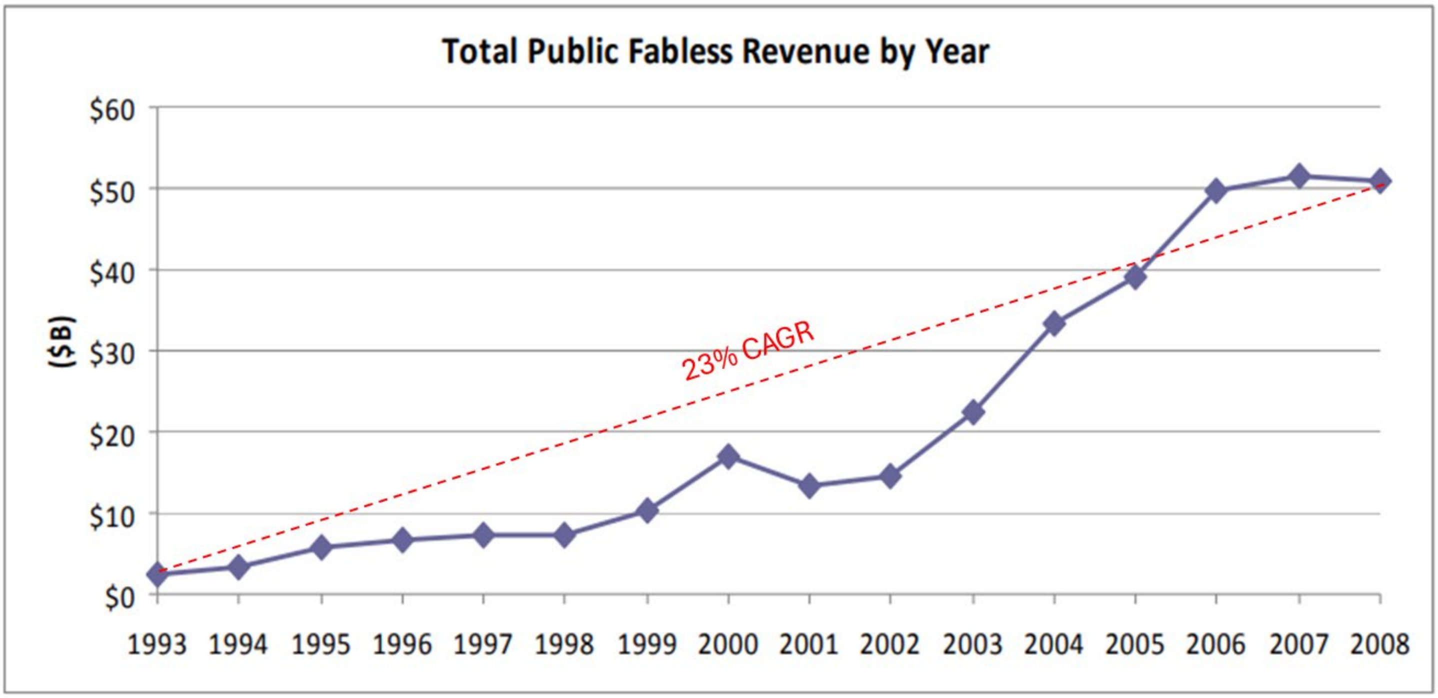
[156] Total IC Unit Shipments Forecast to Climb 9% This Year. https://www.design-reuse.com/news/51764/2022-total-ic-unit-shipments-forecast.html

[157] WSTS Semiconductor Market Forecast Fall 2024. WSTS. https://www.wsts.org/76/Recent-News-Release

Morris Chang, TSMC's founder, noted in his autobiography that in its first two years (1987–1988), TSMC's customer base consisted mostly of small, local design firms in Taiwan. It was not until 1989 that larger foreign integrated device manufacturers (IDMs), such as Intel, Motorola, Texas Instruments, and Philips, began outsourcing their less profitable products to TSMC to enhance their profitability. **From 1991, the number of semiconductor companies rose rapidly. According to the Fabless Semiconductor Association (FSA), the number of fabless companies grew from seven in 1991 to 750 by 2000, with total sales increasing from $2.4 billion in 1993 to $17 billion in 2000, a CAGR of over 32%.**[158] We estimated that global foundry segment accounted for has grown from only 3% of the overall semiconductor industry in 1993 to over 22% in 2023,[159] reflecting a 14% CAGR in value.

Chang estimated that of the $17 billion in sales by fabless companies in 2000, $3.4 billion was directed to foundries.[160] By 2000, TSMC's sales exceeded $5 billion, with approximately 40% from IDMs and over 60% (approximately $3.2 billion) from fabless companies.[161] This indicates TSMC's dominant position among fabless companies for wafer fabrication, despite potential underestimation of the global market size by the FSA.

Figure 19: Total Public Fabless Revenue 1993 – 2008[162]



Note:
1. The data above includes only the publicly traded fabless firms.

In TSMC's 1994 annual report, the company reported capturing nearly 23% of the global integrated circuit foundry market, already making it the world's leading foundry at the time.[163] By 2023, TrendForce, a technology-focused market research firm, estimated that TSMC held a dominant 59% share, with a gradual upward trend,[164] of the $117.5 billion global semiconductor foundry market. The report placed Samsung in second with 11%, followed by United Microelectronics Corporation (UMC) at 6%, GlobalFoundries at 6%, and Semiconductor Manufacturing International Corporation (SMIC) at 5%.[165]

---

[158] FSA later become Global Semiconductor Alliance. Translated or rephrased by the author on a best effort basis. Chapter 20. Morris Chang: An Autobiography. Part II.

[159] In 1993, global foundry sales were $2.4 billion while the overall semiconductor industry was $77.3 billion; In 2023, global foundry sales were $117.5 billion while the overall semiconductor industry was $527 billion. Behind Taiwanese Chip Makers' Japan Investment Spree. https://www.nippon.com/en/in-depth/d00988/; SIA Factbook 2024.

[160] Translated or rephrased by the author on a best effort basis. Chapter 20. Morris Chang: An Autobiography. Part II.

[161] TSMC Q4 2000 Investor Presentation

[162] Global Semiconductor Alliance. Intellectual Property as a Law of Organization. Jonathan Barnett. Southern California Law Review.

[163] TSMC Annual Report 1994

[164] Taiwan And The Global Semiconductor Supply Chain: 2023 in Review. Taipei Representative Office in Singapore.

[165] Behind Taiwanese Chip Makers' Japan Investment Spree. https://www.nippon.com/en/in-depth/d00988/

TSMC essentially has limited competition on advanced process nodes during different time periods and has produced approximately 90% of the world's most advanced semiconductor chips.[166] Over the years, TSMC has consistently led the industry, being the first to bring various process nodes into production, from 90nm and 65nm in the early 2000s to 20nm, 16/12nm, and most recently 3nm.[167] Currently, TSMC and Samsung are the only two companies capable of manufacturing 3nm chips. When TSMC's 3nm process entered production in 2022, yield rates reportedly ranged from 60% to 80%, while Samsung's 3nm production saw yields estimated between 10% and 20%.[168] By Q3 2024, Taiwanese media reported that TSMC's N3E, an enhanced version of its 3nm process, had achieved a yield rate approaching 90%.[169] In contrast, Samsung's first-generation 3nm process reportedly improved to yield rates between 50% and 60%, but its second-generation process saw yields at around only 20%, leaving many customers no choice but to choose TSMC. Samsung has reportedly even considered outsourcing production of some of its flagship Exynos chips to TSMC.

Similarly, in 2022, IDC Research provided comparable market share estimates. According to IDC, TSMC commanded 55.5% of the global foundry market, followed by Samsung Foundry at 16%, UMC at 6.8%, GlobalFoundries at 5.9%, and SMIC at 5.3%.[170]

As of 2023, TSMC produces 28% of the world's semiconductors, excluding memory-related output, underscoring its critical role in the semiconductor supply chain.[171] **It also produces approximately 90% of the world's most advanced semiconductor chips.**[172]

[166] There is no strict definition for "advanced chips." Generally, the term refers to the smallest process nodes available at a given time. For example, while other IDMs and foundries have struggled with 14nm nodes in recent years, TSMC has progressed to 7nm and smaller, reaching as far as 2nm by 2024.

[167] 5nm Technology. TSMC. https://www.tsmc.com/english/dedicatedFoundry/technology/logic/l_90nm

[168] Analysts Estimate TSMC's 3nm Yields Between 60% and 80%. https://www.tomshardware.com/news/analysts-estimate-tsmc-n3-yields-between-60-and-80-percent

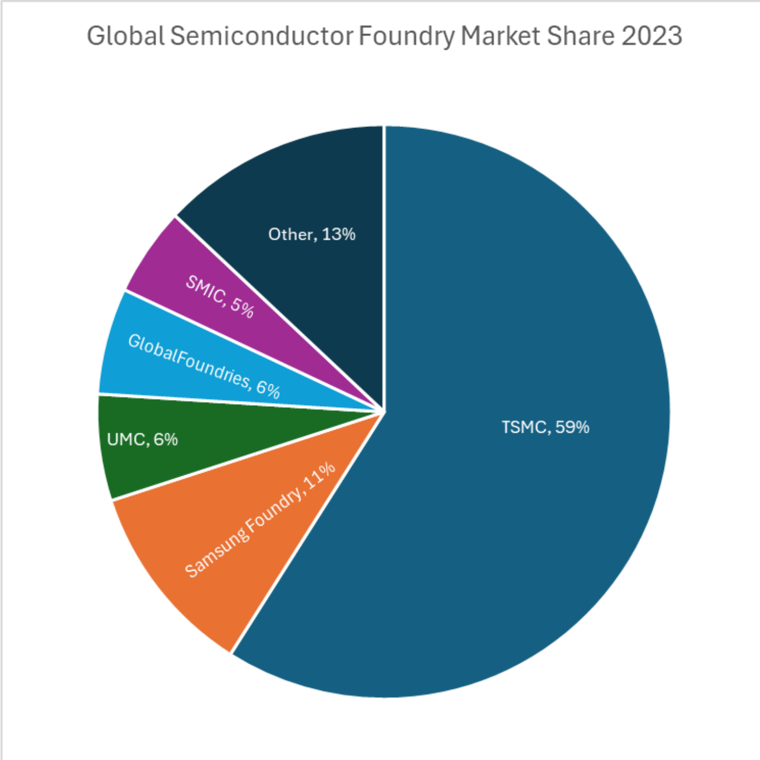
[169] Samsung May Outsource Exynos Production to TSMC Due to Low 3nm Yield Rate. https://www.trendforce.com/news/2024/11/14/news-samsung-may-outsource-exynos-production-to-tsmc-due-to-low-3nm-yield-rate/#:~:text=On%20the%20other%20hand%2C%20TSMC's,%25%2C%20as%20the%20report%20noted; TSMC N3E Yield Rate Approach 90%. https://www.moneydj.com/kmdj/news/newsviewer.aspx?a=c0628954-6020-40af-946d-7e497e8f9814&c=MB010000

[170] Worldwide Semiconductor Foundry Market Grew 27.9 YoY in 2023 due to Inventory Adjustments. IDC Research. https://www.idc.com/getdoc.jsp?containerId=prAP50994023

[171] TSMC 20-F 2023

[172] There is no strict definition for "advanced chips." Generally, the term refers to the smallest process nodes available at a given time. For example, while other IDMs and foundries have struggled with 14nm nodes in recent years, TSMC has progressed to 7nm and smaller, reaching as far as 2nm by 2024.

Figure 20: Global Semiconductor Foundry Market Share 2023[173]



Unprecedent Business Model – A Dedicated Integrated Circuit Foundry, Technology Leader, High Yield

TSMC established the semiconductor dedicated integrated circuit foundry business model when it was founded in 1987. Since its inception, the company has adhered to the principle: "We have treated our customers as partners and have never competed against them."[174] TSMC achieves this by refraining from designing or marketing its own products and instead focusing solely on fabricating integrated circuits based on customer orders while offering services such as packaging and testing.[175] As a dedicated foundry, TSMC has successfully avoided direct competition with semiconductor companies from the U.S., Korea, and Japan, instead converting them into potential customers.[176]

Semiconductor products generally fall into two categories: generic products and custom products. Generic products are sold to multiple customers, typically leading to more competitors and lower profitability, **whereas custom products, on the other hand, are tailored to specific customers' designs and specifications.[177] Morris Chang pointed out that these products typically face little to no competition and yield higher profitability.** However, in some cases, custom chips may yield lower gross margins than generic ones, depending on the company and the product.[178]

From its founding, TSMC committed exclusively to custom products. That is also why TSMC does not fabricate memory products, such as random-access memory and read-only memory, as these are largely standardized products that can be sold by anyone capable of manufacturing them. While there are relatively few competitors in the memory market, those that exist specialize in it, such as Japanese companies in the 1970s and 1980s, and Korean companies such as Samsung in the 1990s.[179]

Another benefit of being a dedicated foundry is its ability to diversify business risks, particularly during TSMC's early years when its scale was small, and the foundry segment just began relative to the overall semiconductor industry. In a 1996

[173] Behind Taiwanese Chip Makers' Japan Investment Spree. https://www.nippon.com/en/in-depth/d00988/; Taiwan And The Global Semiconductor Supply Chain February 2024.
[174] Values and Business Philosophy. TSMC. https://www.tsmc.com/english/aboutTSMC/values
[175] Translated or rephrased by the author on a best effort basis. Chapter 17. Morris Chang: An Autobiography. Part II.
[176] Translated or rephrased by the author on a best effort basis. Chapter 18. Morris Chang: An Autobiography. Part II.
[177] Translated or rephrased by the author on a best effort basis. Chapter 6. Morris Chang: An Autobiography. Part II.
[178] Marvell Wins New AI Chip Business, But at Lower Margins. Reuters. https://www.reuters.com/technology/marvell-wins-new-ai-chip-business-lower-margins-2024-04-11/
[179] Translated or rephrased by the author on a best effort basis. Chapter 23. Morris Chang: An Autobiography. Part II.

interview with the China Times, Morris Chang reflected on TSMC's early days. **At the time, many fabless companies were beginning to design integrated circuits, but most lacked the capital to build their own fabrication facilities (fabs), which was economically unfeasible. This business model benefits both TSMC and fabless companies, allowing each to focus on their core competencies without diverting capital to other areas. The barriers to entry for building a new fab were extremely high, particularly for advanced nodes.**

For example, in 2010, when TSMC built Fab 15 – initially for 28nm production, considered advanced at the time – the project, including later expansions into more advanced nodes, was estimated to cost nearly $10 billion over several phases.[180] By 2024, although starting costs for fabs producing mature process technologies (such as 28nm and above) seem to lower – Beijing Yandong Microelectronics plans to invest $4.6 billion in a 300mm (12-inch) fab[181] – the costs of building facilities for advanced nodes have risen significantly over the years. TSMC's Fab 18, which began construction in 2018 and started volume production in 2020, was estimated to cost $17 billion.[182] Meanwhile, TSMC's three Arizona plants, which will manufacture advanced nodes such as 4nm and below, are projected to cost over $65 billion in total, with each facility exceeding $20 billion.[183] The high cost of building new fabs deters many potential entrants from competing, and even established players hesitate to pursue advanced nodes. This cost barrier, combined with the technological expertise TSMC has accumulated over decades, makes it challenging for competitors to keep pace. This dynamic partly explains why several foundries, such as GlobalFoundries and UMC, have announced in recent years that they will halt development of nodes below 14nm,[184] given the significant expenses in plants and R&D involved as well as annual capital expenses to keep the manufacturing facilities up to date. This leaves chip companies no choice but TSMC for advanced nodes. A former director at TSMC stated that:

> "The sheer volume of the wafer TSMC runs, it helps them to accumulate a lot of knowledge for the process. And so the more wafer you run, you're going to encounter all kinds of problems because of those problems, I don't think TSMC is smarter than Samsung or Intel, but they're very dedicated. They see a problem, they take the problem as the opportunity for improvement. So with the number of wafers they are able to run, they're going to see a lots of problems very quickly, then they have this discipline of solving those problems as they show up, then their learning curve is much, they are able to accumulate those learning much faster than Intel and Samsung."[185]

Chang also noted that even many Integrated Device Manufacturers (IDMs) were reluctant to build their own fabs due to the high costs or lack of the capability.[186] It takes several years for semiconductor manufacturers to build new plants and achieve the desired production capacity. In the 1970s and 1980s, constructing a semiconductor plant typically took about three years, and two years required to build and equip cleanrooms.[187] Today, with far more advanced process nodes and sophisticated machinery that demand greater investments and extensive training, building a modern semiconductor plant takes at least one year longer than it did in the past. This created a significant opportunity for TSMC as a dedicated foundry. By serving multiple customers, TSMC, as a dedicated foundry, can achieve better economies of scale more easily than IDMs,[188] which primarily produce for their own needs. The cost of manufacturing semiconductors using the same process node gradually declines as production volumes increase.

By 2023, TSMC held nearly 60% of the $117.5 billion global semiconductor foundry market[189] and produced approximately 90% of the world's most advanced semiconductor chips.[190] This strong market position grants TSMC a significant edge in economies of scale over its competitors in the foundry segment. TSMC emphasizes that, while they do

---

[180] TSMC Begins Construction on GigafabTM In Central Taiwan. https://pr.tsmc.com/english/news/1629

[181] China to Spend Billions on Another Fab Offering Mature Nodes. https://www.tomshardware.com/tech-industry/china-to-spend-billions-on-another-fab-offering-mature-nodes-ydme-formed-to-operate-new-usd4-6b-facility

[182] TSMC Starts to Build Fab 18 - 5 nm, Volume Production in Early 2020. https://www.anandtech.com/show/12377/tsmc-starts-to-build-fab-18-5nm-in-early-2020

[183] TSMC Arizona. https://www.tsmc.com/static/abouttsmcaz/index.htm

[184] GlobalFoundries Halts 7nm Work. https://www.eetimes.com/globalfoundries-halts-7nm-work/; UMC Not to Rejoin Race to Develop 7nm Technology. https://www.taipeitimes.com/News/biz/archives/2018/09/04/2003699736

[185] Interview with A Former Director at TSMC. 9/17/2024.

[186] Translated or rephrased by the author on a best effort basis. Chapter 24. Morris Chang: An Autobiography. Part II.

[187] Translated or rephrased by the author on a best effort basis. Chapter 29. Morris Chang: An Autobiography. Part II.

[188] Translated or rephrased by the author on a best effort basis. Chapter 32. Morris Chang: An Autobiography. Part II.

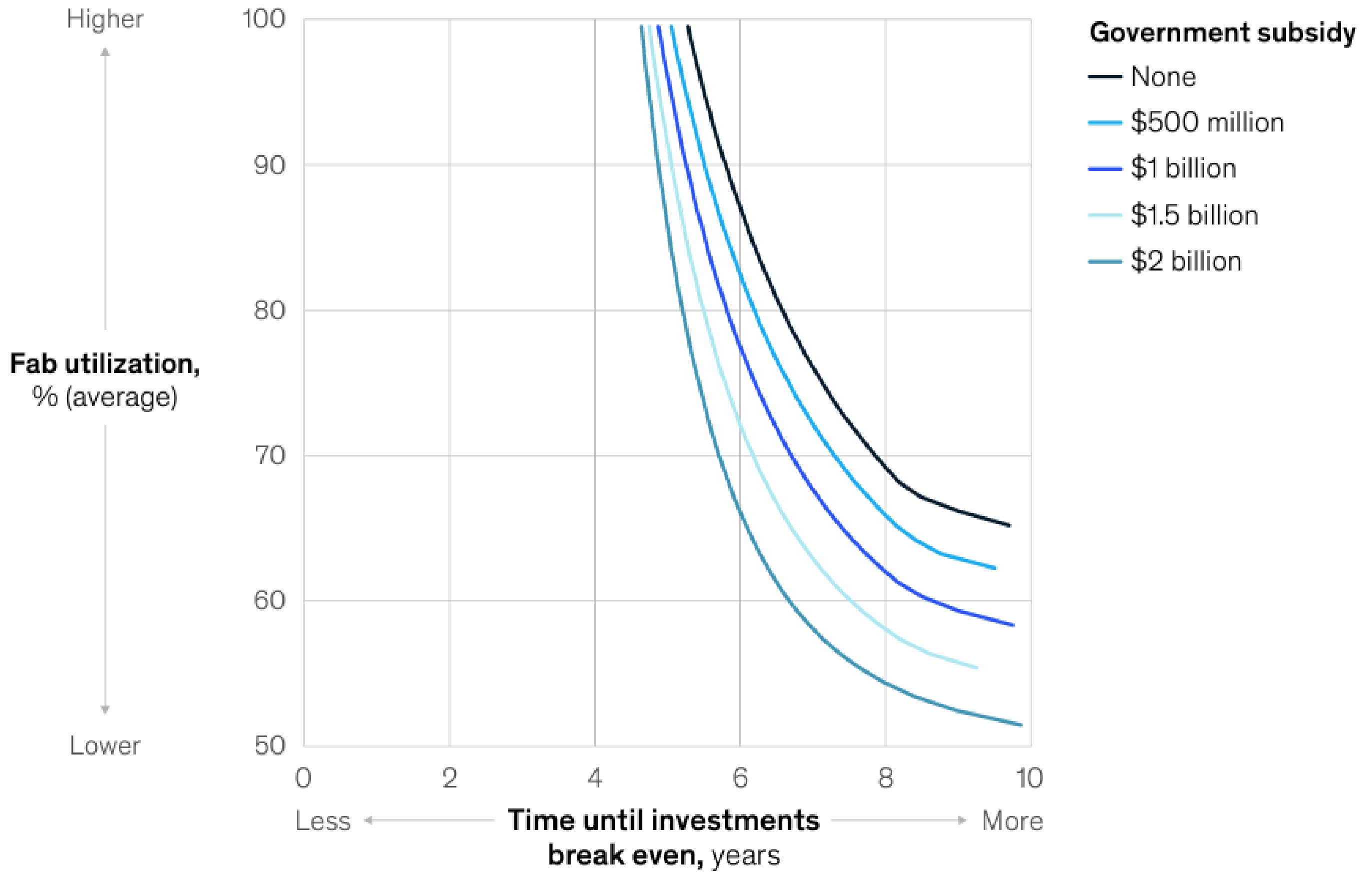
[189] Taiwan And The Global Semiconductor Supply Chain: 2023 in Review. Taipei Representative Office in Singapore.

[190] There is no strict definition for "advanced chips." Generally, the term refers to the smallest process nodes available at a given time. For example, while other IDMs and foundries have struggled with 14nm nodes in recent years, TSMC has progressed to 7nm and smaller, reaching as far as 2nm by 2024.

not focus on payback periods or consider them a key factor, the payback periods for different technologies, whether advanced or mature nodes, tend to be quite similar.[191]

A 2021 McKinsey report indicates that a newly constructed 5nm fab operating at full capacity without government subsidies requires nearly five years to achieve a return on investment, roughly in line with TSMC's 20% to 30% ROIC in recent years. At 70% capacity, the payback period extends to nearly eight years, as Figure 21 shows.[192]

Figure 21: Analysis Based on Model for Leading-Edge Fab Producing 5nm Products[193]



Source: McKinsey analysis

We believe that being a dedicated foundry could also help mitigate the risks of overcapacity and underutilization that IDMs might face. For instance, IDMs primarily allocate their capacity for in-house use while continuing to build new facilities to support advancements in chip design and smaller process nodes. This approach can lead to older technologies becoming underutilized as resources shift toward expanding production for newer technologies, ultimately reducing overall efficiency. **In contrast, the dedicated foundry model addresses these risks by ramping up production for new technologies while allocating capacity for older technologies to other chip design companies that still require them.** For example, nearly 60% of TSMC's sales in 2023 came from integrated circuits manufactured using process nodes of 7nm and below, while the remaining sales were from nodes ranging from 16nm to 0.25µm and above.

Morris Chang is a strong advocate of learning curve theory and has applied it over decades to successfully compete with other foundries.[194] **During his time at Texas Instruments, he learned two key principles of learning curve theory: 1) the importance of having a first-mover advantage to execute a preemptive strike, and 2) the critical role of market share.**[195] We believe these principles help shape TSMC's business model, creating a virtuous cycle that reinforced its success. By receiving orders from a wide range of customers, whether fabless companies or IDMs, TSMC was able to maintain high utilization rates at its manufacturing facilities. This not only drove down production costs but also allowed

[191] TSMC Q2 2019 Earnings Call. 7/18/2019; TSMC Q3 2019 Earnings Call. 10/17/2019.
[192] McKinsey on Semiconductors. McKinsey & Company. November 2021.
[193] McKinsey on Semiconductors. McKinsey & Company. November 2021.
[194] Translated or rephrased by the author on a best effort basis. Chapter 30. Morris Chang: An Autobiography. Part II.
[195] Translated or rephrased by the author on a best effort basis. Chapter 3. Morris Chang: An Autobiography. Part II.

the company to capture a larger market share. For example, prior to 2000, TSMC operated at nearly full capacity for many years.[196] Fast forward to 2024, and the company's production capacity for its most advanced 3nm process node has already been fully allocated until 2026.[197] The company's lower process nodes such as 5nm and 4nm have also remained at 100% utilization rate.[198] Meanwhile, TSMC continues to expand its production capabilities. **One key reason TSMC can consistently maintain a high utilization rate of its production capacity is that it builds capacity based on customer demand rather than speculation.** In other words, the company aligns its capacity expansion with existing orders, rather than building first and seeking business afterward.[199] However, this does not mean that TSMC blindly follows customers' stated demand, as it is often inflated. Instead, TSMC consolidates requests from multiple customers and asks them to collectively justify the proposed demand. If customers genuinely foresee high demand, TSMC requires them to prepay for the additional tooling needed to expand capacity.[200] This process involves ongoing back-and-forth discussions with each customer to fine-tune and align on realistic capacity needs. Ultimately, TSMC develops a consolidated and accurate capacity plan that reflects the true demand of its customers. As the company gains more experience through production and adapts to customer demands, it evolves its process technologies, attracting even more customers. This self-reinforcing cycle of innovation, customer acquisition, and capacity expansion continues to propel TSMC's growth.

In addition, TSMC's business model also helps mitigate market risks by diversifying TSMC's customer base. For instance, if a particular semiconductor product experienced a downturn, the company could still serve customers producing other types of products. This diversified business model made TSMC more resilient to market fluctuations. However, as the company scales up, it inevitably becomes more susceptible to industry cyclicality.[201] For example, while the global semiconductor market declined by over 8% in 1996, grew 4% in 1997, and then fell by another 8% in 1998,[202] the first time the semiconductor industry declined since TSMC's founding, the company sales grew steadily, by 37%, 12%, and 15% during those same years, respectively. In 1999, when the market rebounded with 19% growth, TSMC's sales surged by 45%. In 2020, the U.S. government banned Huawei from having its chips manufactured by TSMC. At the time, Huawei accounted for nearly 15% of TSMC's sales. **Despite this, the ban had little negative impact on TSMC, as the demand left by Huawei was quickly filled by other customers.**[203] By 2024, Apple has become the largest customer to TSMC, accounting for nearly 25% of its overall sales.[204] Between 2020 and 2022, TSMC's sales grew by 25.2%, 18.5%, and 42.6%, before declining by 4.5% in 2023. In comparison, global semiconductor sales during the same period increased by 6.8%, 26.2%, and 3.3%, followed by an 8.2% decline.[205]

Similarly, during the dot-com bubble burst in 2001, the global semiconductor market plummeted by 32%, yet TSMC's sales declined by a relatively smaller 24%. The company recovered quickly the following year, achieving 29% growth, while the overall market inched up by only 1%. This performance highlights TSMC's ability to weather challenging market conditions, a testament to the strength and resilience of its innovative dedicated foundry business model and diversified customer base.

Since the mid-1990s, TSMC has significantly expanded its customer base, growing from over a hundred customers at that time, compared to only 15 customers when it was founded in 1987.[206] However, throughout its history, the largest 15 to 20 customers have consistently accounted for approximately 80% of the company's overall sales,[207] with most of these customers based in the U.S. and Taiwan.

---

[196] TSMC Q4 2000 Investor Presentation.

[197] Major Clients Reportedly Fully Allocate TSMC's Production Capacity Until 2026, 3nm Process in High Demand. https://www.trendforce.com/news/2024/06/11/news-major-clients-reportedly-fully-allocate-tsmcs-production-capacity-until-2026-3nm-process-in-high-demand/

[198] TSMC's 3nm Process at Full Capacity, Led by Intel's Lunar Lake and Apple's iPhone 16 Launch. https://www.digitimes.com/news/a20240904PD213/3nm-tsmc-intel-apple-launch.html

[199] TSMC Q2 2010 Earnings Call. 7/29/2010

[200] Interview with A Former Director at TSMC. 9/17/2024.

[201] Translated or rephrased by the author on a best effort basis. Chapter 29. Morris Chang: An Autobiography. Part II.

[202] OECD Digital Economy Outlook 2015. OECD; Historical Billings Report. World Semiconductor Trade Statistics (WSTS). https://www.wsts.org/67/Historical-Billings-Report

[203] TSMC's Largest Customer Makes Up 25% of Revenue. Taipei Times. https://www.taipeitimes.com/News/biz/archives/2021/03/09/2003753477

[204] Interview with A Former Consultant at TSMC. 10/25/2024

[205] SIA Factbook 2021 – 2024.

[206] Translated or rephrased by the author on a best effort basis. Chapter 26. Morris Chang: An Autobiography. Part II.

[207] Translated or rephrased by the author on a best effort basis. Chapter 24. Morris Chang: An Autobiography. Part II.

While the top 15 customers have always contributed nearly 75% of TSMC's sales, their composition changed rapidly, particularly in the 1990s.[208] For example, by 2000, only five of the top 15 customers from 1997 remained, with ten either going bankrupt, declining, or being replaced by new customers. Since 2000, the top 15 customers have been more stable, with nine of them remaining in the group going forward.

Working with a diverse portfolio of customers allows TSMC to develop expertise and refine its processes by actively listening to customer feedback and continuously adjusting to meet the needs of different market segments. This approach accelerates TSMC's learning curve by enabling them to address and resolve a wide range of customer challenges.[209]

In addition, the concentration of business among the top 15 to 20 customers, despite shifts in the underlying companies over different periods, reflects the advantages of TSMC's position as a dedicated foundry. Unlike integrated device manufacturers, TSMC's pure-play fabrication services are always in demand from other semiconductor companies, whether fabless or integrated device manufacturers. As old customers shift away from TSMC for various reasons such as decline in businesses, new customers will rise as long as TSMC could satisfy their different needs. By 2023, TSMC had grown to serve 528 customers and manufactured 11,895 products across a wide range of applications, including computing, smartphones, automotive, and other digital consumer electronics.[210] **To strengthen relationships with top customers and better understand their needs, during his tenure as TSMC's chairman and president, Morris Chang visited the company's top customers at least once a year, and sometimes even more frequently.**

To monitor customer satisfaction and maintain strong relationships, TSMC began hiring external advisors since 1997 to conduct annual surveys of its customers.[211] These surveys evaluate every aspect of TSMC's services, including capacity availability, response times, pricing, on-time delivery, and more. **Each year, Morris Chang (until his retirement), along with the management team, personally reviews the customer feedback with the advisors and implements improvements accordingly.** A dedicated team oversees the progress to ensure that necessary changes are made. The goal of this program is to identify areas of customer dissatisfaction, address them effectively, and build greater trust with customers by continually improving the company's services.

To elevate its customer service to the next level, TSMC supports its clients in different business prospects such as inventory planning, new employee training, and sales, and grows alongside them during their early stages. For example, in 1997, Jensen Huang from Nvidia approached Morris Chang for TSMC's foundry services for its graphics chips and expressed a willingness to work exclusively with TSMC. **Recognizing this opportunity, TSMC agreed and even sent two engineers to Nvidia, then shorthanded, for over a month to assist with procurement, inventory, sales, and other operational tasks.**[212] From 1997 to 2023, Nvidia's sales grew from $29 million to over $60 billion,[213] representing a 34% CAGR. Nvidia has remained one of TSMC's top five customers since 1998 and has even been its largest customer in some years.

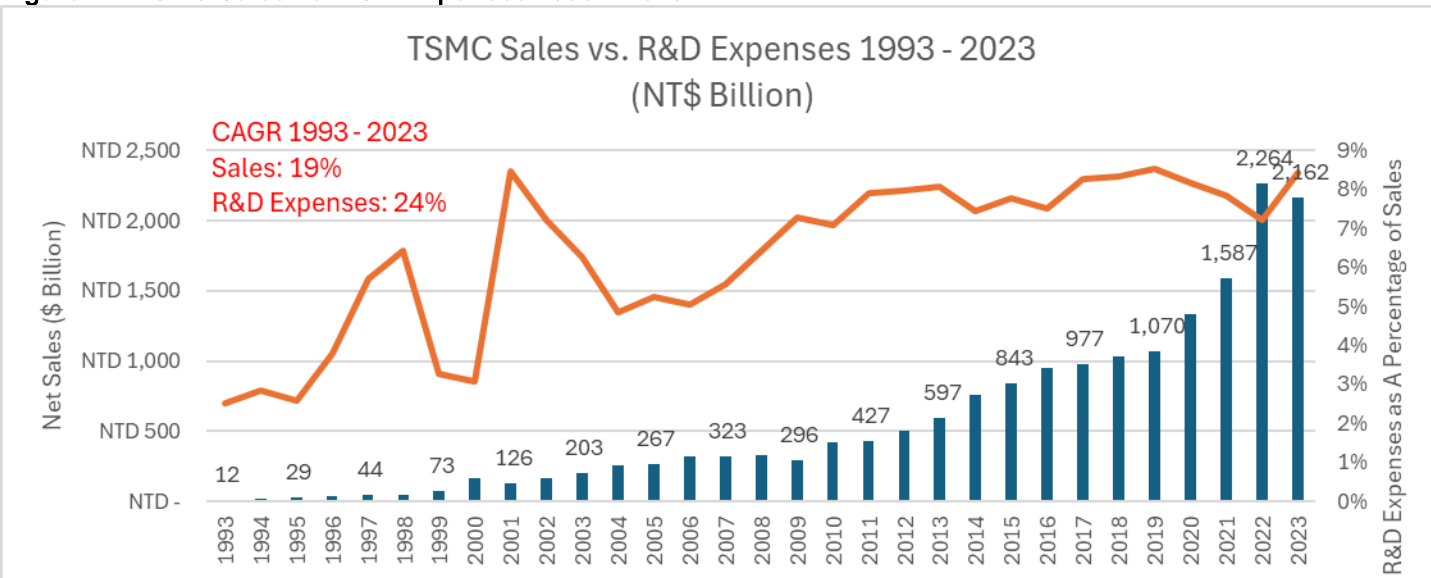
TSMC also adheres to several key principles during market downturns.[214] **First, the company prioritizes supporting its partnerships with customers and suppliers.** When customers or suppliers significantly reduce their orders during a downturn, TSMC works to reasonably adjust to their requests. The company firmly believes that the semiconductor industry will experience long-term growth, and any disruptions are merely transitory. Maintaining strong relationships with customers and suppliers ensures mutual benefits when the market eventually recovers. **Second, TSMC does not resort to laying off employees to cut costs during downturns.** However, in 2008, under the leadership of a new president, the company laid off 800 employees based on KPI assessments.[215] This decision was later reversed by Morris Chang, who reinstated the employees and brought them back into the company. The company views layoffs as a costly decision, not only due to severance packages but also because of the high costs associated with retraining new employees in the future. Layoffs can significantly damage employee morale, as they may perceive that the management team does not value its employees and sees them merely as an expense.[216] Additionally, TSMC continues to invest in research and development during downturns, recognizing these periods as opportunities to acquire top talent, as competitors often

---

[208] Translated or rephrased by the author on a best effort basis. Chapter 26. Morris Chang: An Autobiography. Part II.
[209] Interview with A Former Director at TSMC. 9/17/2024.
[210] Company Info. TSMC. https://www.tsmc.com/english/aboutTSMC/company_profile#:~:text=In%202023%2C%20TSMC%20served%20528,automotive%2C%20and%20digital%20consumer%20electronics
[211] Translated or rephrased by the author on a best effort basis. Chapter 24. Morris Chang: An Autobiography. Part II.
[212] Translated or rephrased by the author on a best effort basis. Chapter 26. Morris Chang: An Autobiography. Part II.
[213] Nvidia S-1 1998; Nvidia Annual Report 2023.
[214] Translated or rephrased by the author on a best effort basis. Chapter 29. Morris Chang: An Autobiography. Part II.
[215] Translated or rephrased by the author on a best effort basis. Chapter 31. Morris Chang: An Autobiography. Part II.
[216] Translated or rephrased by the author on a best effort basis. Chapter 32. Morris Chang: An Autobiography. Part II.

reduce hiring. For instance, during the global semiconductor industry downturn from 2001 to 2003, TSMC's sales declined from NTD 166 billion in 2000 to NTD 126 billion in 2001 and nearly recovered in 2002. Despite this, TSMC doubled its R&D expenses, from NTD 5.1 billion (3% of sales) to over NTD 10 billion (nearly 9% of sales) from 2000 to 2001. In 2009, the company set a target for R&D expenses to account for 8% of its annual revenue moving forward.

Figure 22: TSMC Sales vs. R&D Expenses 1993 – 2023



Morris Chang, who gained experience working on custom products at Texas Instruments, understood the difficulty of earning customers' trust in this business. He recognized that to succeed with custom products, TSMC had to build trust with its clients from the very beginning. Chang noted that many integrated device manufacturers in the U.S. and Japan treated customer fabrication as a sideline business, potentially competing with those same customers they serve.[217]

A notable example is Apple's engagement with Intel before the launch of the first iPhone in 2007. Steve Jobs met with Intel's then-CEO, Paul Otellini, to discuss equipping the iPhone with Intel chips. Since the iPhone was initially intended to run Apple's Mac operating system, using Intel chips, which had already powered Apple's Mac computers, seemed like a logical choice. However, Jobs ultimately rejected Intel's offer, perceiving the company as slow-moving and fearing Intel might sell the same chips to Apple's competitors.[218] Intel, in turn, also declined Apple's request, viewing the mobile phone processor market as too small to justify the high costs of R&D and chip production. Designing and manufacturing chips is an expensive endeavor, and at the time, Intel believed there was little chance of recouping the investment through production volume. Otellini later admitted in a 2013 interview that Intel had misjudged the potential volume of iPhone sales by a factor of 100.[219]

By 2023, as illustrated in Figure 13, smartphones and communication-related products accounted for nearly one-third of semiconductor end-use. Initially, Apple turned to Samsung for chips in its early iPhone models. By 2010, Apple began designing its own processors, starting with the A4 chip,[220] reducing its dependence on third-party suppliers like Samsung. This shift became increasingly critical as Samsung launched its first Android phone in 2009.[221] In 2011, Apple began

---

[217] Translated or rephrased by the author on a best effort basis. Chapter 20. Morris Chang: An Autobiography. Part II.

[218] U.S. Chipmaker Intel Was Once Dominant, Now Struggles to Stay Relevant. CNBC. https://www.cnbc.com/2024/04/26/intel-dominated-us-chip-industry-now-struggling-to-stay-relevant.html#:~:text=Processors%20get%20faster%20with%20more,1%2C000%20times%20smaller%20than%20micrometers

[219] Paul Otellini's Intel Can the Company That Built the Future Survive It. The Atlantic. https://www.theatlantic.com/technology/archive/2013/05/paul-otellinis-intel-can-the-company-that-built-the-future-survive-it/275825/

[220] The Suppliers Making the iPhone Possible. https://quartr.com/insights/company-research/the-suppliers-making-the-iphone-possible

[221] Samsung's First Android Phone was Launched 15 Years Ago. https://www.sammobile.com/news/samsung-first-android-phone-i7500-galaxy-launched-15-years-ago/

outsourcing chip production to TSMC, shifting away from Samsung. By 2020, Apple fully transitioned from Intel for its Mac computers, switching to its own M-series chips, also manufactured by TSMC.[222]

As aforementioned, in contrast to foundries within IDMs such as Intel and Samsung, TSMC positions itself as a pure manufacturing partner, earning the trust of customers who design integrated circuits. Unlike Intel and Samsung, which fabricate wafers for both their own products and third-party clients, TSMC's business model eliminates any concerns that customers might have about potential competition from it. This allows its customers to focus exclusively on circuit design without needing to invest heavily in their own manufacturing plants or R&D for production. As a result, clients can allocate more capital to chip design and functionality, leaving the complexities of manufacturing to TSMC. A former Chief Technology Officer at Synopsys, who had collaborated with global chip manufacturers such as TSMC, Intel, GlobalFoundries, and Samsung, noted that Samsung produces a large volume of chips for its own phones. This creates a conflict of interest, as the foundry may prioritize internal chip production over external clients. In contrast, TSMC does not design or manufacture its own chips, allowing them to focus entirely on serving their customers' needs without competing interests. As a result, TSMC consistently prioritizes its clients, while Samsung, despite having excellent technology, has struggled to gain the same level of market traction.[223]

This approach enhances efficiency and flexibility for TSMC's clients. Over the past two decades, Intel, Nvidia, and AMD have each invested nearly 20% of their sales into R&D (Intel ~18%, Nvidia and AMD ~22%), as Figure 23-1 shows. However, Intel remains the only integrated device manufacturer among the three, while Nvidia and AMD (since 2009) have adopted a fabless model, outsourcing chip production to foundries like TSMC. As a result, integrated device manufacturers must divide their R&D budgets between chip design and manufacturing, whereas fabless companies can focus all their resources on design. This allows fabless firms to potentially develop better chips in relatively lower R&D expenditures over the long term. Intel's R&D expenses as a percentage of revenue have increased from the low teens in the early 2000s to nearly 30% by 2023. In comparison, Nvidia and AMD's R&D spending has been relatively steady and ranged from the mid-teens to the mid-twenties over the same period.

The capital expenditure (CAPEX) of these companies reflects similar trends to their R&D spending. Fabless companies invest significantly less in CAPEX compared to IDMs and foundries, allowing them to allocate more capital to areas critical for chip design, such as R&D. For example, in 2023, fabless Nvidia and AMD reported CAPEX of $1 billion and $0.6 billion, respectively, as illustrated in Figure 23-4. In contrast, Intel, an IDM, spent nearly $26 billion on CAPEX. Meanwhile, TSMC's CAPEX exceeded $30 billion. This stark difference highlights the advantage fabless companies gain by outsourcing the fabrication process to foundries. By avoiding the substantial costs associated with building and maintaining fabrication facilities, fabless companies can potentially redirect a significant portion of their capital toward R&D. On average, fabless companies such as Nvidia and AMD allocate a mid-single-digit percentage of their sales to CAPEX. In contrast, Intel, an integrated device manufacturer, has historically invested a mid-teen percentage of its sales. However, starting in 2022, Intel began significantly increasing its CAPEX, reaching nearly 50% by 2023, as the company works to catch up with chipmakers that outsource advanced process node production to TSMC such as AMD and Nvidia in different segments of processors.

Meanwhile, dedicated foundries such as TSMC, UMC, and SMIC have already consistently invested a substantial portion of their sales in CAPEX to expand production capacity for both new and existing process nodes. Over the past two decades, TSMC has averaged CAPEX investments of around 40% of sales, UMC around 30%, and SMIC approximately 70%.

A 2021 McKinsey report highlights the sharp increase in both R&D and CAPEX as the semiconductor industry advances to smaller, more complex nodes, as Figure 23-5 shows.[224] As chip designs shrink and manufacturing precision increases, the cost of building fabs has grown significantly, often surpassing the R&D expenses required to develop chips at the same process nodes. For example, the average design cost for a 5nm chip is approximately $540 million, compared to $297 million for 7nm, $174 million for 10nm, and $104 million for 16nm. Meanwhile, the cost of constructing and equipping a facility for 5nm production is around $5.4 billion, whereas 7nm fabs cost $2.9 billion, 10nm fabs cost $1.7 billion, and 16nm facilities cost $1.3 billion. In addition to the financial investment, fab construction typically takes between 12 and 24 months, with another 12 to 18 months needed to achieve full production capacity.

---

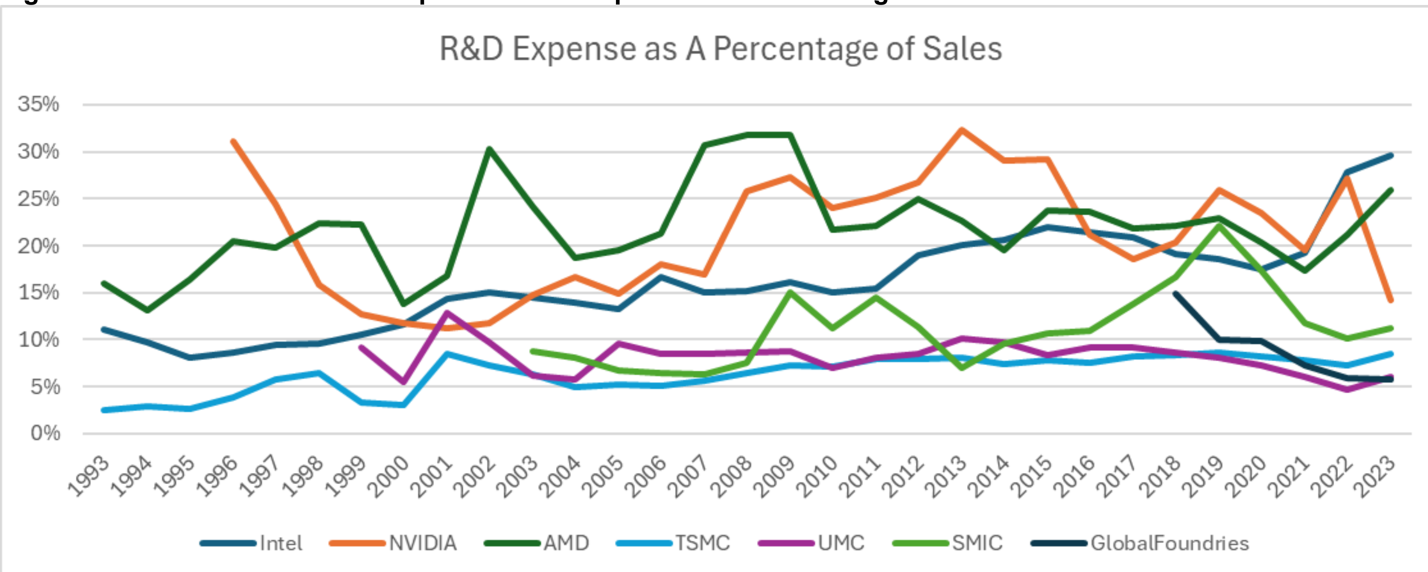
[222] The Suppliers Making the iPhone Possible. https://quartr.com/insights/company-research/the-suppliers-making-the-iphone-possible

[223] Interview with A Former CTO at Synopsys. 10/1/2024.

[224] McKinsey on Semiconductors. McKinsey & Company. November 2021.

For decades, Intel maintained a leading edge in process nodes but gradually lost ground to competitors such as AMD and Nvidia, which outsource to TSMC for production. In 2014, Intel began mass production of 14nm chips,[225] while TSMC was still producing at the 20nm node.[226] However, Intel faced repeated delays in rolling out its 10nm process in the following years. By 2023, TSMC had taken the lead with 3nm technology, while Intel continued to struggle with its 7nm process. In the fast-moving semiconductor industry, delays often compound,[227] making it difficult to catch up. Since 2021, Intel has begun outsourcing some of its flagship processors, including graphics chips for personal computers, to TSMC. This move focuses on utilizing TSMC's advanced nodes, specifically 7nm and below, to better compete with the rising dominance of Nvidia.[228]

Figure 23-1: Semiconductor Companies' R&D Expense as A Percentage of Sales



	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Intel R&D expense as % of sales	11.0%	9.6%	8.0%	8.7%	9.4%	9.5%	10.6%	11.6%	14.3%	15.1%	14.5%	14.0%	13.3%	16.6%	15.0%	15.2%
Nvidia R&D expense as % of sales				31.1%	24.4%	15.8%	12.7%	11.8%	11.2%	11.8%	14.8%	16.7%	14.8%	18.0%	16.9%	25.8%
AMD R&D expense as % of sales	15.9%	13.1%	16.4%	20.5%	19.9%	22.3%	22.2%	13.8%	16.7%	30.3%	24.2%	18.7%	19.6%	21.3%	30.7%	31.8%
TSMC R&D expense as % of sales	2.5%	2.8%	2.6%	3.8%	5.7%	6.4%	3.3%	3.1%	8.5%	7.2%	6.3%	4.9%	5.3%	5.1%	5.6%	6.4%
UMC R&D expense as % of sales							9.2%	5.5%	12.8%	9.8%	6.1%	5.7%	9.6%	8.4%	8.5%	8.5%
SMIC R&D expense as % of sales											8.8%	8.0%	6.7%	6.4%	6.3%	7.6%
GlobalFoundries R&D expense as % of sales																

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Intel R&D expense as % of sales	16.1%	15.1%	15.5%	19.0%	20.1%	20.7%	21.9%	21.5%	20.9%	19.1%	18.6%	17.4%	19.2%	27.8%	29.6%
Nvidia R&D expense as % of sales	27.3%	24.0%	25.1%	26.8%	32.3%	29.0%	29.2%	21.2%	18.5%	20.3%	25.9%	23.5%	19.6%	27.2%	14.2%
AMD R&D expense as % of sales	31.9%	21.6%	22.1%	25.0%	22.7%	19.5%	23.7%	23.6%	21.8%	22.1%	23.0%	20.3%	17.3%	21.2%	25.9%
TSMC R&D expense as % of sales	7.3%	7.1%	7.9%	8.0%	8.1%	7.4%	7.8%	7.5%	8.3%	8.3%	8.5%	8.2%	7.9%	7.2%	8.4%
UMC R&D expense as % of sales	8.8%	6.9%	8.1%	8.5%	10.1%	9.8%	8.4%	9.2%	9.2%	8.6%	8.0%	7.3%	6.1%	4.6%	6.0%
SMIC R&D expense as % of sales	15.0%	11.2%	14.5%	11.4%	7.0%	9.6%	10.6%	10.9%	13.8%	16.6%	22.1%	17.3%	11.7%	10.1%	11.2%
GlobalFoundries R&D expense as % of sales										14.9%	10.0%	9.8%	7.3%	5.9%	5.8%

Notes:

1. Data from FactSet and company documents.
2. UMC's annual reports prior to 1998 are not available.
3. Nvidia went public in 1999.
4. SMIC went public in 2004.
5. GlobalFoundries went public in 2021.

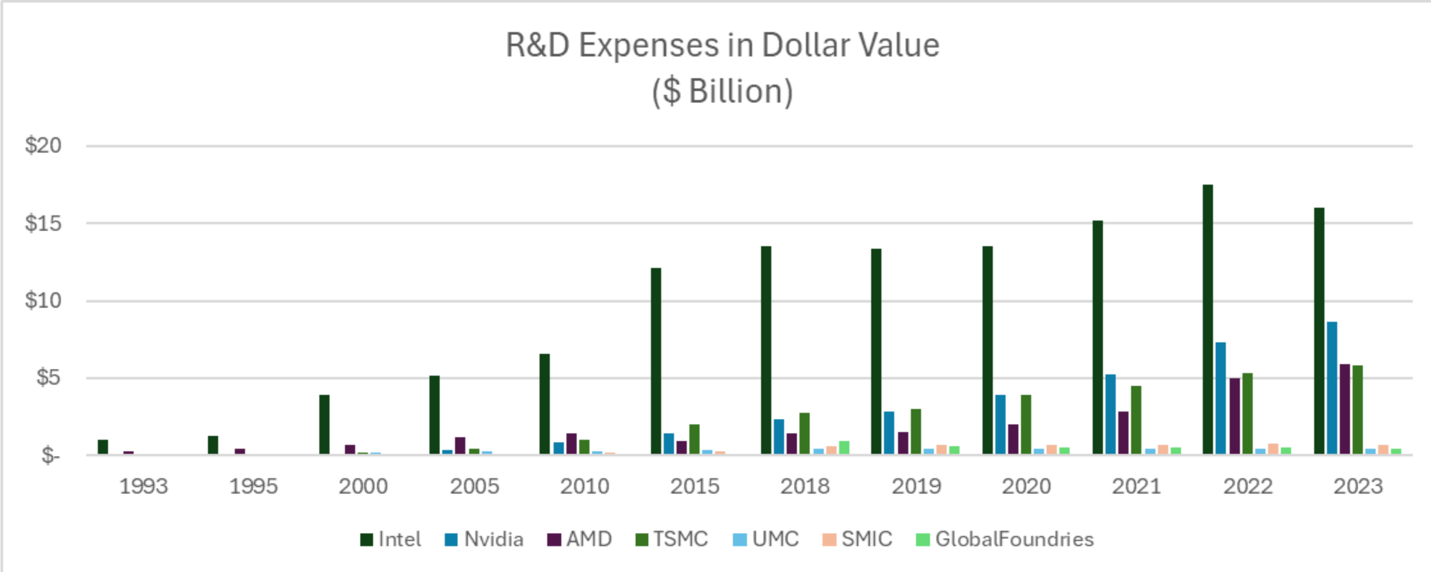
[225] Intel Annual Report 2014.

[226] TSMC Annual Report 2014. Logic Technology. https://www.tsmc.com/english/dedicatedFoundry/technology/logic

[227] U.S. Chipmaker Intel Was Once Dominant, Now Struggles to Stay Relevant. CNBC. https://www.cnbc.com/2024/04/26/intel-dominated-us-chip-industry-now-struggling-to-stay-relevant.html#:~:text=Processors%20get%20faster%20with%20more,1%2C000%20times%20smaller%20than%20micrometers

[228] Intel Special Call. 8/19/2021; Intel to Tap TSMC to Make New Chip Using Enhanced 7nm Process. Reuters. https://www.cnbc.com/2021/01/12/intel-to-tap-tsmc-to-make-new-chip-using-enhanced-7-nm-process-reuters.html

Figure 23-2: Semiconductor Companies' R&D Expense in Dollar Value



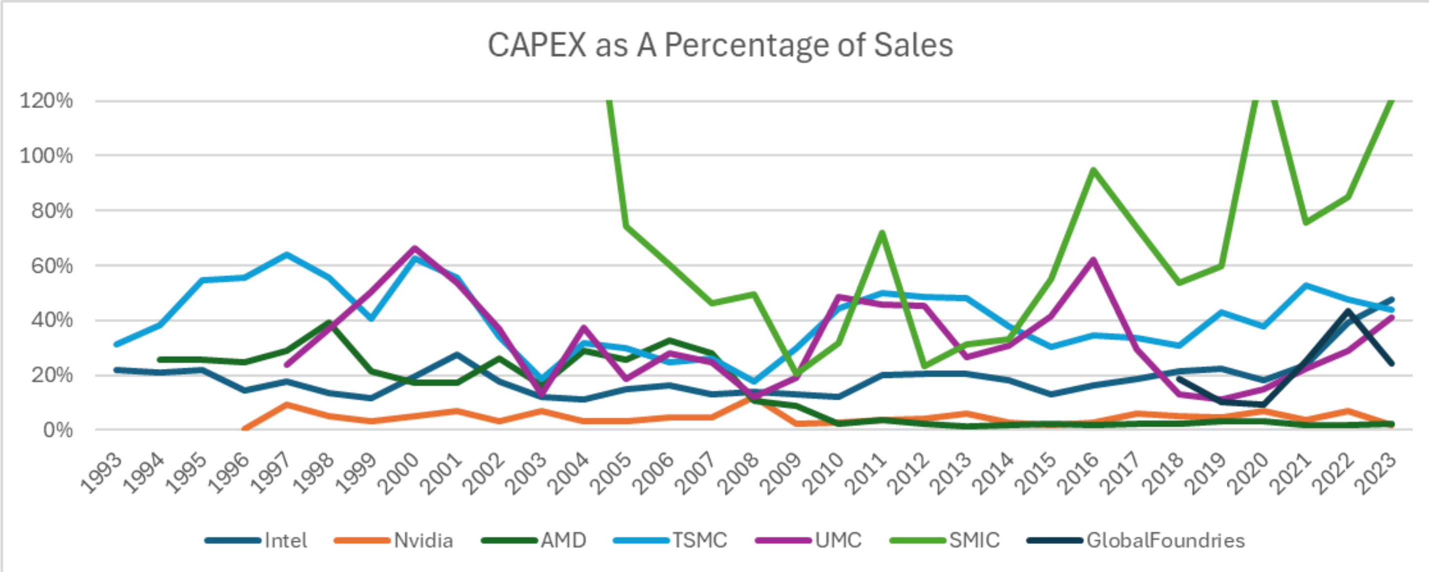
$ Billion	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Intel R&D expense	$ 1.0	$ 1.1	$ 1.3	$ 1.8	$ 2.3	$ 2.5	$ 3.1	$ 3.9	$ 3.8	$ 4.0	$ 4.4	$ 4.8	$ 5.1	$ 5.9	$ 5.8	$ 5.7
Nvidia R&D expense				$ 0.0	$ 0.0	$ 0.0	$ 0.0	$ 0.1	$ 0.2	$ 0.2	$ 0.3	$ 0.3	$ 0.4	$ 0.6	$ 0.7	$ 0.9
AMD R&D expense	$ 0.3	$ 0.3	$ 0.4	$ 0.4	$ 0.5	$ 0.6	$ 0.6	$ 0.6	$ 0.7	$ 0.8	$ 0.9	$ 0.9	$ 1.1	$ 1.2	$ 1.8	$ 1.8
TSMC R&D expense	$ 0.0	$ 0.0	$ 0.0	$ 0.1	$ 0.1	$ 0.1	$ 0.1	$ 0.2	$ 0.3	$ 0.3	$ 0.4	$ 0.4	$ 0.4	$ 0.5	$ 0.6	$ 0.6
UMC R&D expense							$ 0.1	$ 0.2	$ 0.3	$ 0.2	$ 0.2	$ 0.2	$ 0.3	$ 0.3	$ 0.3	$ 0.2
SMIC R&D expense											$ 0.0	$ 0.1	$ 0.1	$ 0.1	$ 0.1	$ 0.1
GlobalFoundries R&D expense																

$ Billion	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Intel R&D expense	$ 5.7	$ 6.6	$ 8.4	$ 10.2	$ 10.6	$ 11.5	$ 12.1	$ 12.7	$ 13.1	$ 13.5	$ 13.4	$ 13.6	$ 15.2	$ 17.5	$ 16.1
Nvidia R&D expense	$ 0.9	$ 0.8	$ 1.0	$ 1.1	$ 1.3	$ 1.4	$ 1.5	$ 1.5	$ 1.8	$ 2.4	$ 2.8	$ 3.9	$ 5.3	$ 7.3	$ 8.7
AMD R&D expense	$ 1.7	$ 1.4	$ 1.5	$ 1.4	$ 1.2	$ 1.1	$ 0.9	$ 1.0	$ 1.2	$ 1.4	$ 1.5	$ 2.0	$ 2.8	$ 5.0	$ 5.9
TSMC R&D expense	$ 0.7	$ 1.0	$ 1.1	$ 1.4	$ 1.6	$ 1.8	$ 2.0	$ 2.2	$ 2.7	$ 2.8	$ 3.0	$ 3.9	$ 4.5	$ 5.3	$ 5.8
UMC R&D expense	$ 0.2	$ 0.3	$ 0.3	$ 0.3	$ 0.4	$ 0.4	$ 0.4	$ 0.4	$ 0.5	$ 0.4	$ 0.4	$ 0.5	$ 0.5	$ 0.4	$ 0.4
SMIC R&D expense	$ 0.2	$ 0.2	$ 0.2	$ 0.2	$ 0.1	$ 0.2	$ 0.2	$ 0.3	$ 0.4	$ 0.6	$ 0.7	$ 0.7	$ 0.6	$ 0.7	$ 0.7
GlobalFoundries R&D expense										$ 0.9	$ 0.6	$ 0.5	$ 0.5	$ 0.5	$ 0.4

Notes:
1. Data from FactSet and company documents.
2. UMC's annual reports prior to 1998 are not available.
3. Nvidia went public in 1999.
4. SMIC went public in 2004.
5. GlobalFoundries went public in 2021.
6. The exchange rates for NTD/USD used to convert R&D expenses of TSMC and UMC were based on the December rates of each year, as provided by the Federal Reserve Bank of St. Louis.[229]

[229] Taiwan Dollars to U.S. Dollar Spot Exchange Rate (EXTAUS). Federal Reserve Bank of St. Louis. https://fred.stlouisfed.org/series/EXTAUS

Figure 23-3: Semiconductor Companies' Capital Expenditure as A Percentage of Sales

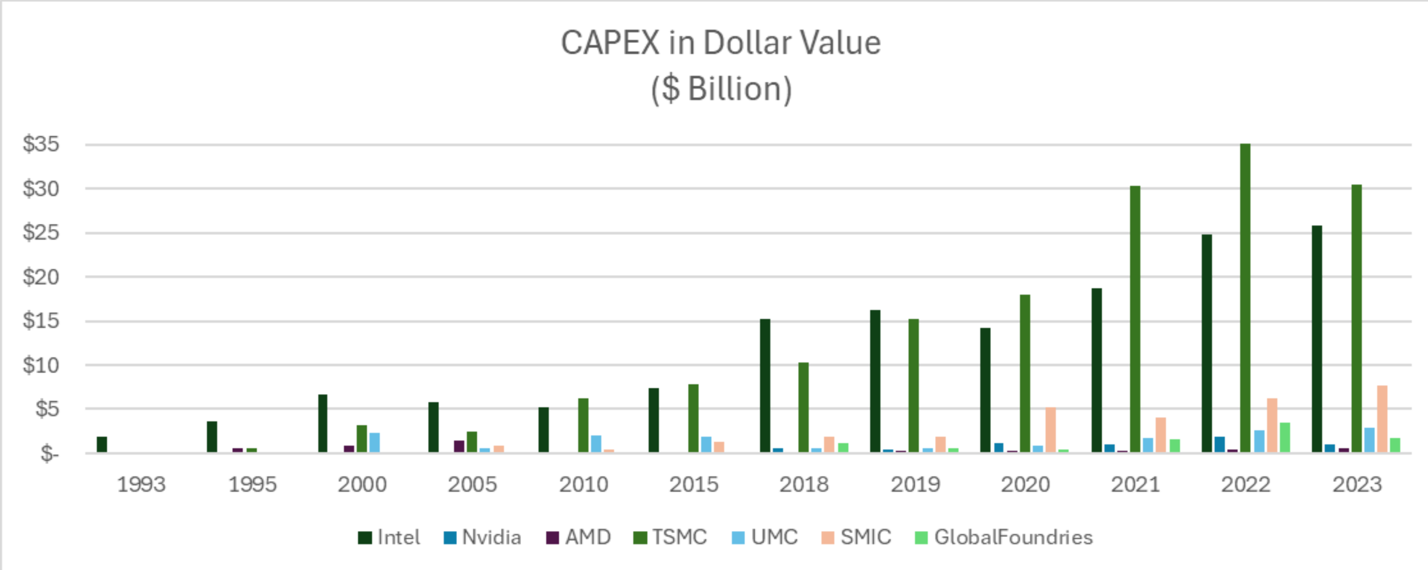


	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Intel CAPEX as a percentage of sales	22.0%	21.2%	21.9%	14.5%	18.0%	13.5%	11.6%	19.8%	27.5%	17.6%	12.1%	11.2%	15.0%	16.3%	13.0%	13.8%
Nvidia CAPEX as a percentage of sales				0.2%	9.4%	5.0%	3.1%	4.9%	7.1%	3.3%	7.0%	3.3%	3.4%	4.7%	4.6%	11.9%
AMD CAPEX as a percentage of sales		25.7%	25.6%	24.8%	29.1%	39.2%	21.7%	17.3%	17.4%	26.1%	16.2%	28.8%	25.9%	32.9%	28.0%	10.7%
TSMC CAPEX as % of sales	31.3%	38.3%	54.8%	55.6%	63.8%	55.7%	40.8%	62.4%	55.8%	34.0%	18.7%	31.5%	30.0%	24.8%	26.0%	17.8%
UMC CAPEX as % of sales					23.9%	37.0%	50.6%	66.3%	53.9%	37.0%	13.1%	37.5%	18.5%	27.9%	24.8%	11.9%
SMIC CAPEX as % of sales											123.9%	188.7%	74.5%	60.2%	46.3%	49.4%
GlobalFoundries CAPEX as % of sales																

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Intel CAPEX as a percentage of sales	12.8%	11.9%	19.9%	20.7%	20.3%	18.1%	13.2%	16.2%	18.8%	21.4%	22.5%	18.3%	23.7%	39.4%	47.5%
Nvidia CAPEX as a percentage of sales	2.3%	2.8%	3.5%	4.3%	6.2%	2.6%	1.7%	2.5%	6.1%	5.1%	4.5%	6.8%	3.6%	6.8%	1.8%
AMD CAPEX as a percentage of sales	8.6%	2.3%	3.8%	2.5%	1.6%	1.7%	2.4%	1.8%	2.1%	2.5%	3.2%	3.0%	1.8%	1.9%	2.4%
TSMC CAPEX as % of sales	29.7%	44.6%	50.1%	48.6%	48.2%	37.8%	30.5%	34.6%	33.8%	30.6%	43.0%	37.9%	52.9%	47.8%	43.9%
UMC CAPEX as % of sales	19.3%	48.5%	45.7%	45.1%	26.6%	30.9%	41.8%	61.9%	29.6%	13.0%	11.1%	14.9%	22.6%	28.7%	41.1%
SMIC CAPEX as % of sales	20.3%	31.6%	72.0%	23.5%	31.4%	33.2%	55.0%	94.6%	73.8%	53.8%	60.0%	135.0%	75.7%	84.9%	120.7%
GlobalFoundries CAPEX as % of sales										18.6%	10.1%	9.3%	25.2%	43.3%	24.4%

Notes:
1. Data from FactSet and company documents.
2. UMC's annual reports prior to 1998 are not available.
3. Nvidia went public in 1999.
4. SMIC went public in 2004.
5. GlobalFoundries went public in 2021.
6. Nvidia CAPEX includes acquisitions of intangible assets.
7. AMD spun off its foundry (GlobalFoundries) in 2009.

Figure 23-4: Semiconductor Companies' Capital Expenditure in Dollar Value



$ Billion	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Intel CAPEX	$ 1.93	$ 2.44	$ 3.55	$ 3.02	$ 4.50	$ 3.56	$ 3.40	$ 6.67	$ 7.31	$ 4.70	$ 3.66	$ 3.84	$ 5.82	$ 5.78	$ 5.00	$ 5.20
Nvidia CAPEX				$ 0.00	$ 0.00	$ 0.01	$ 0.01	$ 0.04	$ 0.10	$ 0.06	$ 0.13	$ 0.07	$ 0.08	$ 0.15	$ 0.19	$ 0.41
AMD CAPEX		$ 0.55	$ 0.62	$ 0.49	$ 0.69	$ 1.00	$ 0.62	$ 0.81	$ 0.68	$ 0.71	$ 0.57	$ 1.44	$ 1.51	$ 1.86	$ 1.69	$ 0.62
TSMC CAPEX	$ 0.14	$ 0.28	$ 0.58	$ 0.80	$ 0.86	$ 0.87	$ 0.94	$ 3.13	$ 2.02	$ 1.59	$ 1.11	$ 2.52	$ 2.40	$ 2.42	$ 2.59	$ 1.79
UMC CAPEX					$ 0.18	$ 0.21	$ 0.47	$ 2.31	$ 1.08	$ 0.80	$ 0.37	$ 1.51	$ 0.56	$ 0.96	$ 0.87	$ 0.35
SMIC CAPEX											$ 0.45	$ 1.84	$ 0.87	$ 0.88	$ 0.72	$ 0.67
GlobalFoundries CAPEX																

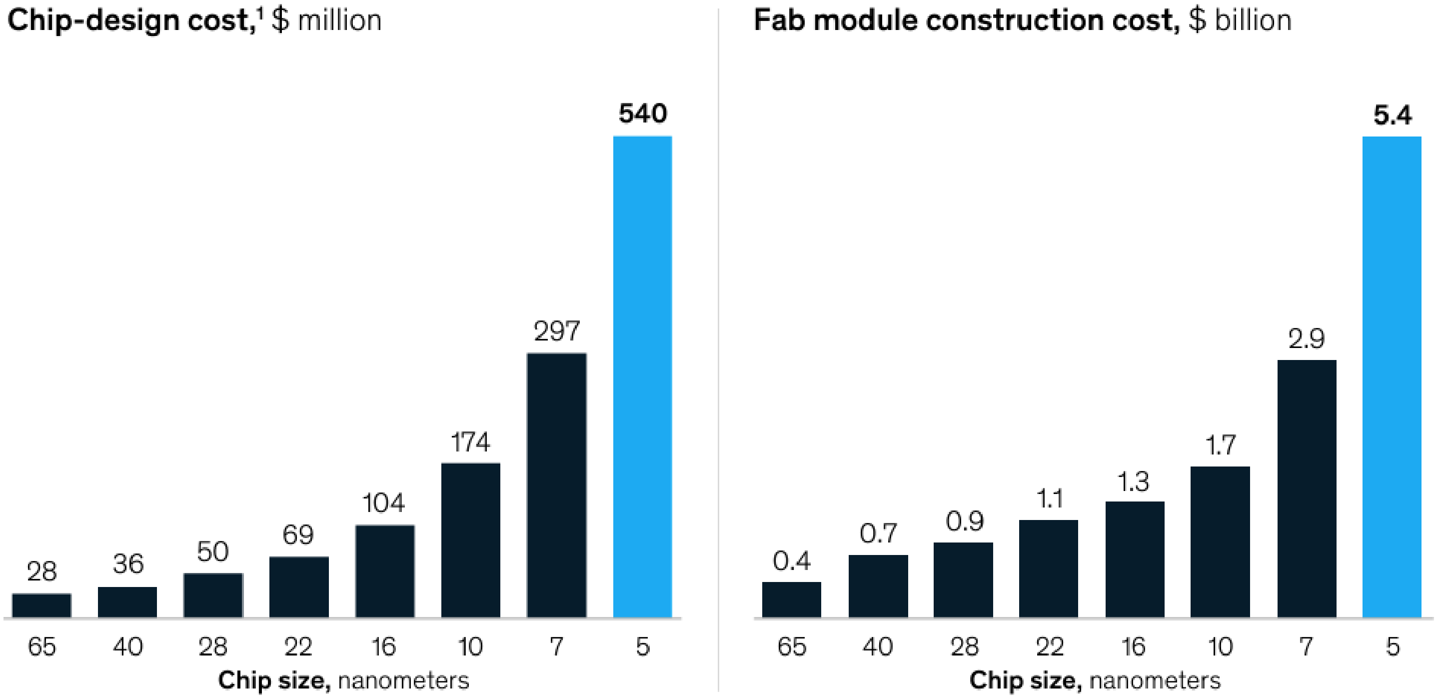
$ Billion	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Intel CAPEX	$ 4.51	$ 5.21	$10.76	$11.03	$10.71	$10.11	$ 7.33	$ 9.63	$11.78	$15.18	$16.21	$14.26	$18.73	$24.84	$25.75
Nvidia CAPEX	$ 0.08	$ 0.10	$ 0.14	$ 0.18	$ 0.26	$ 0.12	$ 0.09	$ 0.18	$ 0.59	$ 0.60	$ 0.49	$ 1.13	$ 0.98	$ 1.83	$ 1.07
AMD CAPEX	$ 0.47	$ 0.15	$ 0.25	$ 0.13	$ 0.08	$ 0.10	$ 0.10	$ 0.08	$ 0.11	$ 0.16	$ 0.22	$ 0.29	$ 0.30	$ 0.45	$ 0.55
TSMC CAPEX	$ 2.72	$ 6.25	$ 7.07	$ 8.47	$ 9.68	$ 9.20	$ 7.85	$10.25	$11.04	$10.25	$15.22	$17.99	$30.24	$35.32	$30.39
UMC CAPEX	$ 0.55	$ 2.05	$ 1.76	$ 1.80	$ 1.11	$ 1.38	$ 1.85	$ 2.86	$ 1.48	$ 0.64	$ 0.55	$ 0.93	$ 1.73	$ 2.61	$ 2.93
SMIC CAPEX	$ 0.22	$ 0.49	$ 0.95	$ 0.40	$ 0.65	$ 0.65	$ 1.23	$ 2.76	$ 2.29	$ 1.81	$ 1.87	$ 5.27	$ 4.12	$ 6.17	$ 7.63
GlobalFoundries CAPEX										$ 1.15	$ 0.59	$ 0.45	$ 1.66	$ 3.51	$ 1.80

Notes:

1. Data from FactSet and company documents.
2. UMC's annual reports prior to 1998 are not available.
3. Nvidia went public in 1999.
4. SMIC went public in 2004.
5. GlobalFoundries went public in 2021.
6. Nvidia CAPEX includes acquisitions of intangible assets.
7. AMD spun off its foundry (GlobalFoundries) in 2009.
8. The exchange rates for NTD/USD used to convert CAPEX of TSMC and UMC were based on the December rates of each year, as provided by the Federal Reserve Bank of St. Louis.[230]

[230] Taiwan Dollars to U.S. Dollar Spot Exchange Rate (EXTAUS). Federal Reserve Bank of St. Louis. https://fred.stlouisfed.org/series/EXTAUS

Figure 23-5: R&D for Chips and Fab Module Construction Costs[231]



[1]Major components include IP qualification, architecture, verification, physical, software, prototyping, and validation.
Source: IBS; McKinsey

Moreover, IDMs often struggled to fabricate wafers for other companies as efficiently as a dedicated foundry. For example, Intel's fabrication processes were tailored specifically for its own production needs, ensuring that each Intel fab was an exact copy of the others.[232] While this approach optimized Intel's internal operations, it limited the company's ability to adapt its manufacturing technology to meet the diverse requirements of external customers, thereby hindering its ability to become a major player in the foundry business. In contrast, TSMC built its business to cater to a wide range of semiconductor customers. This flexibility enabled TSMC to meet diverse customer demands and apply its manufacturing accumulated over large production volume across different platforms, making it a leader in the semiconductor foundry segment.

TSMC has built its reputation on its unwavering philosophy: "We do not make commitments lightly. Therefore, once we make a commitment, we devote ourselves completely to meeting that commitment."[233] This steadfast dedication to its customers has served TSMC well, helping the company win and retain significant clients over the long term. For example, in 2011, when Apple approached TSMC as a potential customer, it requested TSMC to fabricate chips at the 20nm process node. At the time, TSMC was producing at 28nm and actively developing 16nm, the next full process node. Shifting focus to the 20nm process, considered a "half-node" relative to 16nm, would have been a detour from TSMC's long-term R&D roadmap. However, recognizing the value of securing Apple as a customer, TSMC took on the challenge and invested over $10 billion to develop the 20nm process. As anticipated, by 2013, while TSMC was ready for mass production at 20nm, it fell behind on 16nm development. This delay caused TSMC to lose Apple's next order to Samsung, which had stayed focused on advancing its 16nm technology. Despite this setback, TSMC's earlier commitment to Apple built trust. Apple assured TSMC that once it could deliver at the 16nm node, Apple would return as a customer. True to its word, Apple resumed its partnership with TSMC, which has since become one of Apple's largest and most trusted suppliers. Jeff Williams, Apple's Chief Operating Officer, once described the relationship to Morris Chang privately by saying, "TSMC is one of the few best partners to Apple."[234]

When TSMC launched in 1987, it adopted two primary strategies. The primary strategy was to target the U.S. and Europe, then the world's largest semiconductor markets combined, which Morris Chang estimated accounted for over 50% of global sales at the time (as illustrated in Figure 12-1 and 12-2 above).[235] To enter the U.S. market, Chang recruited Jame

---

[231] McKinsey on Semiconductors. McKinsey & Company. November 2021.
[232] Translated or rephrased by the author on a best effort basis. Chapter 26. Morris Chang: An Autobiography. Part II.
[233] Values and Business Philosophy. TSMC. https://www.tsmc.com/english/aboutTSMC/values
[234] Translated or rephrased by the author on a best effort basis. Chapter 33. Morris Chang: An Autobiography. Part II.
[235] Translated or rephrased by the author on a best effort basis. Chapter 18. Morris Chang: An Autobiography. Part II.

Dykes, formerly director of semiconductor operations at General Electric, as TSMC's first president (1987–1988), because the newly formed local team had no experience in the international market.[236]. From 1988 to 1991, Kalus Wiemer, a former Texas Instruments engineer, served as TSMC's second president.[237] Donald Brook, a former colleague and subordinate of Morris Chang from Texas Instruments, took over as the third president from 1991 to 1997.[238]

The second strategy involved leveraging TSMC's existing yield rates on trial lines, initially focusing on low-cost products such as digital watch integrated circuits, to enter mid- and high-end markets in the U.S. and Europe. While TSMC did not disclose its yield rates at the time of its founding, Morris Chang noted that the rates were at a good level for trial lines.

Although TSMC does not publicly disclose its overall or process-node-specific yield rates, industry participants estimated that when the company's 3nm process node entered production in 2022, the yield rate ranged from 60% to 80%, a strong result for early production batches. In contrast, Samsung's 3nm production was estimated to have yield rates between 10% and 20%, with little improvement since the early stages and significant variability in chip quality.[239] By Q3 2024, Taiwanese media reported that the yield rate for TSMC's N3E, an enhanced version of its 3nm process node, had approached 90%.[240] Meanwhile, Samsung has reportedly considered outsourcing production of some of its flagship Exynos chips to TSMC, as Samsung continues to struggle with yield issues. The yield rate for Samsung's first-generation 3nm process reportedly ranged from 50% to 60%, while the second generation fell to around 20%, making it difficult to attract customers. However, since neither company officially discloses yield rates, this information remains speculative and unverifiable. A former TSMC employee stated that in 2022, Qualcomm encountered issues with the Snapdragon A95 and Snapdragon A98. Samsung Galaxy phones, one of the largest users of Qualcomm's CPUs and GPUs, experienced significant performance problems, high power consumption, and low production yields. Frustrated by these inefficiencies, Qualcomm decided to shift production from Samsung to TSMC, as Samsung's process was unable to meet performance and yield expectations.[241]

Depending on the customer, some sign contracts with TSMC to secure a guaranteed, predetermined capacity for a set number of years.[242] For example, in 2013, Apple and TSMC reportedly entered into a three-year agreement for Apple's A-series chips, including the A8, A9, and A9X.[243] As of 2024, while TSMC does not explicitly disclose its customer agreements, the company's 3nm process capacity is reportedly fully booked by Apple, Qualcomm, Nvidia, and AMD. This high demand has resulted in a queue of customers extending into 2026,[244] driven by TSMC's undisputed technological leadership in advanced process nodes.

By 1999, TSMC introduced a third key strategy: establishing technology leadership. This marked a shift from its original approach, which had been primarily focused on capitalizing on ITRI's superior yields in mature nodes. [245] From 1987 to 2000, TSMC's process technology advanced from the 2.0μm node inherited from ITRI to the 0.18μm node, spanning nine generations of progress.[246] TSMC also strives to remain technology-independent. For example, in 1999, the company declined an invitation from IBM – one of the earliest players in semiconductors, despite experiencing a slowdown – to collaborate on developing the next generation of process nodes. TSMC believed that sending its R&D teams thousands of miles away to IBM's facilities carried significant risks, particularly if the partnership encountered challenges such as ineffective communication or mutual disagreements, potentially ruining the outcome of the whole generation of new process node.

---

[236] Translated or rephrased by the author on a best effort basis. Chapter 18. Morris Chang: An Autobiography. Part II.
[237] Translated or rephrased by the author on a best effort basis. Chapter 19. Morris Chang: An Autobiography. Part II.
[238] Translated or rephrased by the author on a best effort basis. Chapter 19. Morris Chang: An Autobiography. Part II.
[239] Analysts Estimate TSMC's 3nm Yields Between 60% and 80%. https://www.tomshardware.com/news/analysts-estimate-tsmc-n3-yields-between-60-and-80-percent
[240] Samsung May Outsource Exynos Production to TSMC Due to Low 3nm Yield Rate. https://www.trendforce.com/news/2024/11/14/news-samsung-may-outsource-exynos-production-to-tsmc-due-to-low-3nm-yield-rate/#:~:text=On%20the%20other%20hand%2C%20TSMC's,%25%2C%20as%20the%20report%20noted; TSMC N3E Yield Rate Approach 90%. https://www.moneydj.com/kmdj/news/newsviewer.aspx?a=c0628954-6020-40af-946d-7e497e8f9814&c=MB010000
[241] Interview with A Former Consultant at TSMC. 10/25/2024
[242] TSMC Annual Report 2006
[243] Apple Reportedly Reaches Deal with TSMC for Next-Gen Chips. https://www.cnet.com/tech/tech-industry/apple-reportedly-reaches-deal-with-tsmc-for-next-gen-chips/
[244] Apple, Qualcomm, Nvidia, AMD Fully Book TSMC's 3nm Capacity. https://technode.com/2024/06/12/apple-qualcomm-nvidia-amd-fully-book-tsmcs-3nm-capacity-until-2026/
[245] Translated or rephrased by the author on a best effort basis. Chapter 27. Morris Chang: An Autobiography. Part II.
[246] Translated or rephrased by the author on a best effort basis. Chapter 27. Morris Chang: An Autobiography. Part II.

In 1987, TSMC's fabrication technology lagged two to three generations behind leading semiconductor companies like IBM, which were capable of mass-producing chips at 1.25μm to 1.0μm nodes, compared to TSMC's 2.0μm. However, by 1999, TSMC had risen to become a tier-1 semiconductor company, producing 0.18μm nodes with superior yield performance. In 2018, TSMC became the first foundry to achieve mass production of the 7nm process node, marking the first time it led the industry in advancing to a new generation of technology nodes that uses Extreme Ultraviolet (EUV) technology.[247] This milestone not only solidified TSMC's determination to become technology-independent but also strengthened its position as a global technology leader.[248] By 2023, TSMC achieved mass production of semiconductors at the 3nm node, with plans to begin volume production of 2nm chips by 2025.[249] This progress is closely followed by Samsung. In contrast, Intel, which was several generations ahead when TSMC was founded, now trails TSMC significantly in process node advancements. As of 2024, many of Intel's flagship chips are still produced at the 7nm node,[250] some of which have been outsourced to TSMC since 2021, while TSMC has already fabricated 3nm chips for its customers.

Notably, the partnership between TSMC and Intel did not just begin in recent years. In November 1987, within TSMC's first year of founding, Morris Chang received a call from a senior vice president at Intel expressing interest in visiting TSMC. At the time, Intel was the world's second-largest semiconductor company, behind Texas Instruments, but was seen as technologically more advanced and poised to overtake TI.[251] A few months later, Intel placed an order with TSMC to fabricate 1.5μm microcontrollers, then TSMC's most advanced technology but two generations (~three years) behind Intel's own. Intel chose TSMC to free up its resources for more advanced products. Rather than dictate the process, Intel requested TSMC to use its self-developed process nodes for qualification tests. Over three years, TSMC successfully completed two deals with Intel, transitioning from a team focused on low-tier products to a world-class manufacturing team. Intel's orders paved the way for other customers, including Philips, Texas Instruments, and Motorola, who outsourced to TSMC either to reallocate their resources to advanced products or to leverage TSMC's higher yields and lower costs. The yield rate in the early years was not provided by the company.

Although TSMC initially incurred losses on Intel's orders, it persisted, guided by its commitment to customers – "We do not make commitments lightly. Therefore, once we make a commitment, we devote ourselves completely to meeting that commitment."[252] During this period, Intel also outsourced to another company, which eventually abandoned the project due to losses.[253] TSMC's perseverance on Intel's orders became a milestone in Chang's view, validating its business model of being a dedicated foundry, manufacturing capabilities, and focus on the western market. In addition, it also solidified the company's value and business philosophy.

Being government-owned and -supported, especially in the beginning years when TSMC was founded, has played an important role in the company's success. In his autobiography, Morris Chang acknowledges that without the investment and help from the government, he was unable to start TSMC. Reflecting on his experience in both the U.S. and Taiwan, Chang thought that something still needs to be done by the government even in a "market economy",[254] without further explanation. This could be exemplified by TSMC's initial deals with Intel as mentioned above. Having the government as a major shareholder can allow a company to absorb greater losses, leveraging deep financial resources to secure business or achieve long-term goals. In contrast, being privately owned may lead to a stronger focus on short-term profitability, as private investors typically lack the same level of financial backing as the government. Chang stated that U.S. in recent years suddenly realized that they have lost most of the semiconductor manufacturing capabilities during the past three decades, which are essential to a country's defense and welfare, thus starting subsidies and local semiconductor facilities.

The relatively low operating costs in Taiwan also played a significant role in TSMC's success.[255] By 1996, as customers continued to demand increased production capacity, TSMC's plants in Taiwan boasted a strong 48% operating margin. Responding to these demands, Morris Chang and Donald Brooks, then president of TSMC, decided to form a joint

---

[247] EUV technology is essential for process nodes below 7nm. EUV technology is essential for process nodes below 7nm. TSMC Leads in Adoption of EUV. https://www.eetimes.com/tsmc-leads-in-adoption-of-euv/

[248] TSMC's Industry-First and Leading 7nm Technology Enters Volume Production. TSMC. https://esg.tsmc.com/en-US/articles/237; Translated or rephrased by the author on a best effort basis. Chapter 22. Morris Chang: An Autobiography. Part II.

[249] TSMC Annual Report 2023

[250] U.S. Chipmaker Intel Was Once Dominant, Now Struggles to Stay Relevant. CNBC. https://www.cnbc.com/2024/04/26/intel-dominated-us-chip-industry-now-struggling-to-stay-relevant.html#:~:text=Processors%20get%20faster%20with%20more,1%2C000%20times%20smaller%20than%20micrometers.

[251] Translated or rephrased by the author on a best effort basis. Chapter 19. Morris Chang: An Autobiography. Part II.

[252] Values and Business Philosophy. TSMC. https://www.tsmc.com/english/aboutTSMC/values

[253] Translated or rephrased by the author on a best effort basis. Chapter 19. Morris Chang: An Autobiography. Part II.

[254] Translated or rephrased by the author on a best effort basis. Chapter 22. Morris Chang: An Autobiography. Part II.

[255] Translated or rephrased by the author on a best effort basis. Chapter 24. Morris Chang: An Autobiography. Part II.

venture with its customers, Altera, Analog Devices, and ISSI. **Together, they established a new fab in Washington State, U.S., naming the company WaferTech. However, from 1996 to 2000, costs in the U.S. consistently exceeded budget, despite TSMC already having experienced cost specialists based in Taiwan. Overruns affected nearly every aspect of the project, including the construction of the factory and cleanroom, machinery, salaries, and even office furniture. By 1998, when the new fab began mass production, operational costs remained higher than anticipated.**

Cultural and operational challenges further compounded the issues. Employees in the U.S. did not show proper respect for personnel sent from TSMC's headquarters, leading to management tensions. As WaferTech continued to lose money, Morris Chang took decisive action. First, he opted to buy back shares of WaferTech from its partners at a slightly higher price than their initial investment. This move, while costly, preserved strong relationships with TSMC's customers. Second, he replaced the existing manager, who failed to cooperate with headquarters, with a senior manager directly from TSMC. It took nearly four years for WaferTech to stabilize after the new manager, finally showing signs of improvement by 2004. However, significant cost discrepancies persisted. WaferTech's gross margin remained 20 to 25 percentage points lower than TSMC's fabs in Taiwan, despite producing the same products at the same prices. While TSMC's gross margin in Taiwan hovered around 45%, WaferTech managed only 20% to 25%, achieving a marginally positive operating margin. Today, WaferTech remains part of TSMC, but the company has chosen not to expand its operations. The extra land purchased at the outset was eventually sold, reflecting TSMC's measured approach toward the site.

Since 2020, to support the U.S. government's goal of onshoring semiconductor manufacturing, strengthening national economic competitiveness, and bringing the most advanced chip manufacturing capabilities to the country, TSMC started to build fabrication facilities in Arizona with total investments exceeding $65 billion for three fabs.[256] These fabs are expected to begin producing chips with 4nm and more advanced process nodes starting between 2025 and 2028. **However, industry experts estimate that chips produced using TSMC's latest process technologies in the U.S. will cost 20% to 30% more than those manufactured in Taiwan, meaning U.S.-based clients will pay a significant premium for chips made domestically.[257] In addition, TSMC's first facility in Japan, which was opened in 2024 to diversify supply chains away from Taiwan amid intensifying U.S. – China trade tensions[258] and focuses on older technologies such as the 22/28nm nodes, also incurs costs 10% to 15% higher than similar chips produced in Taiwan. The significantly lower cost of producing chips locally in Taiwan highlights its inherent competitive advantage over other countries.**

In an interview, TSMC founder Morris Chang noted that while the U.S. excels in chip design talent, it faces a significant shortage of skilled workers for chip fabrication. He also highlighted that producing chips in the U.S. is approximately 50% more expensive than in Taiwan.[259] In 2023, TSMC executives also elaborated those factors such as construction costs, labor expenses, permits and regulatory compliance, rising living costs, and the learning curve associated with training new personnel contribute to the cost of setting up a U.S.-based plants being four to five times higher than in Taiwan.[260]

In addition, TSMC benefited from generous tax incentives provided by the Taiwanese government, particularly during its early years. Before 2002, TSMC not only avoided paying taxes but also received substantial tax credits due to its tax-exempt status.[261] Between 1993 and 2001, while TSMC generated NTD 172.5 billion (approximately $5.6 billion) in pre-tax income, it received NTD 10.6 billion (approximately $0.3 billion) in net tax credits.

Many of TSMC's manufacturing facilities and expansions were granted temporary tax exemptions, usually five years. For instance, its first manufacturing plant was tax-exempt from 1989 to 1993, while its second plant enjoyed tax exemptions from 1992 to 1996.[262] Similarly, the expansion of its seventh manufacturing plant was tax-exempt from 1998 to 2001.[263]

---

[256] TSMC Arizona. https://www.tsmc.com/static/abouttsmcaz/index.htm

[257] TSMC to Charge up to 30% More for Chips Made in the U.S. https://www.tomshardware.com/news/tsmc-to-charge-extra-for-us-made-chips

[258] TSMC Opens New Plant in Japan as It Diversifies Away from Taiwan. CNBC. https://www.cnbc.com/2024/02/26/tsmc-opens-new-plant-in-japan-as-it-diversifies-away-from-taiwan.html#:~:text=Located%20in%20Kumamoto%2C%20the%20chip,end%20of%202024%2C%20TSMC%20said.

[259] Morris Chang on Building Fabs in U.S. https://www.chinatimes.com/realtimenews/20230723000019-260410?chdtv

[260] TSMC 2022 Earnings Call. 1/12/2023.

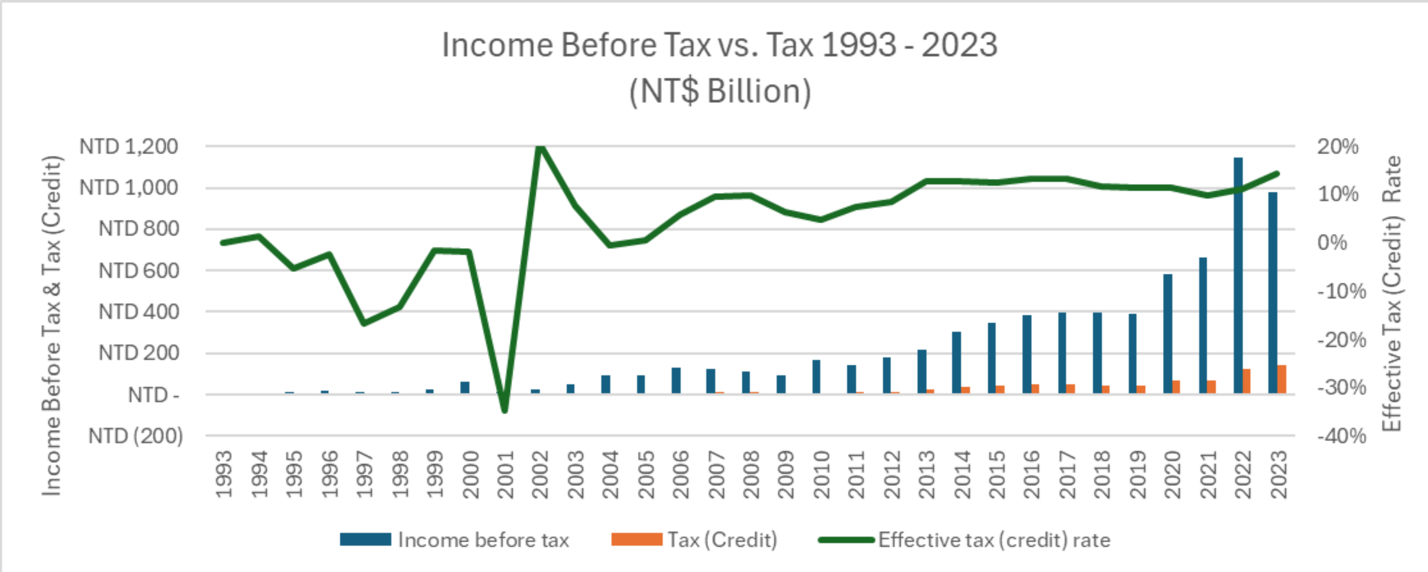
[261] TSMC Annual Report 1994 – 2002

[262] TSMC Annual Report 1994.

[263] TSMC Annual Report 2001.

Even as recently as 2022, TSMC had unused tax exemptions that applied to construction and expansion activities dating back to 2009.[264]

Figure 24: TSMC Income Tax 1993 – 2023



Another key to TSMC's success can be attributed to its second factory, built in 1988 and operational by 1990, following decisions insisted by Morris Chang and his team rather than Philips' shareholder board. Two groundbreaking innovations that seemed to be risky at that time were implemented.[265] First, TSMC adopted the Standard Mechanical Interface (SMIF), a miniature wafer carrier system developed in Silicon Valley for cleanroom environments. This approach reduced the need for costly ventilation systems while potentially improving yields by creating a cleaner environment. Although Intel had tested SMIF in a lab setting, it deemed the risk too high for a company-wide implementation. Therefore, Morris Chang decided to proceed with SMIF, which later applied it to all TSMC's factories. He thought that in order for a small company to catch up with its larger counterparts, it must do things that large companies are not willing to or dare not do at the right place.

Furthermore, a significant decision that TSMC made since its second factory was to use lithography systems from ASML, then a newly established company funded by Philips, coincidentally. Unlike market leaders Nikon and Canon, which nearly occupied the world's photolithography systems, ASML had no proven track record. Despite the risks, TSMC identified unique technological advantages in ASML's systems and became its first customer. Similar to adopting SMIF, TSMC thought that in order for a small company to catch up its larger counterparts, it must do things that large companies are not willing to or dare not to do at the right place.[266] Over the next three decades, TSMC and ASML grew as partners. By 2024, ASML has become the world's largest supplier of photolithography machines, commanding an estimated 90% market share and significantly outpacing Nikon and Canon.[267] Today, ASML is the only company in the world that manufactures Extreme Ultraviolet Lithography (EUV) machines, which are necessary to print advanced microchips, with TSMC accounting for over 80% of its sales.[268]

Shortly after the founding of TSMC, the world's semiconductor market grew rapidly entering the 1990s, from $50 billion in 1990 to nearly $150 billion in 1999,[269] nearly 13% CAGR. The market only saw declines in 1996 and 1998

[264] TSMC Annual Report 2022.
[265] Translated or rephrased by the author on a best effort basis. Chapter 19. Morris Chang: An Autobiography. Part II.
[266] Translated or rephrased by the author on a best effort basis. Chapter 19. Morris Chang: An Autobiography. Part II.
[267] Translated or rephrased by the author on a best effort basis. Chapter 19. Morris Chang: An Autobiography. Part II. TSMC Report. Morningstar. https://www.morningstar.co.uk/uk/news/256096/going-into-earnings-is-asml-stock-a-buy.aspx#:~:text=ASML%20is%20the%20world's%20largest,with%20around%2090%25%20market%20share.
[268] Inside ASML, The Company Advanced Chipmakers Use for EUV Lithography. CNBC. https://www.cnbc.com/2022/03/23/inside-asml-the-company-advanced-chipmakers-use-for-euv-lithography.html
[269] OECD Digital Economy Outlook 2015. OECD; Historical Billings Report. World Semiconductor Trade Statistics (WSTS). https://www.wsts.org/67/Historical-Billings-Report

during this decade by about 8% each year. As a result, TSMC frequently operated under capacity constraints, with customers urging the company to build new plants and expand production.[270]

By 1997, TSMC had already built 5 fabrication plants (fabs) and continued to expand the capacity of existing plants.[271] From 1991 to 2000, the company's production capacity increased from 84,000 pieces to 1.45 million pieces of 12-inch equivalent wafers,[272] a 37% CAGR, while its revenue grew from NTD 4.5 billion to NTD 166.2 billion, reflecting a 49% CAGR.

TSMC has consistently operated at full capacity while advancing its technology nodes. Between 1991 and 2000, it improved its process technology from 1μm to 0.18μm, a leap spanning six generations. Although wafer prices for the same node typically decline over time, wafers produced using newer nodes command higher prices.[273] This trend has allowed TSMC's average selling price (ASP) per wafer to increase nearly every year. Combined with operating at full capacity, this has driven revenue growth that has consistently outpaced capacity expansion.

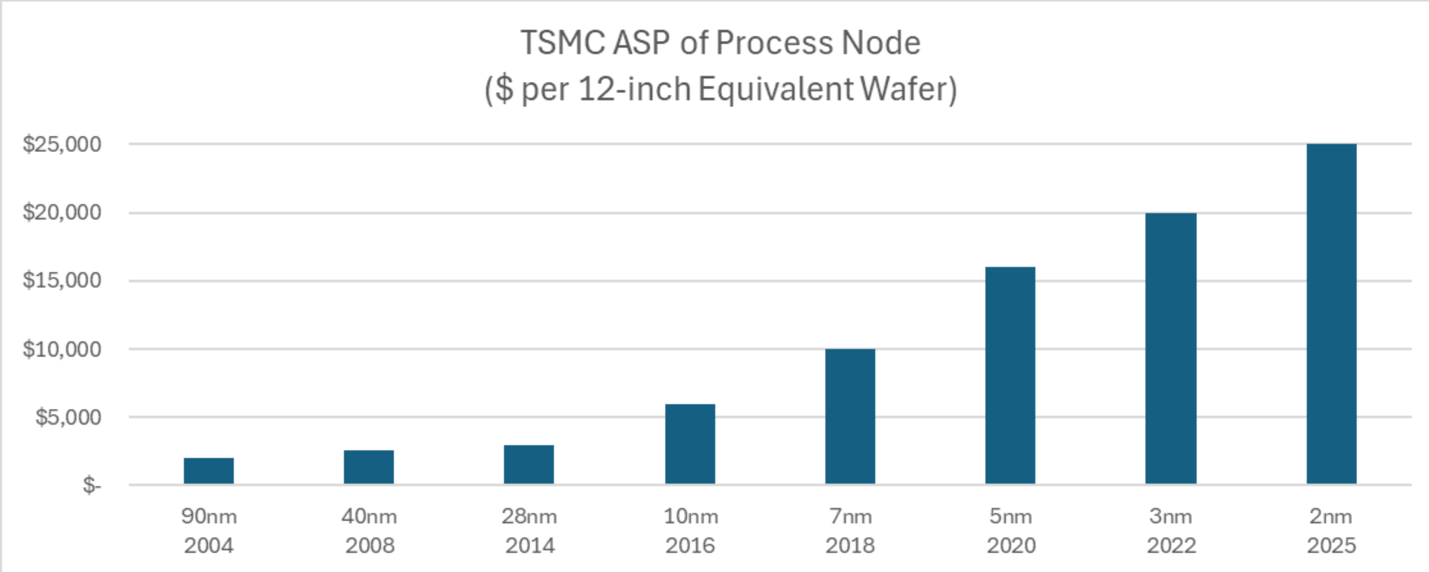
From 1991 to 2023, TSMC's production capacity for 12-inch equivalent wafers grew from 84,000 to 16 million,[274] representing an 18% CAGR. During the same period, its revenue grew from NTD 4.5 billion to NTD 2,162 billion (approximately $0.2 billion to $70 billion), achieving a 21% CAGR. Notably, TSMC's ASP per 12-inch equivalent wafer has continued to rise. According to estimates from the Taiwanese media, the price of wafers increases as process nodes advance. In 2004, a 12-inch equivalent wafer processed with the 90nm node cost $2,000. By 2025, a 12-inch wafer processed with TSMC's cutting-edge 2nm node is projected to reach $25,000,[275] reflecting a 26% CAGR over the past 20 years.

We estimate that TSMC's average selling price per 12-inch equivalent wafer grew from approximately $1,500 in 1990[276] to over $5,000 in 2023,[277] a 4% CAGR. This slower CAGR, compared to the price growth of each process node, is due to product mix. For instance, in 2023, despite 3nm being TSMC's most advanced technology in production, the company continued manufacturing less advanced nodes such as 5nm, 7nm, and 14nm, as well as mature nodes at 28nm, 90nm, and beyond, based on customer demand. However, over time, revenue from more advanced technologies has increasingly dominated TSMC's product portfolio. As of 2023, approximately 70% of TSMC's total revenue comes from 16nm and more advanced nodes, with contributions from 3nm and 2nm technologies expected to grow in the coming years.[278] Revenue from mature nodes accounts for about 20% of the company's overall sales.

Due to its technological leadership in advanced nodes, TSMC is the first to apply price premiums when expanding its capacity, particularly for cutting-edge processes. In fact, TSMC sets the market direction for advanced nodes. Many customers enter into long-term agreements that span multiple technology nodes, securing a specific global capacity across four or five nodes at locked prices.[279]

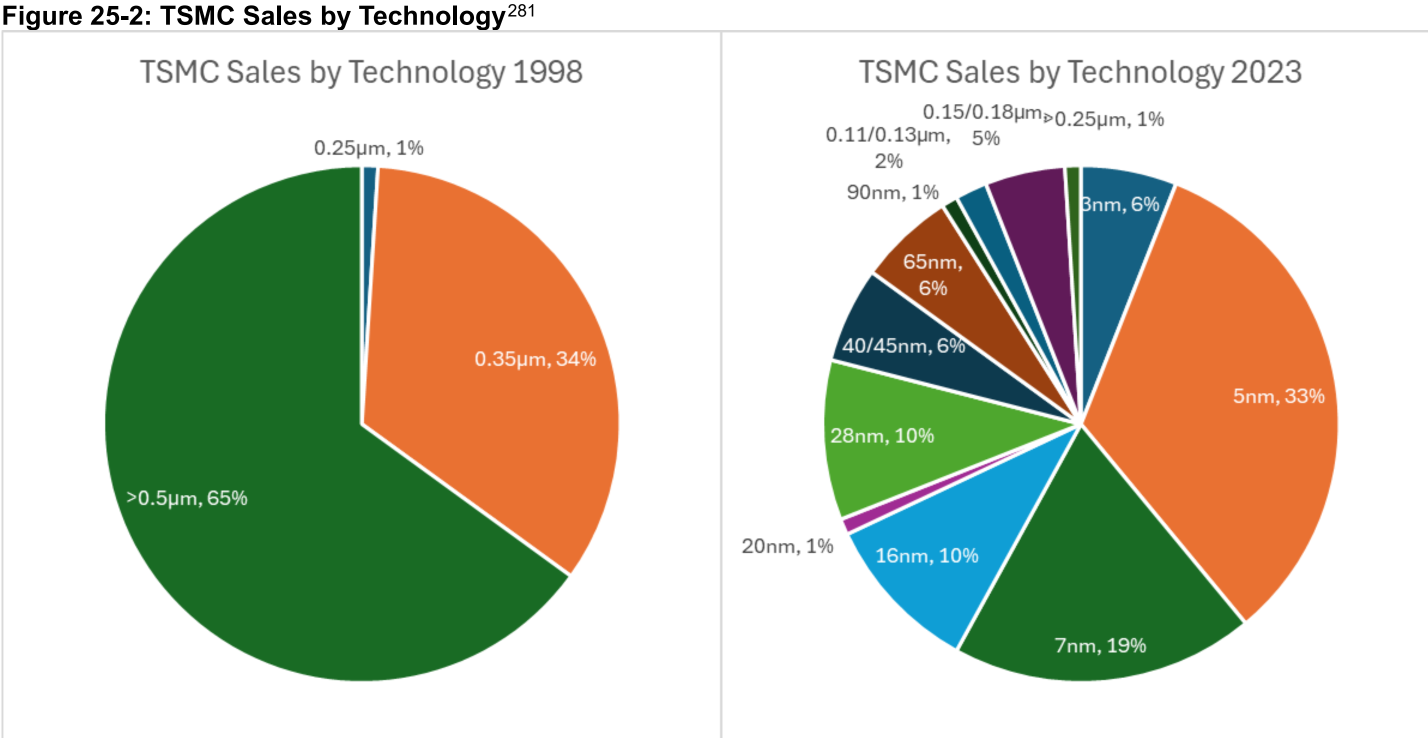
[270] Translated or rephrased by the author on a best effort basis. Chapter 24. Morris Chang: An Autobiography. Part II.
[271] TSMC Annual Report 1997
[272] Translated or rephrased by the author on a best effort basis. Chapter 24. Morris Chang: An Autobiography. Part II.
[273] Translated or rephrased by the author on a best effort basis. Chapter 24. Morris Chang: An Autobiography. Part II.
[274] Translated or rephrased by the author on a best effort basis. Chapter 24. Morris Chang: An Autobiography. Part II; TSMC Annual Report 2023.
[275] TSMC 3 nm Wafer Pricing to Reach $20,000. https://www.techpowerup.com/301393/tsmc-3-nm-wafer-pricing-to-reach-usd-20-000-next-gen-cpus-gpus-to-be-more-expensive; TSMC Expected to Charge $25,000 per 2nm Wafer. https://www.tomshardware.com/news/tsmc-expected-to-charge-25000usd-per-2nm-wafer
[276] In 1990, TSMC produced 176,334 6-inch wafers, according to the company's 1994 annual report. This output is equivalent to 44,028 12-inch wafers, based on the following conversion factors: one 12-inch wafer is equivalent to 2.25 8-inch wafers, and one 8-inch wafer is equivalent to 1.78 6-inch wafers, according to TSMC Form 6-K in July 2004. By 1994, TSMC's total wafer production value amounted to NTD 1.79 billion (approximately $66 million), translating to an average of $1,500 per twelve-inch equivalent wafer.
[277] According to TSMC 2023 annual report, the company shipped over 12 million 12-inch equivalent wafers, generating a revenue of NTD 1,882 billion (approximately $60 billion). Also confirmed in Interview with A Former CTO at Synopsys 10/2/2024.
[278] TSMC Annual Report 2023.
[279] Interview with CEO and Founding Partner at Fab Economics. 9/23/2024

Figure 25-1: TSMC ASP by Process Node[280]



Note:
1. The ASP was calculated in 12-inch equivalent per wafer.

Figure 25-2: TSMC Sales by Technology[281]



Thanks to its leadership in wafer fabrication technology, TSMC can charge a significant premium compared to its competitors. Among the world's top four largest foundries after TSMC, there is a notable disparity in ASPs. In 2023, SMIC's ASP for 12-inch equivalent wafers was over $2,400.[282] However, due to the U.S. – China trade war, Chinese chipmakers have faced challenges in acquiring advanced wafer fab equipment needed for nodes such as 7nm and

[280] TSMC 3 nm Wafer Pricing to Reach $20,000. https://www.techpowerup.com/301393/tsmc-3-nm-wafer-pricing-to-reach-usd-20-000-next-gen-cpus-gpus-to-be-more-expensive; TSMC Expected to Charge $25,000 per 2nm Wafer. https://www.tomshardware.com/news/tsmc-expected-to-charge-25000usd-per-2nm-wafer

[281] TSMC Q4 2000 Investor Presentation; TSMC Q4 2023 Investor Presentation

[282] According to SMIC's 2023 annual report, the company shipped approximately 5.867 million 8-inch equivalent wafers, which translates to around 2.6 million 12-inch equivalent wafers, generating a total revenue of $6.32 billion.

5nm.[283] While SMIC no longer discloses revenue by technology node, it is believed that most of its revenue comes from nodes at 28nm and above. There is speculation that SMIC has limited production at 14nm and even 7nm, but no definitive proof exists.

GlobalFoundries had an estimated ASP of $3,000 in 2023, with its technology nodes ranging from 14nm and above.[284] UMC's ASP was approximately $2,200, also for nodes at 14nm and above.[285] Samsung does not disclose separate data for its foundry business. However, industry reports suggest its ASP may be around $4,500.[286] Given that both Samsung and TSMC are at the forefront of fabricating wafers using cutting-edge nodes such as 3nm and below, this estimate seems reasonable.

In October 2021, during a technology forum, Morris Chang for the first time revealed some of TSMC's strategy hand-written by him in 1998, during a slow period for semiconductor industry, when the global semiconductor market saw changes of -8.6%, 4.0%, and -8.4% from 1996 to 1998, respectively.[287]

> "TSMC's strategy was to beat its competitors in every field. Because of this, we had to maintain a good relationship with our clients. We had to be flexible in our pricing, so we could establish a "first and last look" relationship with the clients."[288]
>
> \- Morris Chang, 1998

This philosophy, combined with bold innovation and strong partnerships, has made TSMC a leader in the foundry segment.

TSMC Strategy Written in 1998 (Excerpts)[289]

Target

To become a professional integrated circuit manufacturing service company with a global reputation, service-oriented and able to create the greatest overall benefits for customers, thereby becoming the largest and most profitable company in this industry.

Measures and Metrics

1. Conduct regular independent customer surveys.
2. Customers' direct response and satisfaction in handling problems for customers.
3. Financial performance (especially revenue growth and ROE).
4. Stock price.
5. Market share (especially compared with competitors).
6. Financial reports and mass media reports.

TSMC pioneered the dedicated integrated circuit fabrication services business model in 1985. At that time, there was no stable market for such a business model. TSMC's only business opportunities came from the periodic

---

283 SMIC Removes Mentions of 14nm Node. https://www.tomshardware.com/news/smic-removes-mentions-of-14nm-node
284 According to GlobalFoundries 2023 annual report, the company generated $6.82 billion in revenue from wafer fabrication, with approximately 2.2 million 300mm (12-inch) equivalent semiconductor wafers shipped.
285 According to UMC 2023 annual report, the company shipped 3.195 million 12-inch equivalent wafers, generating revenue of NTD 211.5 billion from wafers, approximately $6.8 billion.
286 TSMC's 2023 Wafer Average Selling Price Rises by 22%. https://www.trendforce.com/news/2024/01/24/news-tsmcs-2023-wafer-average-selling-price-rises-by-22-driven-by-n3-process-success/
287 OECD Digital Economy Outlook 2015; Historical Billings Report. World Semiconductor Trade Statistics (WSTS). https://www.wsts.org/67/Historical-Billings-Report
288 Morris Chang's Master Plan for 50 Years. Commonwealth Magazine. https://english.cw.com.tw/article/article.action?id=3114
289 Morris noted that the original strategy was written in English. TSMC's public relations team then translated it into Chinese. The author has now retranslated and reinterpreted it back into English with the best effort to accurately convey its meaning based on the Chinese version. Chapter 21. Morris Chang: An Autobiography. Part II.

outsourcing business of integrated device manufacturers, as well as the few fabless (chip design) companies that had just entered the market at that time. Despite initial difficulties, TSMC persisted in its business model of focusing on professional integrated circuit manufacturing services. Our faith and efforts paid off in the late 1980s and early 1990s, when entrepreneurs discovered that TSMC was a reliable dedicated integrated circuit foundry, and a large number of fabless companies began to be established. The initial success achieved by fabless companies through cooperation with TSMC, which produced chips for them, led to the establishment of more fabless companies. **Today, in 1998, hundreds of fabless companies have been established, with the largest concentration in Silicon Valley. The fabless company became the backbone of TSMC's market, enabling TSMC to grow rapidly in 1990 – 1996.**

At the same time, TSMC's success attracted many competitors to invest in the industry. Competitors took advantage of TSMC's capacity shortages (which occurred in parts of 1993, 1995 and 1997) and relatively high profit margins to provide TSMC's customers with capacity and/or lower prices, eroding TSMC's market share.

The slowdown in the semiconductor industry since 1996 has intensified competition. However, TSMC's dedicated foundry model remains the same as before with sustaining advantages for the following considerations:

1. Design (fabless) industry – Entrepreneurial spirits will drive the establishment of more fabless companies. Some fabless companies may eventually fail, but new companies will enter the market. Fabless companies do not have the burden of large investments in building factories. Compared with large integrated device manufacturers (IDM), fabless companies can respond to market demand more quickly and grow faster. Their proportion in the semiconductor industry will become larger and larger.

2. Integrated device manufacturer companies – wafer fabrication technology itself is no longer a decisive factor in most competitive landscape…IDM companies face the risks of spending huge amounts of money to invest in wafer fabs, as well as the increasing competition from fabless companies, making them choose to work with foundries or establish joint venture wafer fabs to minimize its risk and capital expenditure.

Strategy

I. Meet Customer Needs

What do customers want?

1) Technologies that enable customers to stand out, or at least compete with their competitors.

2) TSMC's flexibility in facing customer needs.

3) Low price.[290]

4) The cycle time from product design finalization to mass production is short.

5) Quality and reliability.

6) Design services that can help customers surpass their competitors, or at least compete with their competitors.

7) The communication between customers and TSMC is close and seamless.

8) Comprehensive one-stop integrated services.

9) Protect customers' intellectual property.

10) Able to jump in immediately and propose solutions to any problems that may arise.

11) TSMC's partnership attitude and behavior towards customers.

[290] Morris Chang did not elaborate on this point. We believe it does not necessarily imply the lowest price but rather a competitive price relative to the technology, quality, and yield provided. Due to TSMC's leadership in advanced nodes, direct price comparisons with other foundries at the same technology level are challenging.

TSMC's strategy is to be clearly superior to competitors in all aspects except (3) above, in order to earn a premium on (3).[291] Our pricing strategy is to obtain a premium, but not lose the business. To execute this strategy successfully, it's essential to have an excellent relationship with the customer. The benchmark of that relationship is to have the "first and last look" with the customer. We can be flexible in pricing with one-time-only "buffer" deals. But to be loyal to other customers, when a one-time "buffer" deal is offered to one customer, similar deals should be offered to his direct competitors in the same field.

II. Organizationally Become A Market- and Service-Oriented Enterprise

There is a huge difference between a manufacturing or engineering-oriented company and a market- and service-oriented company. Our goal is to become a market- and service-oriented company. To do so:

1) Every employee is a salesperson; even professional engineers, accountants, and managers are TSMC's salespersons.

2) Senior managers must also be excellent businessmen. If they are not currently, they should train themselves and get training to become businessmen.

3) To effectively implement our pricing strategy, business specialists must receive thorough training and develop a comprehensive understanding of the company's key metrics, such as costs, capacity utilization rates, and required profit. Their roles and compensation should be aligned with their demonstrated understanding and ability to meet these standards.

4) We must build a world-class marketing team. Their duties include:

    a. working with the R&D department to determine the technology blueprint.

    b. suggesting new services or technologies.

    c. working with business units to develop new customers.

    d. TSMC's marketing strategies for different application products (graphics chips, chipsets, etc.), different fields (computers, mobile phones, etc.), different regions, and different customers (in the same market field or product application).

    e. information on markets and the competitive landscape.

    f. tactical pricing adjustments.

    g. TSMC's brand identity.

    h. becoming "chief of staff" to top management in business and marketing.

III. Expand Core Strength

1) Our core strengths lie in engineering technology and manufacturing capabilities. We must expand our leadership in these areas. Specifically, we must continue to pursue yield, production cycle, productivity, etc.

2) Actively acquire intellectual property rights inside and outside the company. In addition to quantity, we should pay more attention to their quality.

IV. Fabless, Integrated Component Manufacturing Companies And System Manufacturers

Our strategy is to aggressively pursue all potential customers, including fabless, IDM companies, and system manufacturers.

---

[291] Morris Chang's Master Plan for 50 Years. Commonwealth Magazine. https://english.cw.com.tw/article/article.action?id=3114; https://www.thepaper.cn/newsDetail_forward_15277755

V. Financial Strategy

1) Maintain a conservative debt/equity structure: 35% debt/65% equity.

2) Conservatively manage financial assets.

3) Invest only in businesses directly related to our core business.

4) Joint ventures to establish wafer manufacturing plants will only be considered as a last resort.

VI. Corporate Culture

Our corporate culture is expressed in ten business philosophies (discussed in the section below), the connotations of which are consistent with and interdependent with this strategy. The ten business philosophies and this strategy should complement each other.

VII. Desirable Quantitative Outcomes

Colleagues should view this as the result of successfully executing this strategy, rather than the goal itself.

1) Maintain ROE greater than 20%.

2) Become the world's largest integrated circuit manufacturing services company, leading the second largest wafer fabricating company in revenue by at least 2:1 (double).

3) Sales reach $10 billion by 2010. (The company actually reached nearly $14 billion in sales in 2010)

In the mid-1990s, before writing TSMC's business strategy, Morris Chang outlined ten principles that have remained as the unchanging foundational values and business philosophy of TSMC. These principles were inspired by his experiences with family, education, career, and society. They have been published in brochures distributed to all employees and are prominently displayed in TSMC's lobby, allowing customers, suppliers, and visitors to access and appreciate them.[292] During his 31-year tenure at TSMC, Morris Chang and his colleagues rarely violated any of these principles.

Business Philosophy[293]

1. **Integrity**
   - We tell the truth.
   - We believe that the record of our achievements is the best proof of our merit. Hence, we do not brag or boast.
   - We do not make commitments lightly. Therefore, once we make a commitment, we devote ourselves completely to meeting that commitment.
   - With competitors, we compete to our fullest within the limits of the law, but we do not slander them in order to gain benefit for ourselves. We also respect the intellectual property rights of others.
   - With vendors, we maintain an objective, consistent, and impartial attitude.
   - We do not tolerate any form of corrupt behavior or politicking. At TSMC, company politics are forbidden. When selecting new employees, we place emphasis on the candidates' qualifications and character, not connections or "guan-xi".[294]

2. **Focus on our Core Business – IC Foundry**
   - We must focus on our business at all times, which is dedicated integrated circuit foundry, and not distract ourselves with other pursuits.

[292] Translated or rephrased by the author on a best effort basis. Chapter 21. Morris Chang: An Autobiography. Part II.
[293] Values and Business Philosophy. TSMC. https://www.tsmc.com/english/aboutTSMC/values; Chapter 21. Morris Chang: An Autobiography. Part II.
[294] "Guan-xi" is a term used in Chinese culture to describe an individual's social network of mutually beneficial personal and business relationships.

3. **Globalization**
   - Our target is and always has been the global market. We do not limit ourselves to Taiwan or any other specific geographical region. We recognize that the semiconductor business has no national boundaries, and that to be competitive anywhere we must be competitive worldwide.
   - Rooted in Taiwan, TSMC aims to establish bases in major markets worldwide. When it comes to talent, we prioritize merit over nationality.[295]

4. **Long-term Vision and Strategies**
   - An enterprise whose success endures is much like a successful marathon runner, whose skills and objectives are quite different from a short-distance sprinter. We truly believe that a person or company that does not plan carefully for the future will soon have problems in the present. We are confident that if we do a good job of long-term planning and execution, we will greatly reduce the need for crisis management.
   - In addition to creating a rolling five-year strategic plan each year, our daily work should remain closely aligned with long-term outcomes and returns.[296]

5. **Treating Customers as Partners**
   - Since the company was founded, we have treated our customers as partners and have never competed against them. This policy is the key to our current success and will be crucial to our continued growth. At TSMC, customers come first. Their success is our success, and we value their ability to compete as we value our own.

6. **Building Quality into all Aspects of our Business**
   - Every TSMC employee is responsible for providing the highest quality service. To achieve this, each person continuously evaluates and improves the quality of his or her own work. Our greatest goal is to achieve and maintain complete customer satisfaction.
   - Whether internally or externally, everyone we serve is our customer, and customer satisfaction defines quality.[297]

7. **Unceasing Innovation**
   - Innovation is the wellspring of TSMC's growth. It is vital to all sectors of our business, from strategic planning to marketing to management to technology and production.
   - We must continuously ensure that the company remains vibrant and dynamic, always maintaining a proactive, efficient approach to adapt to the ever-changing nature of the industry.[298]

8. **Fostering a Dynamic and Fun Work Environment**
   - For most people who work at TSMC, participating in a challenging and enjoyable work environment full of opportunities to learn new skills is even more important than monetary rewards. To retain talented people who share our goals and interests, we work hard to foster a dynamic and enjoyable work environment.

9. **Keeping Communication Channels Open**
   - TSMC has implemented an open-style management system designed to keep all lines of communication open. Employees openly cooperate with one another, while treating each other with honesty and sincerity. Everyone welcomes constructive criticism and is willing to seek improvement. This management style allows all opinions to be expressed before a final decision is made. Once a decision is made, everyone works together to achieve the set goal.

10. **Caring for Employees and Shareholders, and Being a Good Corporate Citizen**
    - Employees and shareholders are both important constituents of our company. Our goal is to provide salary and benefits packages for employees that are above the industry average. TSMC also aims to earn a return on investment for shareholders above the industry average. We clearly understand that the success of our company depends greatly on the well-being of society and the environment where the company is established. Therefore, it is essential that we give back to society, consistently within our means, and serve as a model corporate citizen.

---

[295] Translated or rephrased by the author on a best effort basis. Chapter 21. Morris Chang: An Autobiography. Part II.
[296] Translated or rephrased by the author on a best effort basis. Chapter 21. Morris Chang: An Autobiography. Part II.
[297] Translated or rephrased by the author on a best effort basis. Chapter 21. Morris Chang: An Autobiography. Part II.
[298] Translated or rephrased by the author on a best effort basis. Chapter 21. Morris Chang: An Autobiography. Part II.

Ownership Structure

In order to successfully list on the Taiwan Stock Exchange, prior to its IPO in 1994, TSMC's financial advisor recommended limiting the ownership of any single large shareholder to under 50%. At the time of TSMC's founding, the company had an agreement with Philips Electronics N.V. that granted the latter the right to purchase up to 51% of TSMC's shares from other shareholders in exchange for its funding.[299] Philips had expressed interest in exercising this right before the IPO. However, TSMC successfully persuaded Philips to cap its ownership at 40%. Morris Chang, TSMC's founder, believed this arrangement not only met the requirements for the IPO but was also a reasonable compromise for Philips, which ultimately agreed. In his autobiography, Chang emphasized that a company's operational control is more important than its ownership structure.[300]

By the end of 1994, the year TSMC became a publicly traded company on the Taiwan Stock Exchange, Morris Chang held only 6,512,777 shares, representing approximately 0.8% of TSMC's total issued shares.[301]

Soon after TSMC's listing in Taiwan, Chang, with advice from Goldman Sachs, explored listing TSMC shares on the U.S. market through American Depositary Receipts (ADR). The U.S. market was more active than Taiwan's stock market, and Chang discovered that TSMC shares traded six times more frequently in the U.S. than in Taiwan. This move was intended to encourage major shareholders such as Philips and the National Development Fund to quickly reduce their stakes. Chang viewed their significant ownership as a "Sword of Damocles" that could threaten the company's leadership stability.

Before TSMC's U.S. listing, Philips owned 31% of the company. By 2005, Philips had reduced its stake to 16.4%, and by 2008, it owned no shares.[302] The National Development Fund reduced its ownership to 6.4% by 2005 and has maintained approximately the same level since then. Chang suggested that the National Development Fund remain TSMC's largest shareholder to provide support for professional managers without interfering in the company's operations, a role he believed the Fund was well-suited to play. As of 2023, the National Development Fund continues to hold 6.38% of TSMC's total outstanding common shares.[303]

Culture and Employees

As discussed in the previous section, TSMC treats its employees as valuable assets rather than expenses and avoids layoffs, even during industry downturns such as the Global Financial Crisis in 2008. The company views layoffs as a costly and counterproductive decision, not only due to severance payments but also because of the significant expenses involved in retraining new employees in the future.[304] In addition, layoffs can harm employee morale, as they may perceive that management does not value them and sees them merely as expenses.

As of 2023, TSMC employed over 76,000 people globally, with nearly 90% of its workforce based in Taiwan.[305] **The company's employee turnover rate in 2021 was just 6.8%, significantly lower than the average turnover rate of 15% for companies in Taiwan.**

TSMC's compensation package includes a monthly salary, profit sharing, and performance bonuses based on quarterly business results, and profit-sharing based on annual outcomes.[306] These programs are designed to reward employees appropriately, encourage consistent contributions to TSMC's success, and align employee interests with those of shareholders, fostering a win-win relationship among the company, its shareholders, and employees. The amounts allocated for bonuses and profit-sharing are determined by the company's operating results and prevailing industry practices in Taiwan.

According to a 2023 report, TSMC ranked as the 7th highest-paying employer among public companies in Taiwan and was the only foundry company in the top 10 highest-paying companies.[307] Although it is not the highest-paying semiconductor employer in Taiwan, it leads among foundry companies. Higher-paying semiconductor employers in Taiwan are typically fabless companies specializing in chip design. In 2023, TSMC's average salary was NTD 2.84 million

---

[299] Translated or rephrased by the author on a best effort basis. Chapter 17. Morris Chang: An Autobiography. Part II.
[300] Translated or rephrased by the author on a best effort basis. Chapter 22. Morris Chang: An Autobiography. Part II.
[301] TSMC Annual Report 1994.
[302] Translated or rephrased by the author on a best effort basis. Chapter 22. Morris Chang: An Autobiography. Part II.
[303] TSMC 20-F 2023.
[304] Translated or rephrased by the author on a best effort basis. Chapter 31. Morris Chang: An Autobiography. Part II.
[305] Taiwan's TSMC Experiences Higher Employee Turnover Than Samsung. https://www.taiwannews.com.tw/news/4586957
[306] TSMC Annual Report 2023
[307] Taiwan Companies Salaries. https://www.inside.com.tw/article/35498-salary-comparison

(approximately $86,000), significantly higher by over 60% than the average salary in the overall semiconductor industry, which was NTD 1.75 million (approximately $53,000). Notably, the semiconductor sector is the highest-paying industry in Taiwan.

When TSMC was founded in 1987, one of the officials from the Industrial Technology Research Institute (ITRI), who later joined TSMC alongside Morris Chang as part of the "core founding team," suggested early on that the company issue dividends to employees to incentivize global competitiveness. Less than two years after its establishment, TSMC began issuing dividends, a practice it has maintained consistently. In 1989, TSMC introduced an employee stock purchase program, allowing employees to subscribe to company stock. Between 1989 and 1992, employees purchased TSMC stock five times, eventually owning 8.5% of the company before the program was discontinued by Philips, who was then the second largest shareholder following the government fund.[308] Philips argued that the program diluted its ownership of TSMC from over 27% to nearly 25% and noted that there was no precedent for employee ownership at Philips' parent company.

Building on its competitive compensation structure, TSMC launched a global Employee Stock Purchase Plan (ESPP) in 2022 for all regular employees of TSMC and its wholly owned subsidiaries. This program enables employees to invest in TSMC's long-term success by allocating up to 20% of their monthly salary toward the ESPP. Employees contribute 85% of the fund value, with TSMC subsidizing the remaining 15%. **As of 2023, approximately 70% of TSMC's employees participated in the program.**[309]

TSMC's generous employee packages have fostered a culture of efficiency and discipline, setting the company apart among Taiwanese firms. As a 24/7 operation running year-round, TSMC must ensure its equipment functions smoothly at all times. Morris Chang highlighted this culture by comparing TSMC to companies in the U.S., stating:

> "**If [the machine] breaks down at 1 a.m. in the morning, in the U.S., it will be fixed in the next morning. However, in Taiwan, it will be fixed at 2 a.m. If an engineer gets a call when he is asleep, he will wake up and start dressing. If his wife asks: 'What's the matter?' He would say: 'I need to go to the factory.' The wife would go back to sleep without saying another word. This is the work culture.**"[310]

A former director at TSMC also noted that TSMC runs with a great deal of discipline compared to Intel:

> "The company is very paranoid. They're constantly looking for opportunities to improve and try to figure out what could go wrong with their business plan or their product, their process… The fab operation, the R&D operation operate like a military… there's a very strong hierarchy and people within the organization, they're very dedicated, work hard…the senior management of TSMC's are very experienced. They have been in this industry for many, many years. They do not hesitate to take in charge and give direction and be hold accountable for their decision"[311]

As a manufacturing company, many TSMC employees work as direct labor in cleanrooms, operating around the clock in essential yet junior roles. To support these workers, TSMC introduced a dedicated system in 1990.[312] This platform enables employees to raise questions, make suggestions, or voice complaints, with all issues tracked and resolved transparently across all facilities, including those overseas.

By 2013, the system had received over 100,000 submissions, addressing topics ranging from workplace conditions to innovative proposals. For example, optimizing the cleaning process for cleanroom apparel saved NT$3.25 million (approximately $100,000) annually, while reusing certain manufacturing components reduced costs by over NT$10 million (around $300,000).

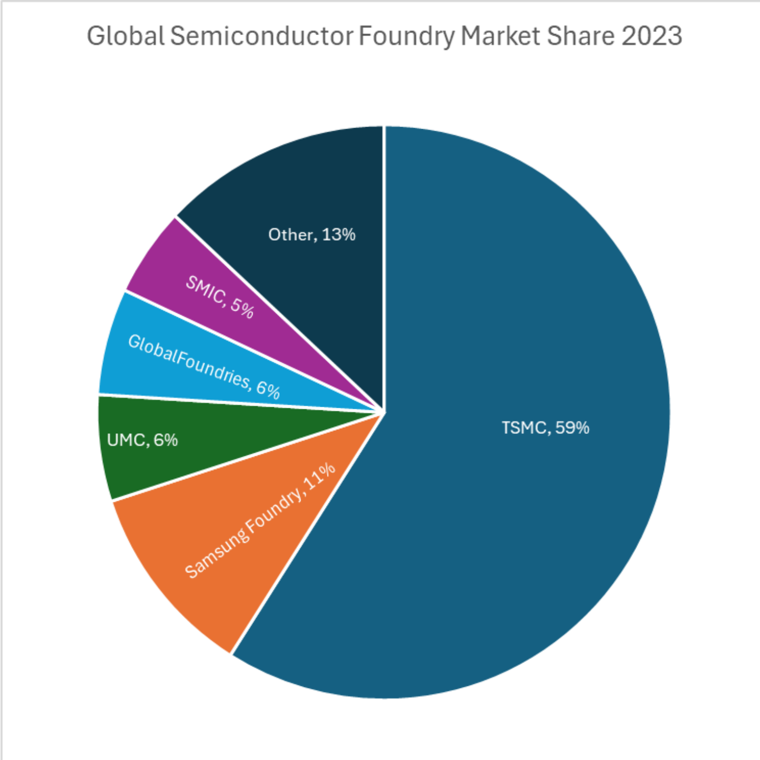
The system's transparency, with all questions, responses, and resolutions publicly accessible, encourages employees to use their real names without fear of retaliation. This initiative has significantly improved employee satisfaction and loyalty, reducing the technician turnover rate from over 30% in the 1990s and early 2000s to just 3.5% by 2012. This increased stability has helped TSMC lower recruitment and training costs while maintaining high production quality.

---

[308] Translated or rephrased by the author on a best effort basis. Chapter 19. Morris Chang: An Autobiography. Part II.
[309] TSMC Launch Global Employee Stock Purchase Program. https://www.businesstoday.com.tw/article/category/183008/post/202408010016/
[310] Translated or rephrased by the author on a best effort basis. This Is The TSMC Culture. Yahoo News.
[311] Interview with A Former Director at TSMC. 9/17/2024.
[312] TSMC Wins Employee Satisfaction. https://esg.gvm.com.tw/article/615

Pure-Play Competitors – UMC, GlobalFoundries, SMIC

Figure 26: Global Semiconductor Foundry Market Share 2023[313]



TSMC pioneered the dedicated foundry business model and has been a dominant player in the industry since its inception. Although estimating the exact size of the foundry market was challenging in the early years, by 1994, when TSMC went public, it was reportedly already the largest foundry in the world, commanding 23% of the global integrated circuit foundry market.[314] By 2023, TSMC was estimated to hold nearly 60% of the global foundry market share, far ahead of its competitors. Samsung Foundry followed with 11%, UMC with 6%, GlobalFoundries with 6%, and SMIC with 5%.

Samsung is not a pure-play foundry in the semiconductor industry but an integrated device manufacturer. It operates a variety of other businesses, including consumer electronics such as smartphones and computers. The company produces its own chips and memory devices for use in its products, in addition to offering foundry services. Despite its presence in the foundry market, Samsung does not disclose detailed financial data specific to its foundry business, as it represents a relatively small portion of the company's overall operations. Based on our estimates, Samsung Foundry generated approximately $12 billion in revenue in 2023,[315] accounting for less than 7% of Samsung's total business.[316]

Based on public information, TSMC was in close competition with Samsung in advanced technology nodes. In 2013, while TSMC was ready for mass production at the 20nm node, it fell behind in 16nm development after taking a technological detour to meet Apple's order requirements. This delay resulted in TSMC losing Apple's subsequent order to Samsung (Apple later came back to TSMC as promised earlier), which had remained focused on advancing its 16nm technology.[317]

In 2018, TSMC became the first foundry to achieve mass production of the 7nm process node, marking the first time it led the industry in advancing to a new generation of technology nodes that uses Extreme Ultraviolet (EUV) technology.[318]

---

[313] Behind Taiwanese Chip Makers' Japan Investment Spree. https://www.nippon.com/en/in-depth/d00988/

[314] TSMC Annual Report 1994.

[315] Behind Taiwanese Chip Makers' Japan Investment Spree. https://www.nippon.com/en/in-depth/d00988/

[316] Samsung Electronics Announces Fourth Quarter and FY 2023 Results. https://news.samsung.com/nl/samsung-electronics-announces-fourth-quarter-and-fy-2023-results

[317] Translated or rephrased by the author on a best effort basis. Chapter 33. Morris Chang: An Autobiography. Part II.

[318] EUV technology is essential for process nodes below 7nm. EUV technology is essential for process nodes below 7nm. TSMC Leads in Adoption of EUV. https://www.eetimes.com/tsmc-leads-in-adoption-of-euv/

This milestone not only solidified TSMC's determination to become technology-independent but also strengthened its position as a global technology leader.[319]

Since then, TSMC has become the leader in the advanced processing technology in semiconductor manufacturing, with Samsung following. By 2023, TSMC achieved mass production of semiconductors at the 3nm node, with plans to begin volume production of 2nm chips by 2025.[320] This progress is followed by Samsung. In recent years, some market analysts have estimated that TSMC manufactures approximately 90% of the world's most advanced semiconductor chips,[321] which power everything from smartphones to AI applications.[322]

In recent years, Samsung has reportedly considered outsourcing production of some of its flagship Exynos chips to TSMC, as Samsung continues to struggle with yield issues. The yield rate for Samsung's first-generation 3nm process reportedly ranged from 50% to 60%, while the second generation fell to around 20%, making it difficult to attract customers, compared to TSMC's nearly 90%.[323]

Another key difference between TSMC and Samsung Foundry lies in their business models. TSMC operates as a dedicated semiconductor foundry and does not compete with its customers. In contrast, although Samsung Foundry engages in the foundry business, its parent company also designs and manufactures its own semiconductor products, such as processors and memory storage devices. In addition, Samsung also produces consumer electronics, including smartphones and tablets, which can potentially place it in competition with many of its customers.

United Microelectronics Corporation (UMC)

UMC and TSMC share a common origin. Founded in 1980 as Taiwan's first semiconductor company, UMC was spun off from the government-owned Industrial Technology Research Institute (ITRI).[324] Initially operating as an integrated device manufacturer (IDM), UMC transitioned to a pure-play foundry model in 1995. By 1997, wafers accounted for only 41% of their total sales, with the remainder coming from packaged integrated circuit products and chips. By 2023, 95% of UMC's sales were derived from wafers.

Despite being one of the top five foundries in the world, UMC's technological advances have lagged behind TSMC. For instance, in 1998, while UMC began producing its 0.25μm process node in the second half of the year, TSMC had already started mass production of both 0.25μm and 0.22μm in the same year.[325] Additionally, TSMC planned to commence mass production of the 0.18μm node in the first quarter of 1999, whereas UMC did not anticipate reaching mass production of the same node until the second quarter of 1999. The gap in technology between the two companies continued to widen in the following year. By 2023, while TSMC has already started the mass-production in 3nm technology, and expect to mass-produce in 2nm in 2025, UMC only entered mass-production stage of its 14nm process technology in 2023.[326]

UMC successfully entered mass production for its 14nm process in 2017. However, in 2018, the company announced it would not pursue the development of technologies beyond 14nm. This decision came as part of a strategic restructuring aimed at boosting return on investment, given the significant capital required for advanced R&D.[327] Between the 1990s and 2017, UMC's gross margin declined from over 40% to just 20%, while its operating margin dropped from the 30-40% range to low single digits. In contrast, TSMC managed to maintain a gross margin of nearly 50% and an operating margin of around 40% during the same period.

---

[319] TSMC's Industry-First and Leading 7nm Technology Enters Volume Production. TSMC. https://esg.tsmc.com/en-US/articles/237; Translated or rephrased by the author on a best effort basis. Chapter 22. Morris Chang: An Autobiography. Part II.

[320] TSMC Annual Report 2023

[321] There is no strict definition for "advanced chips." Generally, the term refers to the smallest process nodes available at a given time. For example, while other IDMs and foundries have struggled with 14nm nodes in recent years, TSMC has progressed to 7nm and smaller, reaching as far as 2nm by 2024.

[322] How Taiwan Secured Semiconductor Supremacy. The Guardian. https://www.theguardian.com/world/article/2024/jul/19/taiwan-semiconductor-industry-booming

[323] Samsung May Outsource Exynos Production to TSMC Due to Low 3nm Yield Rate. https://www.trendforce.com/news/2024/11/14/news-samsung-may-outsource-exynos-production-to-tsmc-due-to-low-3nm-yield-rate/#:~:text=On%20the%20other%20hand%2C%20TSMC's,%25%2C%20as%20the%20report%20noted; TSMC N3E Yield Rate Approach 90%. https://www.moneydj.com/kmdj/news/newsviewer.aspx?a=c0628954-6020-40af-946d-7e497e8f9814&c=MB010000

[324] Overview. UMC. https://www.umc.com/en/About/about_overview

[325] UMC Annual Report 1998; TSMC Annual Report 1998.

[326] UMC Annual Report 2023.

[327] UMC Not to Rejoin Race to Develop 7nm Technology. https://www.taipeitimes.com/News/biz/archives/2018/09/04/2003699736

As of 2023, nearly all of UMC's sales come from the 22nm process node and older technologies, while only 30% of TSMC's sales are from process nodes above 22nm, highlighting the contrasting market focus of the two companies.

Figure 27-1: UMC vs. TSMC Sales in NTD 1994 – 2023

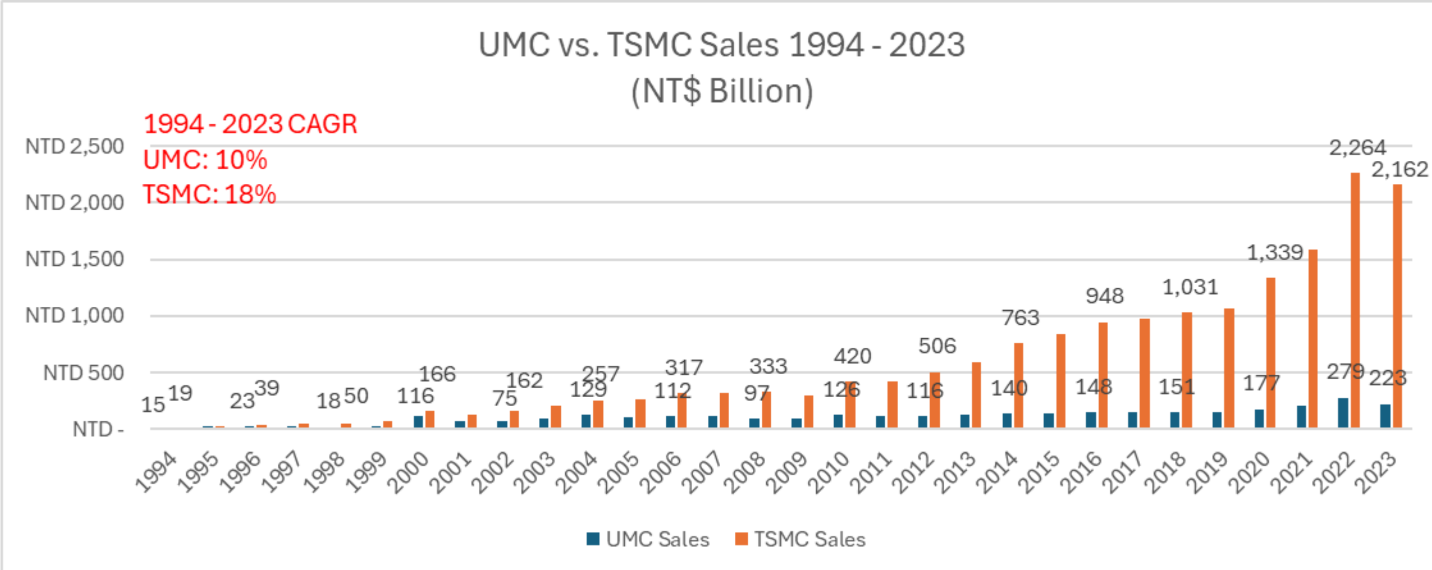
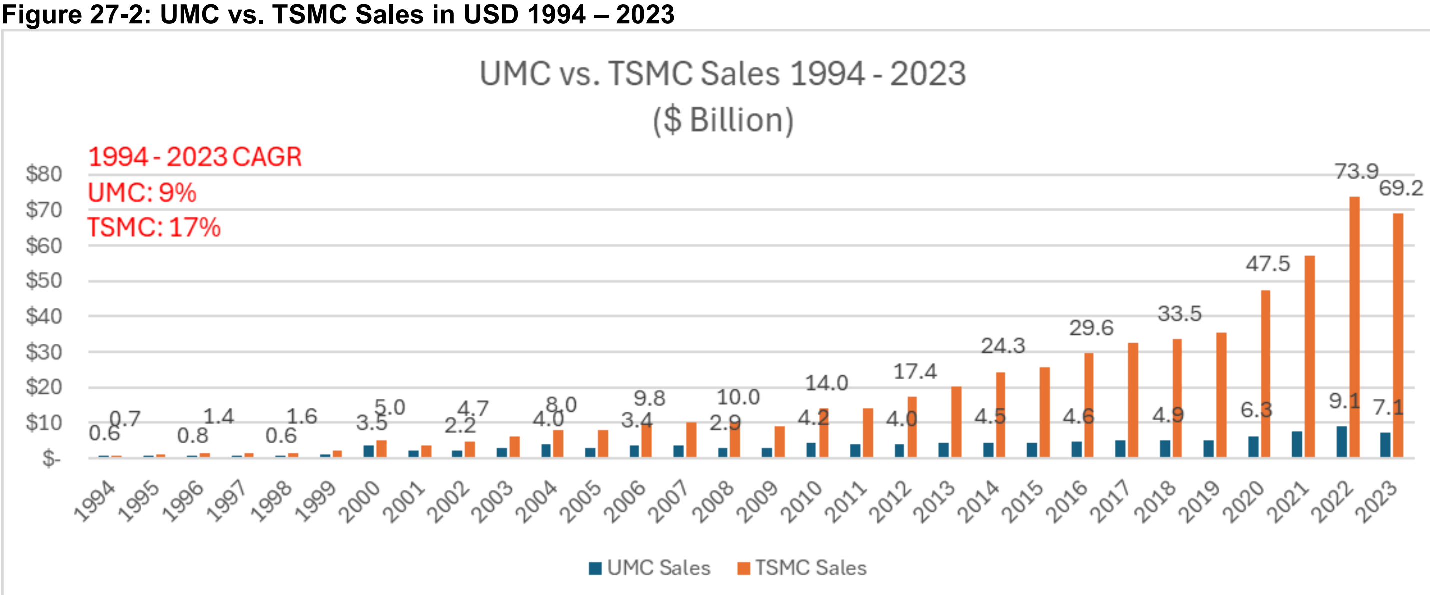


Figure 27-2: UMC vs. TSMC Sales in USD 1994 – 2023



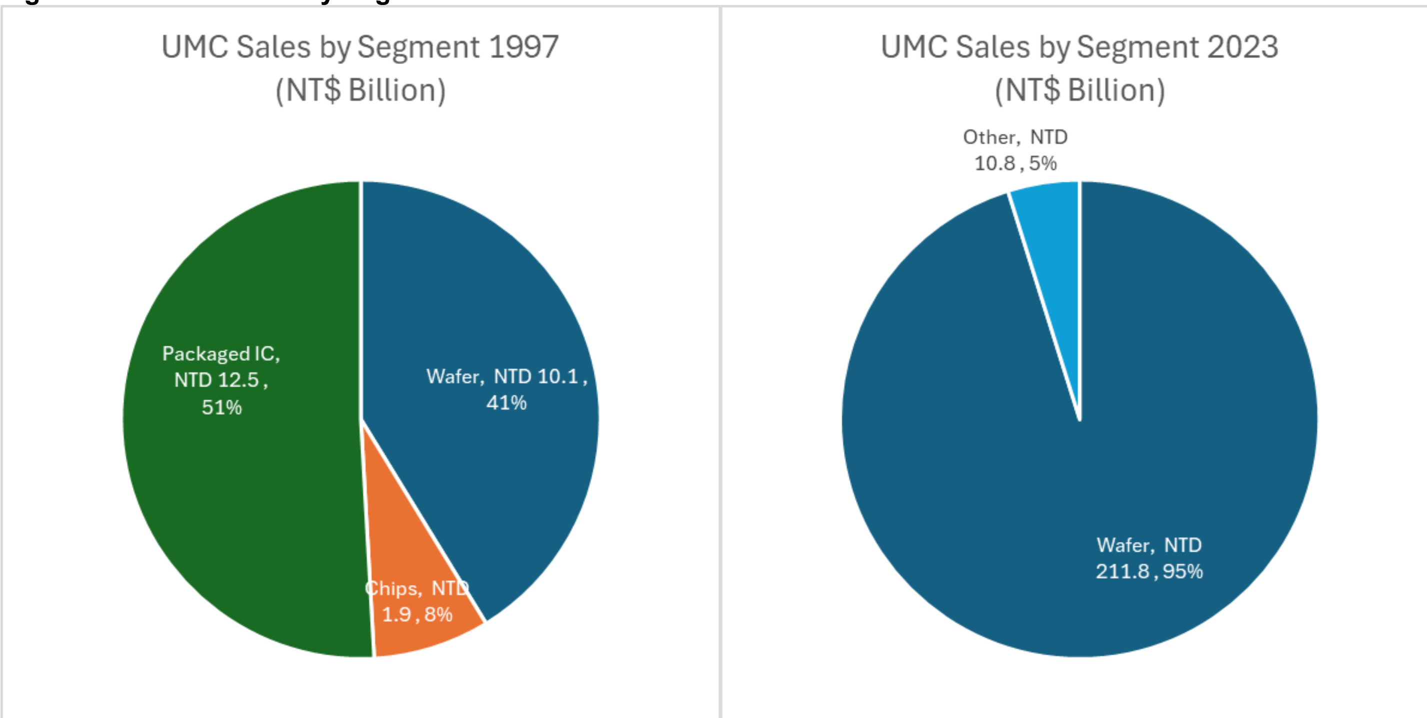
Note:

1. The exchange rates for NTD/USD used to convert net sales were based on the December rates of each year, as provided by the Federal Reserve Bank of St. Louis.[328]

---

[328] Taiwan Dollars to U.S. Dollar Spot Exchange Rate (EXTAUS). Federal Reserve Bank of St. Louis. https://fred.stlouisfed.org/series/EXTAUS

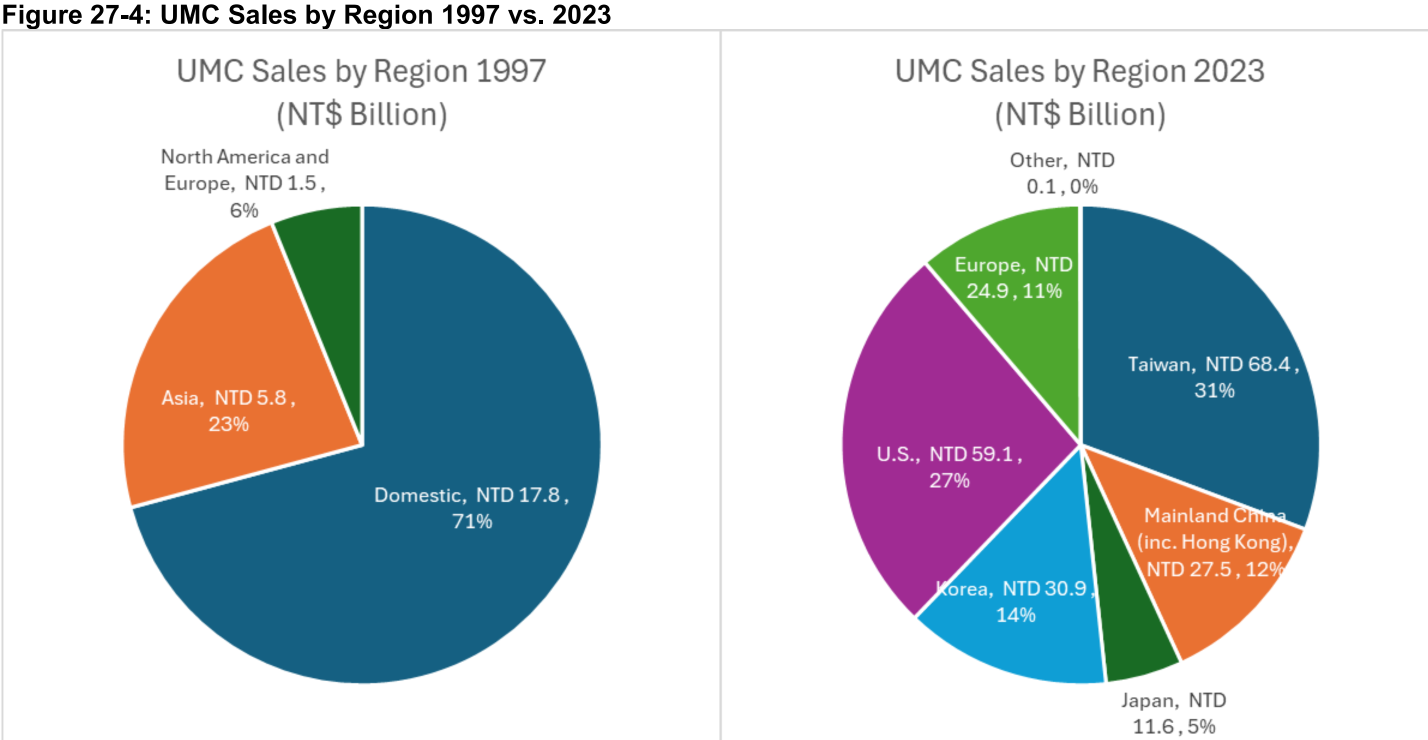
Figure 27-3: UMC Sales by Segment 1997 vs. 2023



Note:

1. Segment data begins in 1997 due to the availability of information.

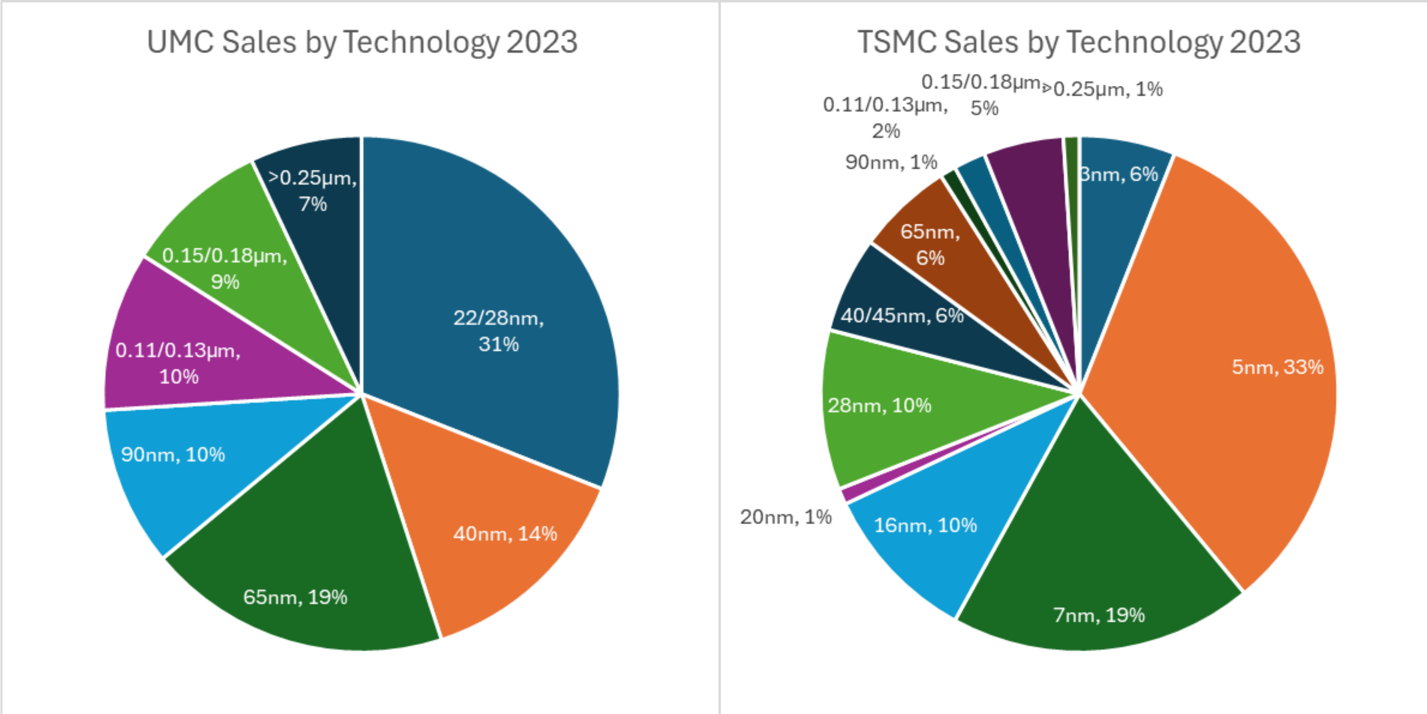
Figure 27-4: UMC Sales by Region 1997 vs. 2023



Note:

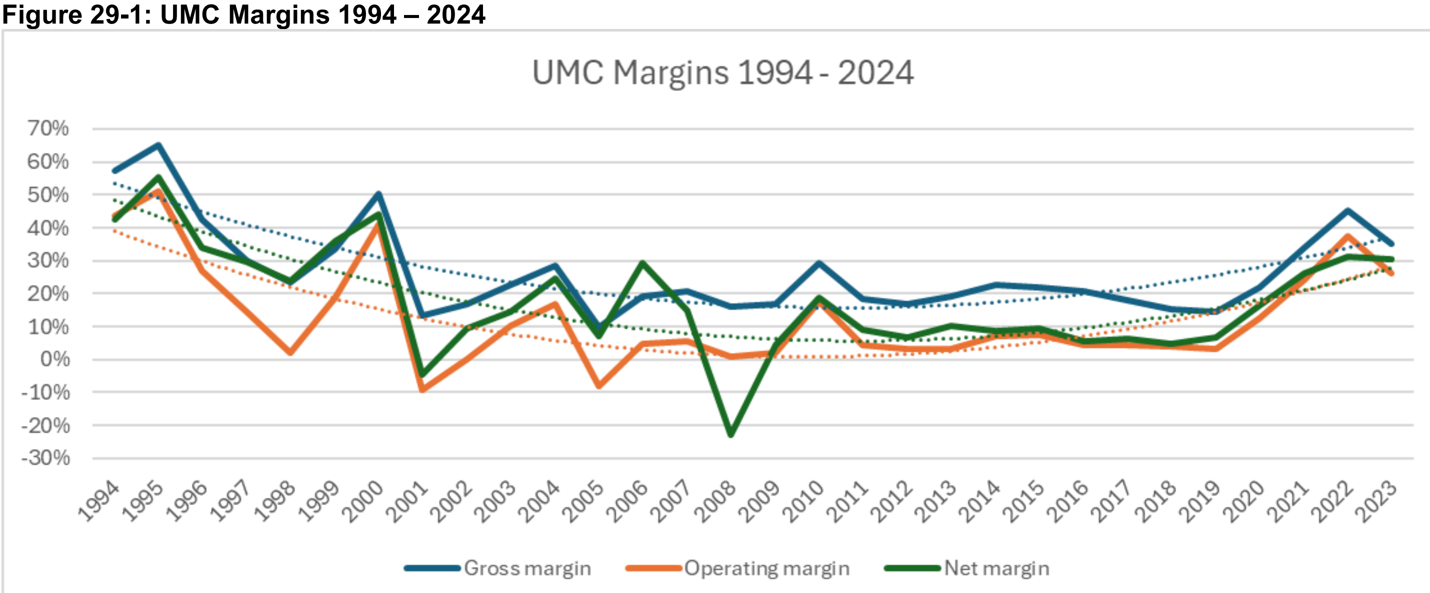
1. Regional data begins in 1997 due to the availability of information.

Figure 28: UMC vs TSMC Sales by Technology 2023[329]



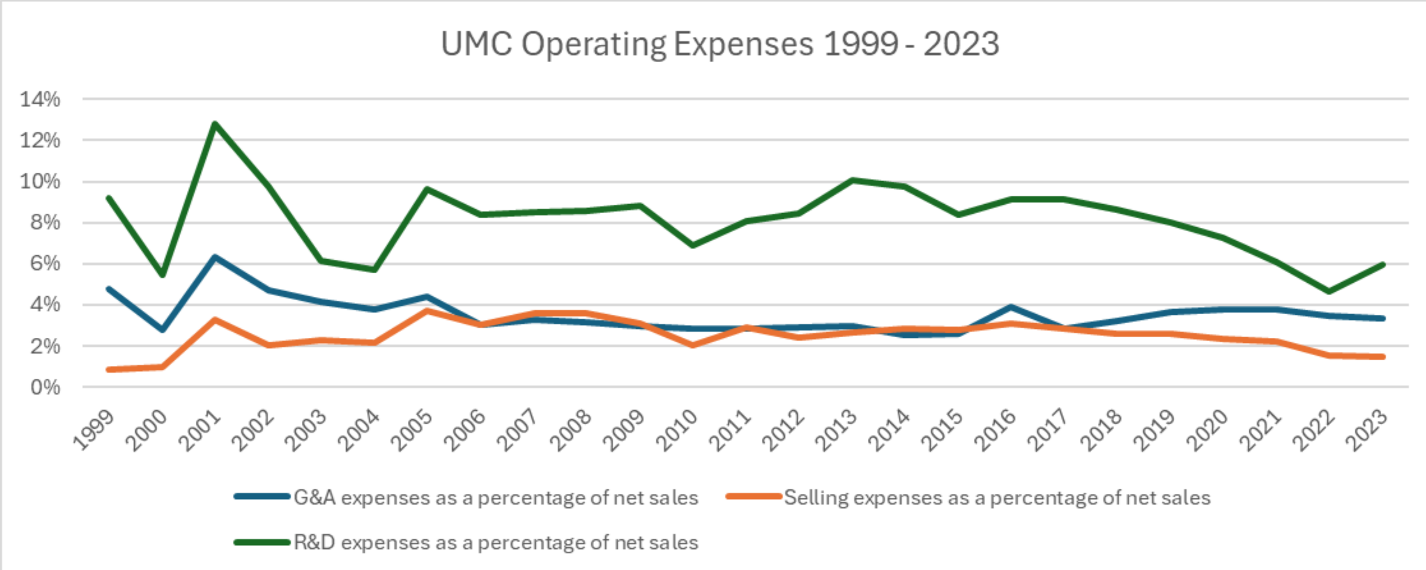
Notes:
1. The term "μm" stands for "micrometer." One micrometer is equal to one millionth of a meter (0.000001 m) or approximately 1/25,400 of an inch (0.00003937 inches).
2. The term "nm" stands for "nanometer." One nanometer is equal to 0.001μm.

Figure 29-1: UMC Margins 1994 – 2024



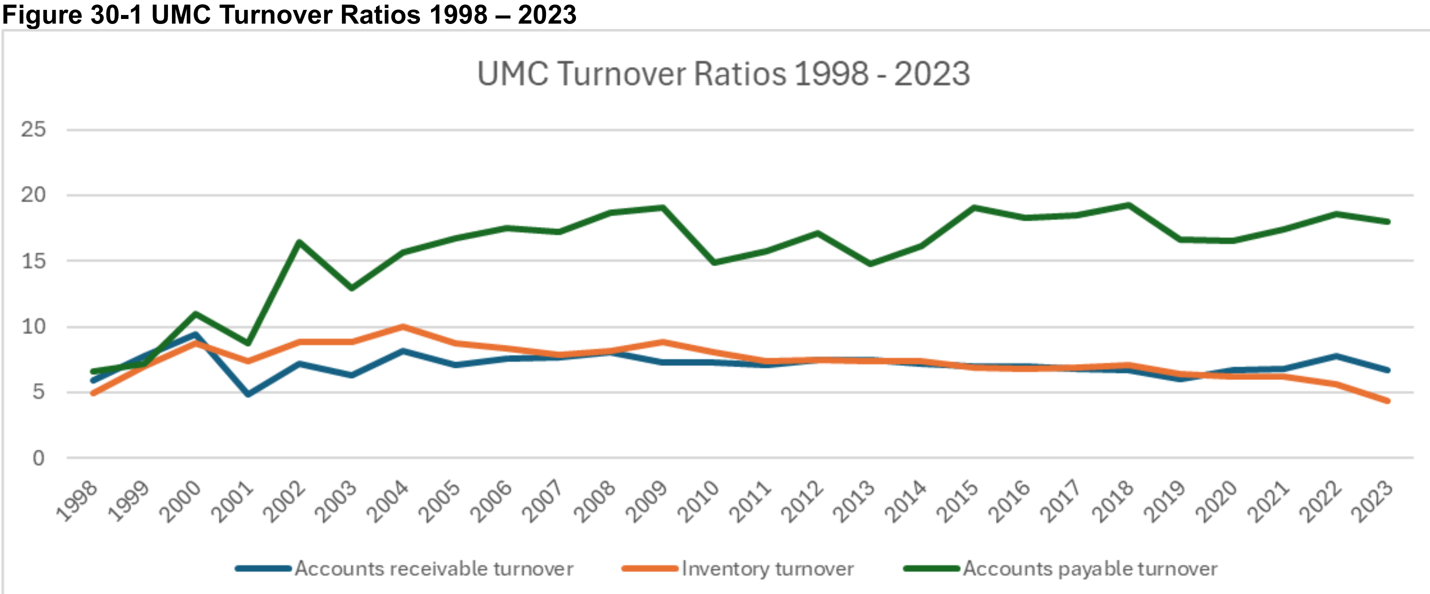
[329] UMC Q4 2024 Investor Presentation; TSMC Q4 2023 Investor Presentation

Figure 29-2: UMC Operating Expenses 1999 – 2024



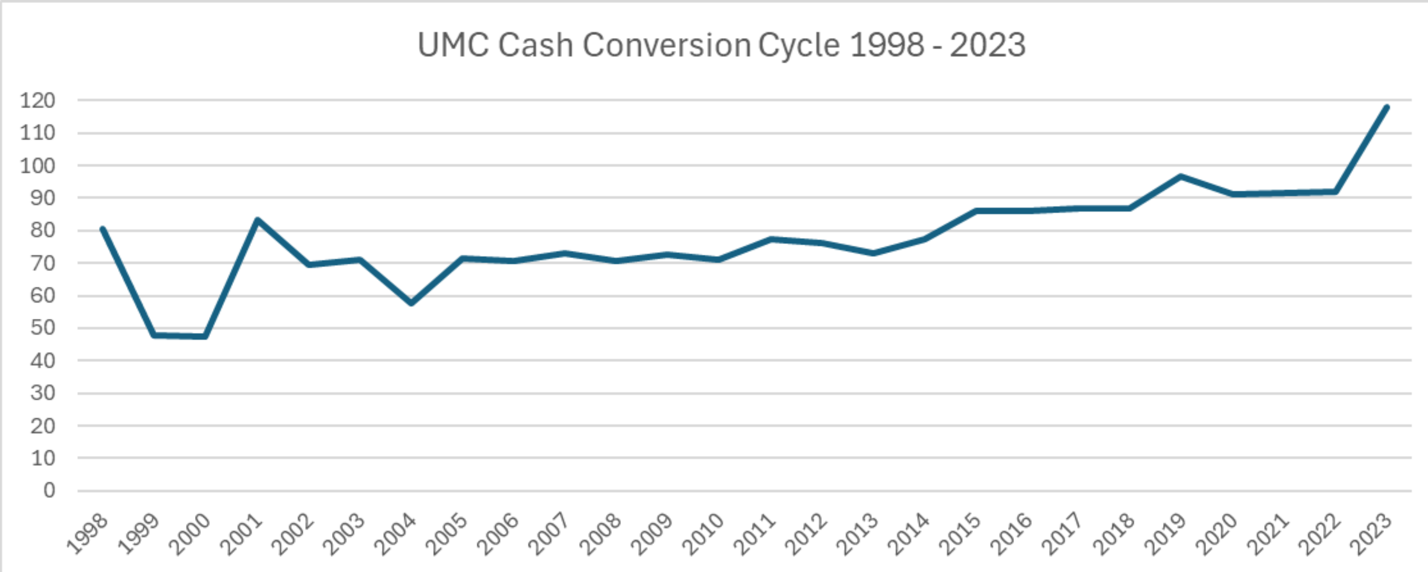
Note:
1. Data prior to 1999 is not available.

Figure 30-1 UMC Turnover Ratios 1998 – 2023



Note:
1. The data begins in 1998 due to the availability of information.

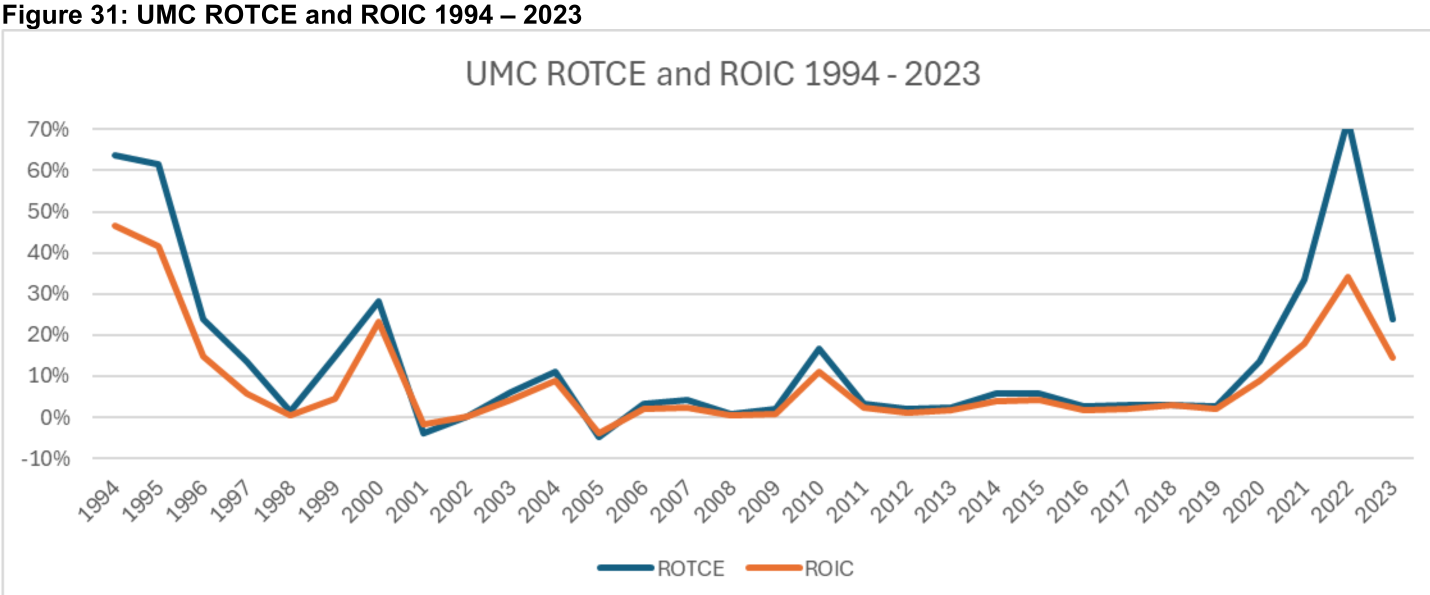
Figure 30-2 UMC Cash Conversion Cycle 1998 – 2023



Note:

1. The data begins in 1998 due to the availability of information.

Figure 31: UMC ROTCE and ROIC 1994 – 2023



GlobalFoundries

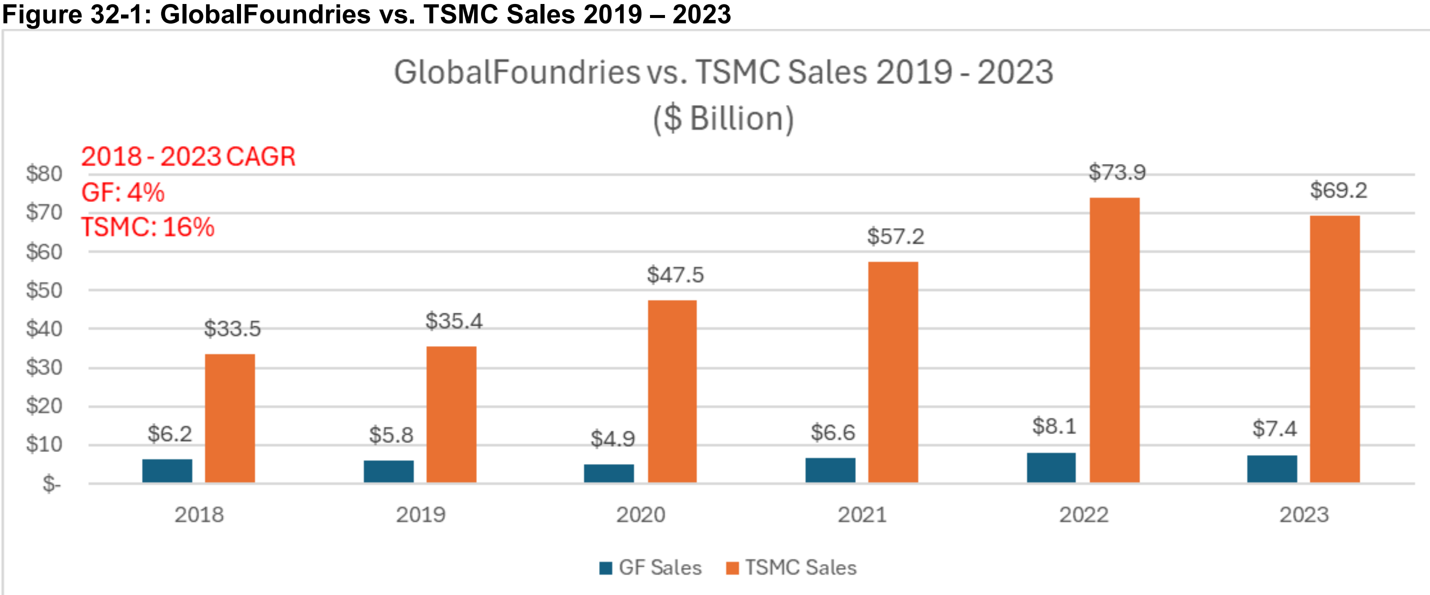
GlobalFoundries, originally called The Foundry Company, initially the manufacturing arm of AMD focusing on chip production, spun off from AMD to become an independent entity in 2008, primarily owned by the Abu Dhabi sovereign fund, Mubadala Investment Company, as AMD transitioned to a fabless business model. Following the spin-off, AMD retained a 34% ownership stake, with the remaining shares held by the sovereign fund.[330] By 2012, AMD had fully exited its stake in GlobalFoundries.[331]

At the time of the spin-off in 2009, GlobalFoundries relied solely on AMD as its customer.[332] According to its IPO documents filed in 2021, the company's most advanced process technology by 2021 was the 28/22nm node, significantly lagging behind TSMC, which had already achieved the 5nm process at that time.

In 2018, GlobalFoundries announced it would halt development of its 7nm process technology. This decision was driven by Mubadala's strategic focus on improving the company's financial position. **Mubadala concluded that further investment in advanced nodes was not viable, as customers requiring such technology were increasingly turning to TSMC.**[333] **<u>This exemplifies the "virtuous cycle" TSMC has established, where its dominance in advanced chipmaking attracts more customers, further strengthening its market position and gradually edging out competitors, especially in the more advanced market segment.</u>** By 2023, all of GlobalFoundries' revenue came from process nodes of 12nm and above, while TSMC derived nearly 60% of its revenue from 7nm and below.

Before the COVID-19 pandemic in 2021, GlobalFoundries struggled with negative gross margins, reflecting the challenges it faced in competing with industry leaders like TSMC.

Figure 32-1: GlobalFoundries vs. TSMC Sales 2019 – 2023



Notes:
1. GlobalFoundries IPO was in Q4 2021.
2. GlobalFoundries' data is sourced from its F-1 registration statements submitted to the SEC and its annual reports.

---

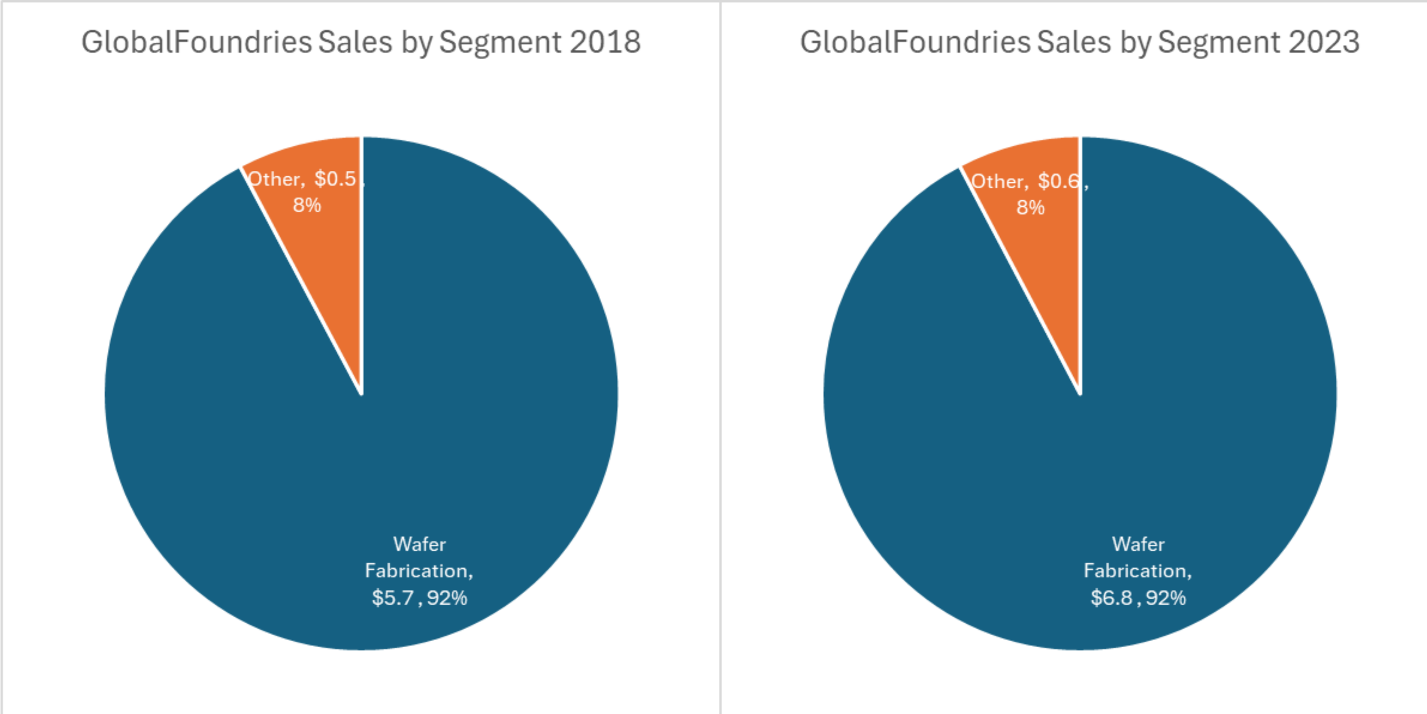
[330] AMD the Advanced Technology Investment Company and Mubadala Amend Transaction Agreements. https://www.mubadala.com/en/news/amd-advanced-technology-investment-company-and-mubadala-amend-transaction-agreements

[331] GlobalFoundries Granted Independence, Acquires Remaining Stake from AMD. https://www.anandtech.com/show/5627/globalfoundries-granted-independence-acquires-remaining-stake-from-amd

[332] GlobalFoundries S-1 2021.

[333] GlobalFoundries Halts 7nm Work. https://www.eetimes.com/globalfoundries-halts-7nm-work/

Figure 32-2: GlobalFoundries Sales by Segment 2018 vs. 2023



Notes:

1. GlobalFoundries IPO was in Q4 2021.
2. GlobalFoundries' data is sourced from its F-1 registration statements submitted to the SEC and its annual reports.

Figure 32-3: GlobalFoundries Sales by Region 2018 vs. 2023

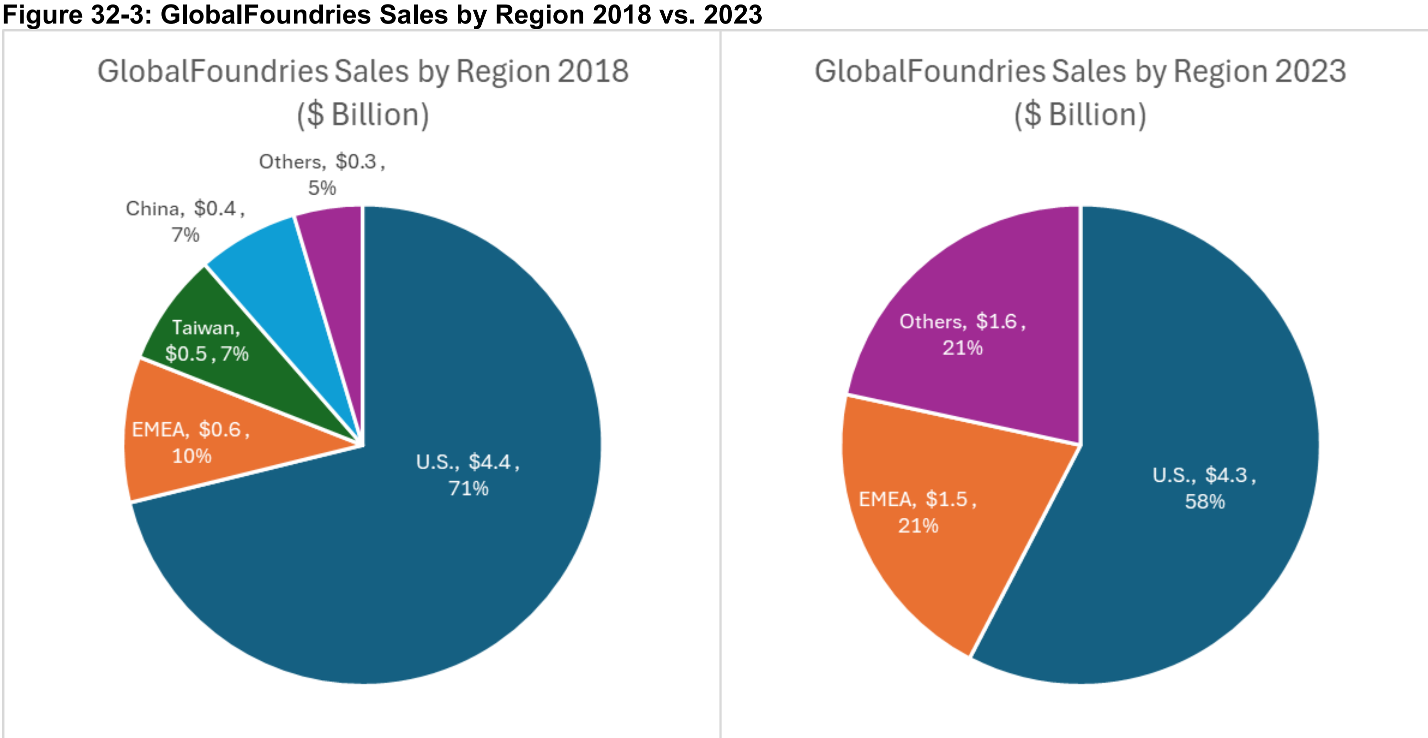
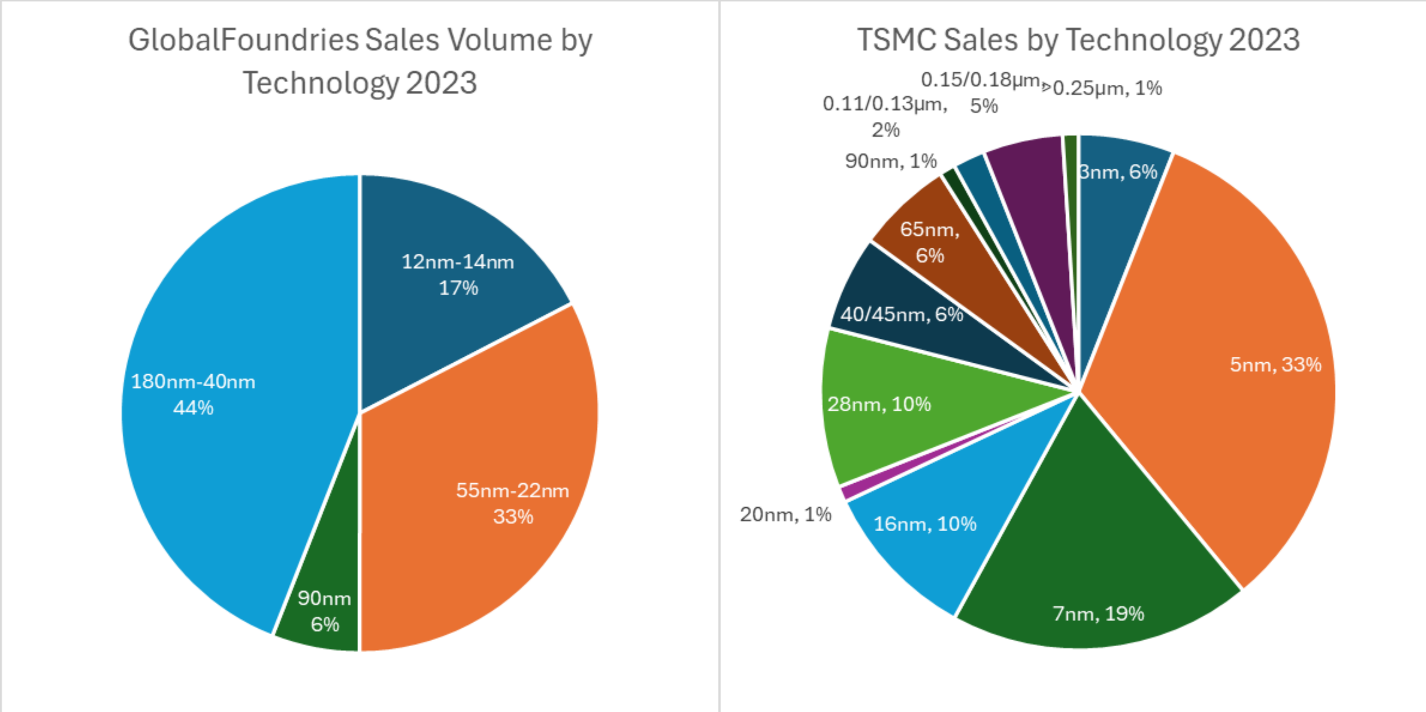


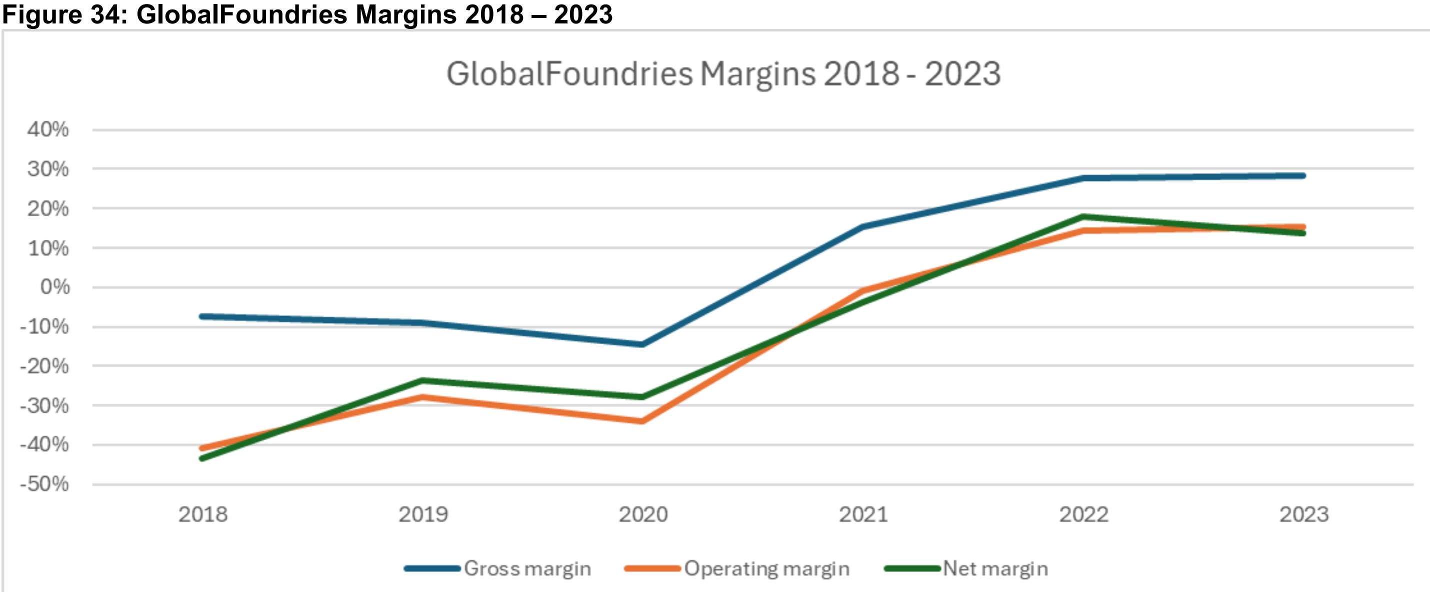
Figure 33: GlobalFoundries vs TSMC Sales by Technology[334]



Note:

1. GlobalFoundries does not disclose its sales by technology node. We estimate the breakdown based on the volume shipped in 2023 provided in its annual report.
2. The term "µm" stands for "micrometer." One micrometer is equal to one millionth of a meter (0.000001 m) or approximately 1/25,400 of an inch (0.00003937 inches).
3. The term "nm" stands for "nanometer." One nanometer is equal to 0.001µm.

Figure 34: GlobalFoundries Margins 2018 – 2023

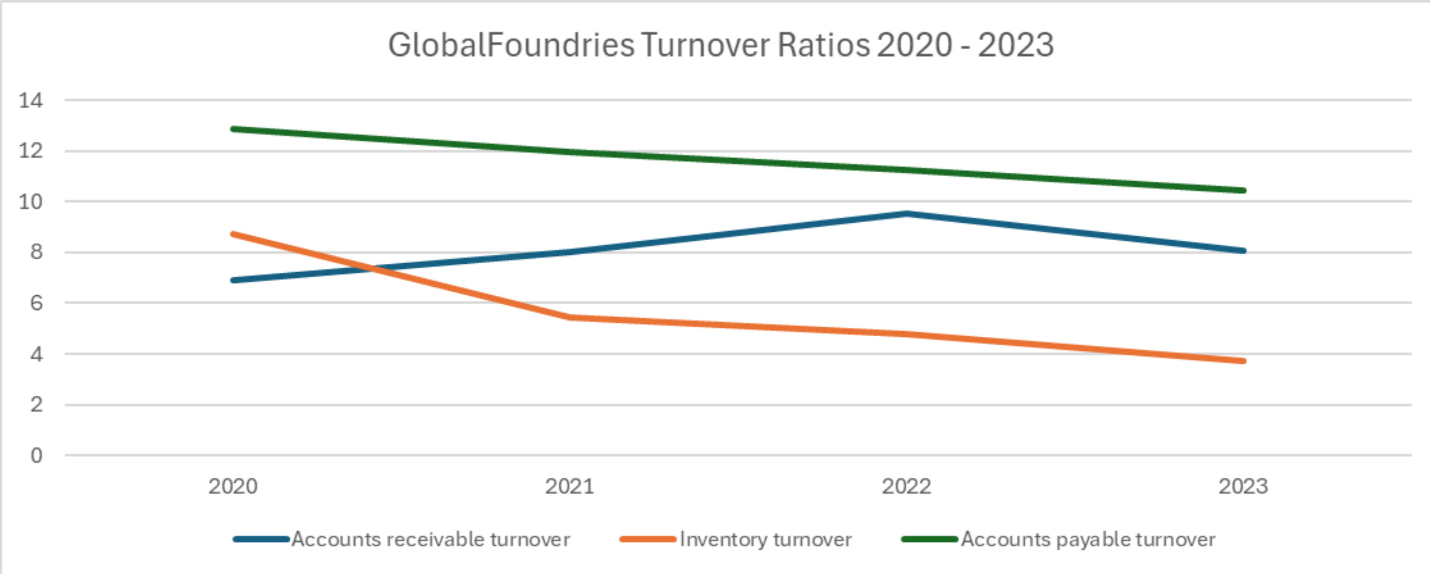


Notes:

1. GlobalFoundries IPO was in Q4 2021.
2. GlobalFoundries' data is sourced from its F-1 registration statements submitted to the SEC and its annual reports.

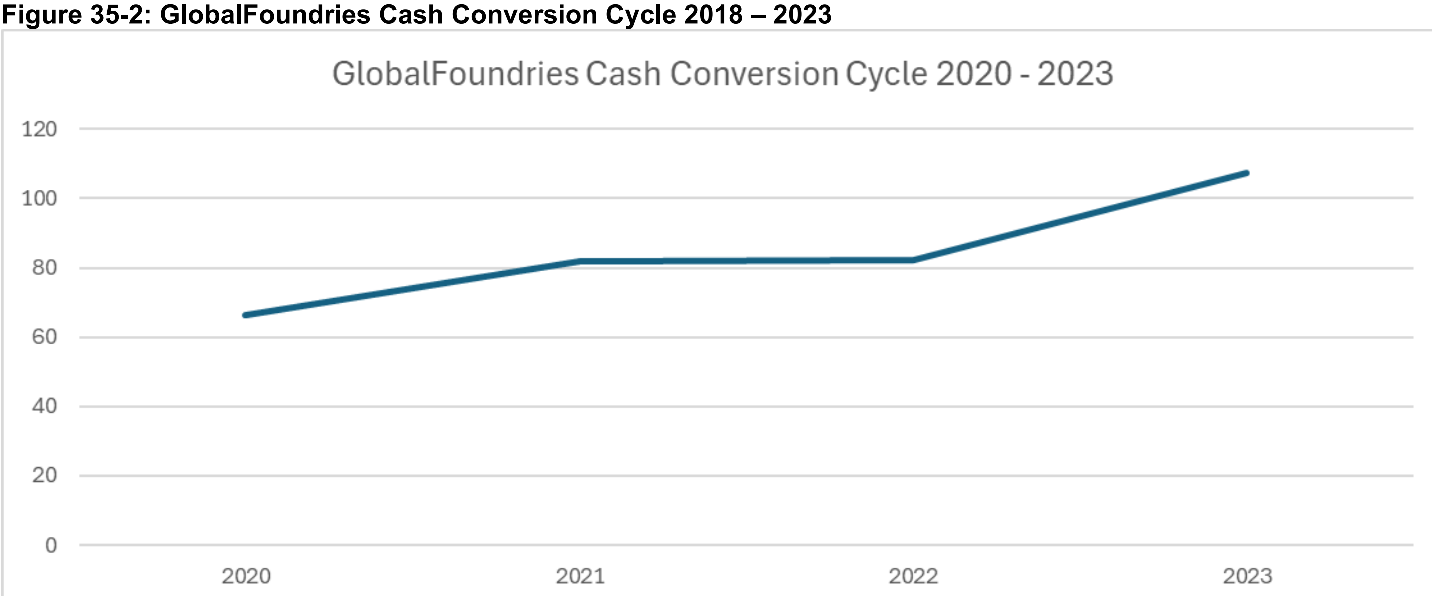
[334] GlobalFoundries Annual Report 2023; TSMC Q4 2023 Investor Presentation

Figure 35-1: GlobalFoundries Turnover Ratios 2018 – 2023



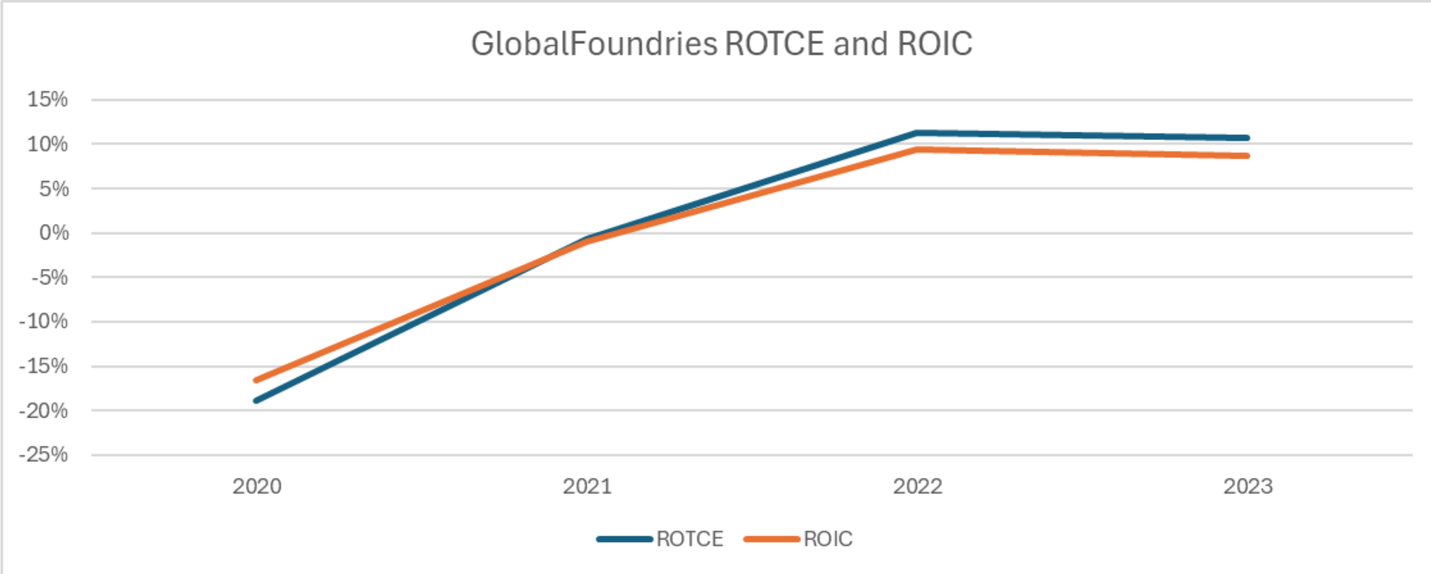
Note:
1. The data begins in 2020 due to the availability of information.

Figure 35-2: GlobalFoundries Cash Conversion Cycle 2018 – 2023



Note:
1. The data begins in 2020 due to the availability of information.

Figure 36: GlobalFoundries ROTCE and ROIC 2018 – 2023



Semiconductor Manufacturing International Corporation (SMIC)

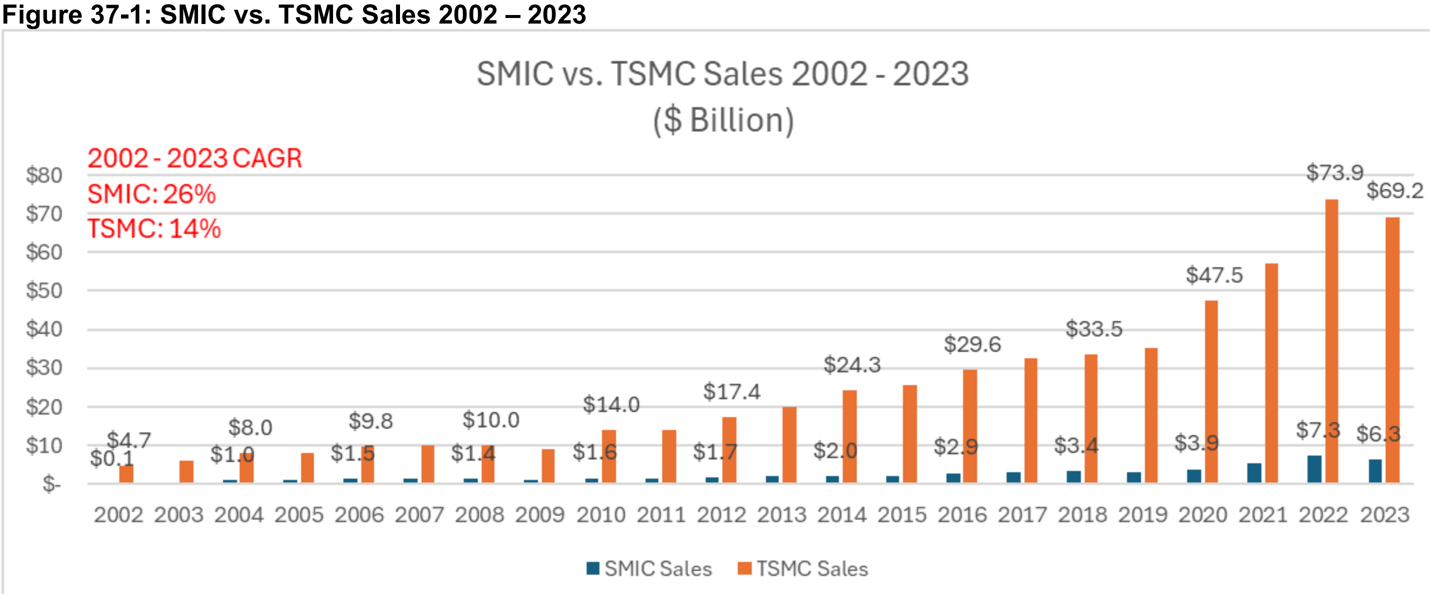
SMIC was founded by Richard Chang (Ru-Gin Chang) as a pure-play foundry, who had an extensive career at Texas Instruments from the 1970s to the 1990s. Chang worked at Texas Instruments from the 1970s to the 1990s and briefly worked with Morris Chang at TSMC before establishing SMIC. The company received partial funding from Chinese state-owned enterprises, underscoring its strategic importance to China's semiconductor industry.

Twelve years after its founding, SMIC achieved operational profitability, with its operating margin increasing from 1.3% in 2012 to 6% in 2023, peaking during 2021 and 2022 amid a global chip shortage driven by the COVID-19 pandemic. Over the years, SMIC has maintained a gross margin in the range of 20% to 30%, which is lower than TSMC's average of 50%.

At the time of its IPO in 2004, SMIC was capable of fabricating both memory and logic wafers using process technologies comparable to TSMC's, about 12% of its revenue comes from the 0.13µm node, with the rest coming from larger nodes.[335] However, SMIC's revenue in 2003 was only 7% of TSMC's, despite its sales of products utilizing 0.13µm relative to its overall sales being only by a few percentage points lower than that of TSMC.

During the U.S. – China trade war, Chinese chipmakers, including SMIC, were banned in 2020 from acquiring equipment necessary for producing semiconductors at advanced process nodes.[336] While SMIC stopped disclosing revenue by technology node in 2022, it is believed that the majority of its revenue comes from nodes at 28nm and above. Although there is speculation about limited production at 14nm (disclosed in the 2020 annual report) and even 7nm, no definitive evidence has confirmed these capabilities.

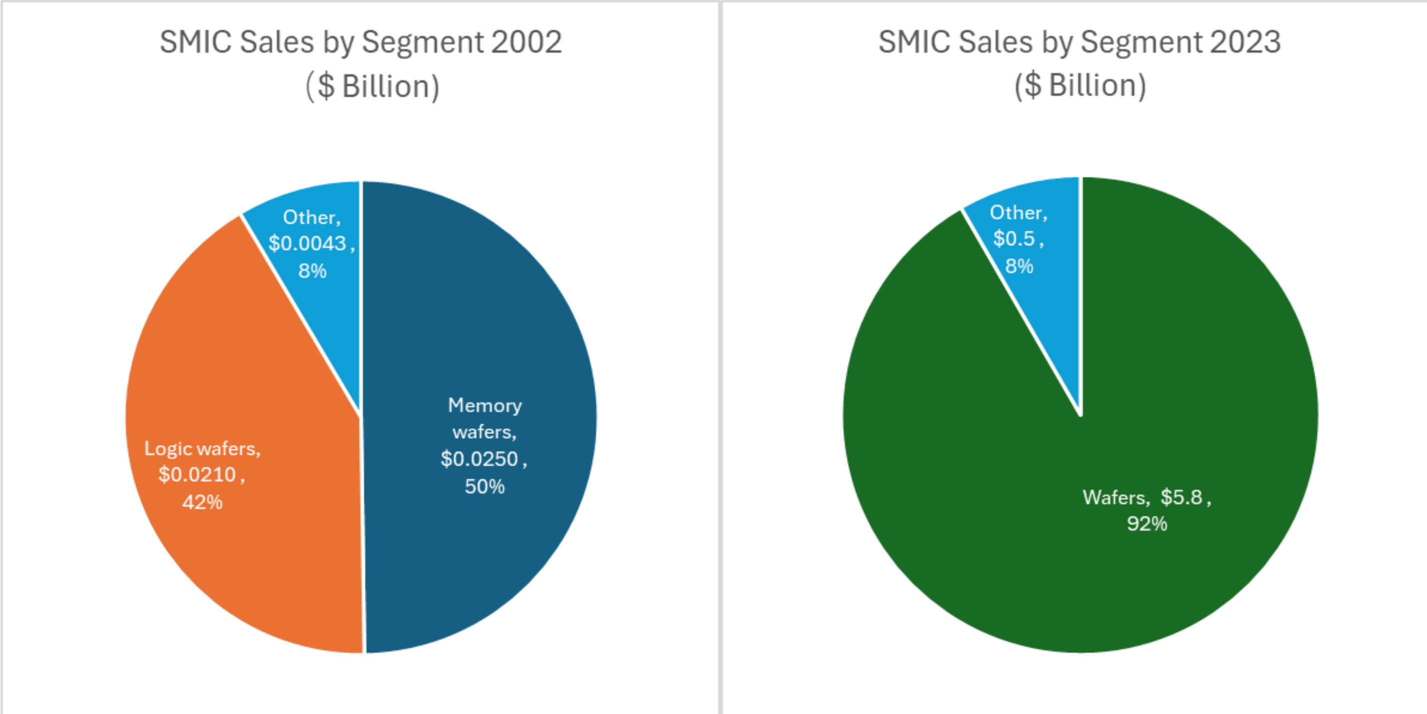
Figure 37-1: SMIC vs. TSMC Sales 2002 – 2023



Notes:
1. SMIC went public in 2004.
2. SMIC data is sourced from its F-1 registration statements submitted to the SEC and its annual reports.

335 SMIC IPO Prospectus 2004.
336 SMIC Removes Mentions of 14nm Node. https://www.tomshardware.com/news/smic-removes-mentions-of-14nm-node

Figure 37-2: SMIC Sales by Segment 2002 vs. 2023



Notes:

1. SMIC went public in 2004.
2. SMIC data is sourced from its F-1 registration statements submitted to the SEC and its annual reports.

Figure 37-3: SMIC Sales by Region 2018 vs. 2023

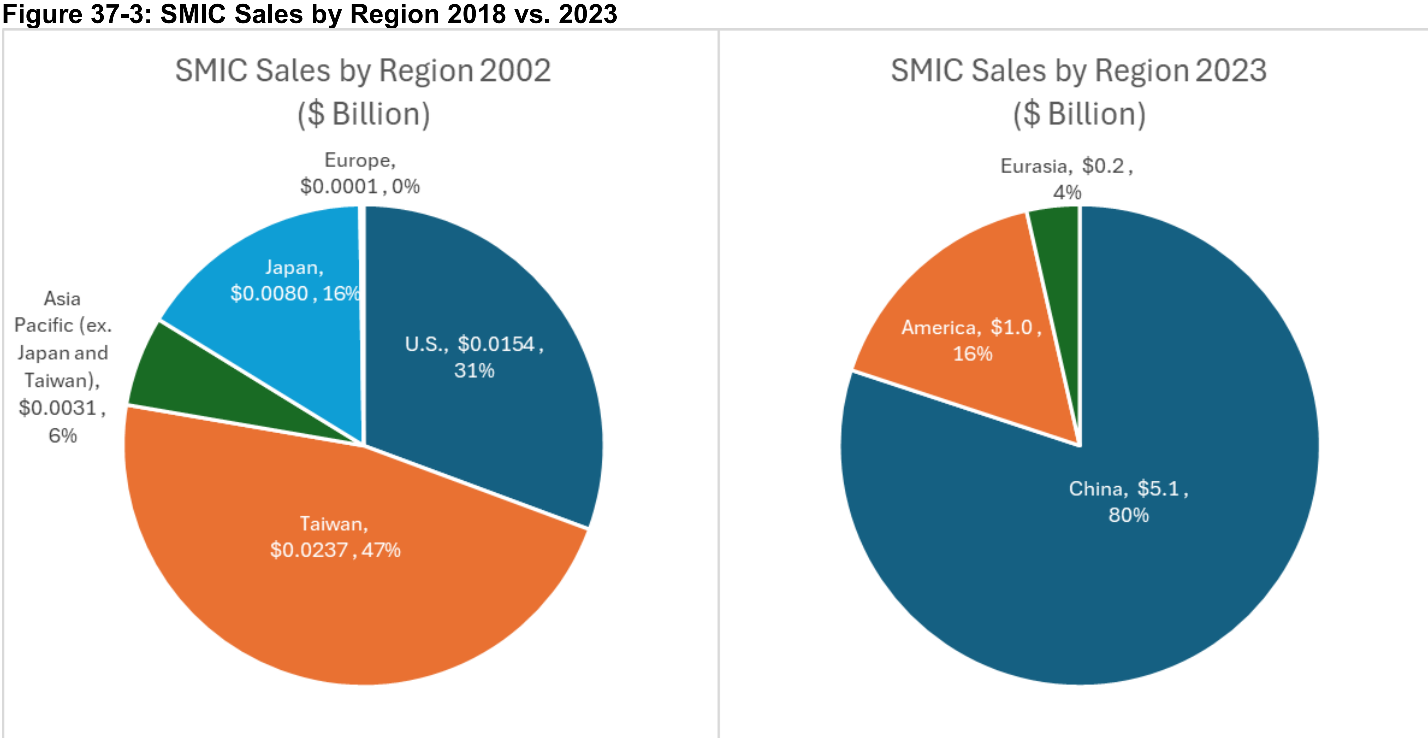
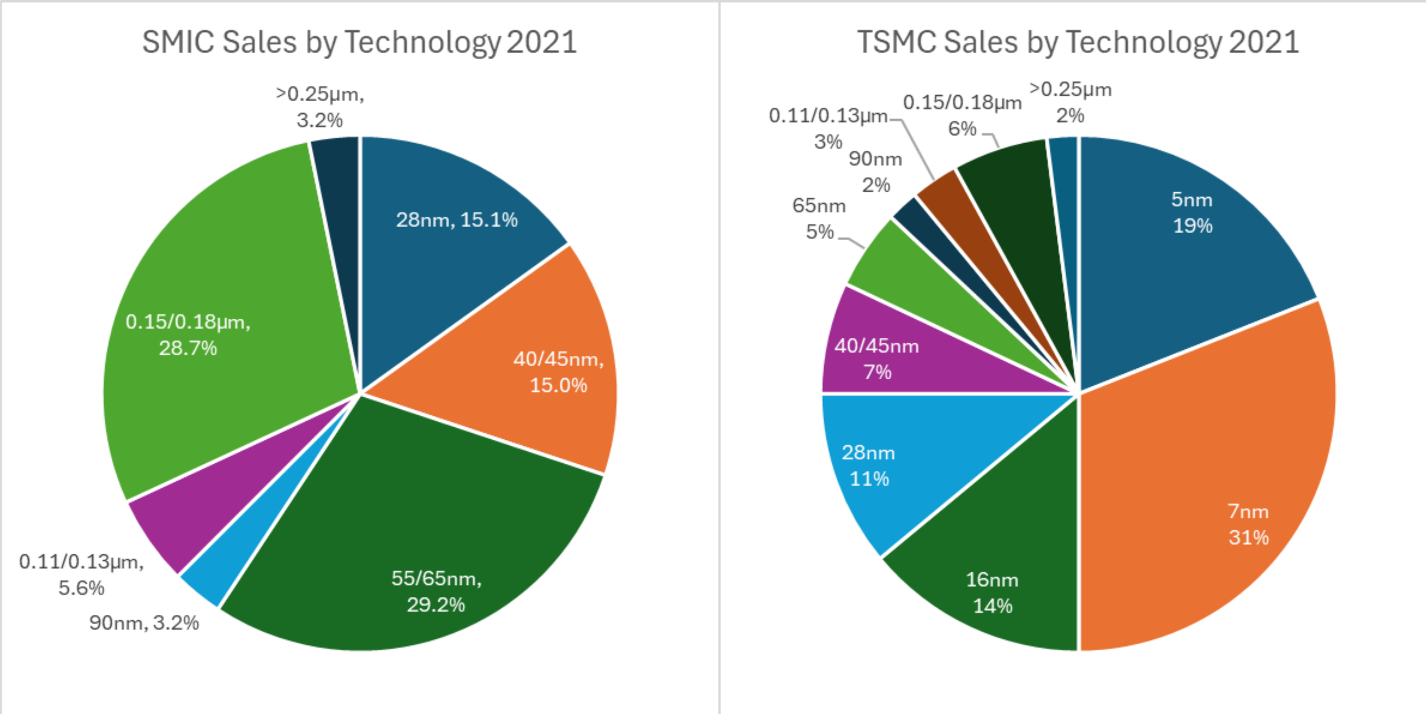
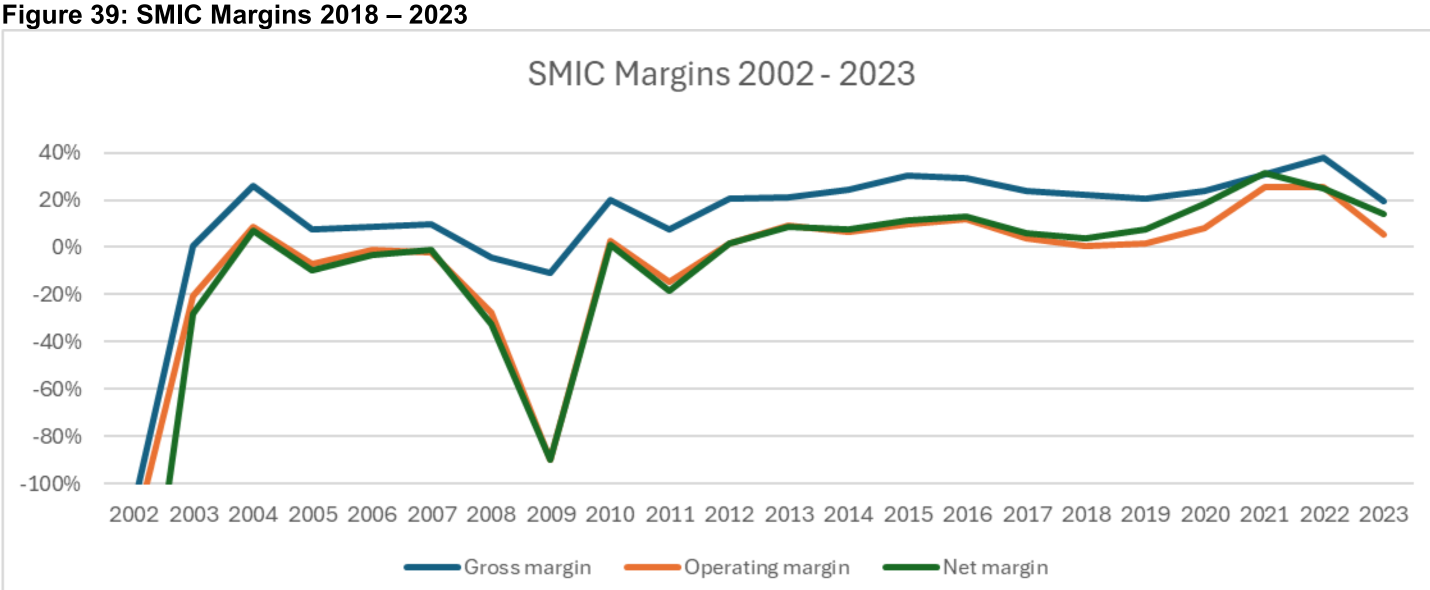


Figure 38: SMIC vs. TSMC Sales by Technology 2021



Notes:
1. Due to the U.S. – China trade war, Chinese chipmakers have faced challenges in acquiring advanced wafer fab equipment needed for nodes such as 7nm and 5nm. While SMIC no longer discloses revenue by technology node since 2022, it is believed that most of its revenue comes from nodes at 28nm and above. There is speculation that SMIC has limited production at 14nm and even 7nm, but no definitive proof exists.
2. In 2021, TSMC was estimated to be at least three generations ahead of SMIC in terms of technology nodes.
3. The term "μm" stands for "micrometer." One micrometer is equal to one millionth of a meter (0.000001 m) or approximately 1/25,400 of an inch (0.00003937 inches).
4. The term "nm" stands for "nanometer." One nanometer is equal to 0.001μm.

Figure 39: SMIC Margins 2018 – 2023



Notes:
1. SMIC went public in 2004.
2. SMIC data is sourced from its F-1 registration statements submitted to the SEC and its annual reports.
3. In 2009, SMIC's operating margin decreased significantly due to 1) a reduced gross margin resulting from the aftermath of the 2008 Global Financial Crisis, which led to continued losses while the company increased its R&D and marketing expenditure despite the market downturn, and 2) a $269.6 million expense related to the settlement of

litigation with TSMC.[337] The lawsuit, filed in 2003, alleged infringement of certain patents and misappropriation of trade secrets related to semiconductor fabrication methods and integrated circuit manufacturing. SMIC settled all pending litigation with TSMC in 2009. After adjusting for litigation expenses, the company's operating margin for 2009 would have been approximately -65%.

Figure 40-1: SMIC Turnover Ratios 2002 – 2023

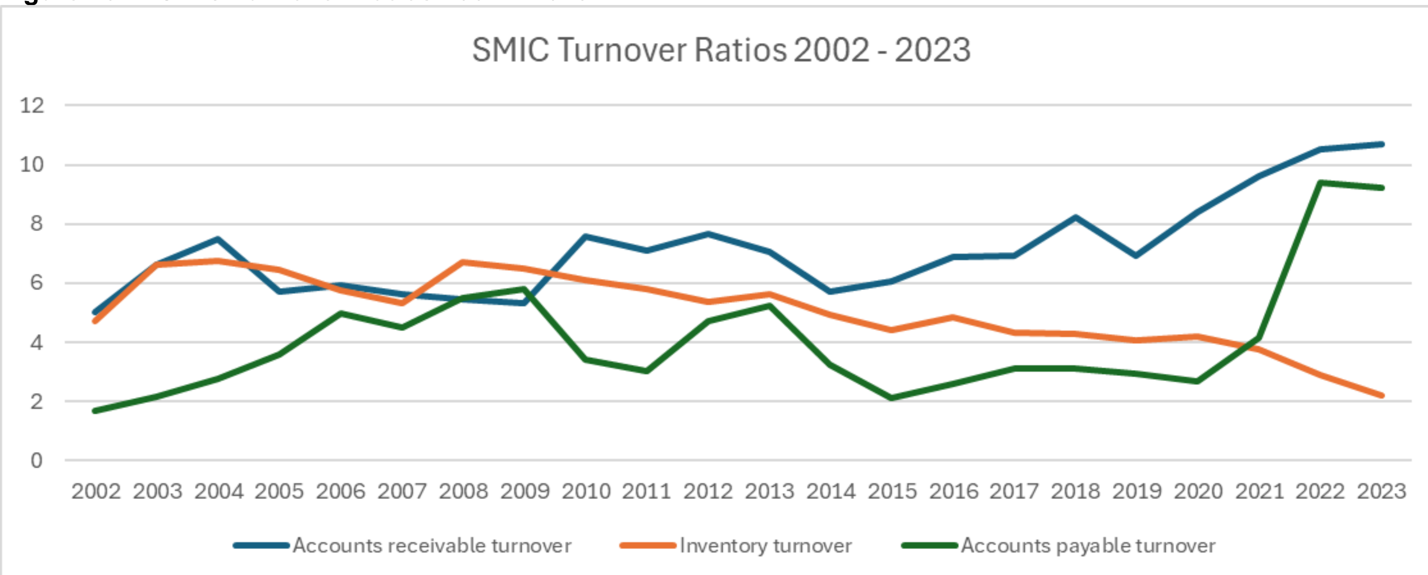
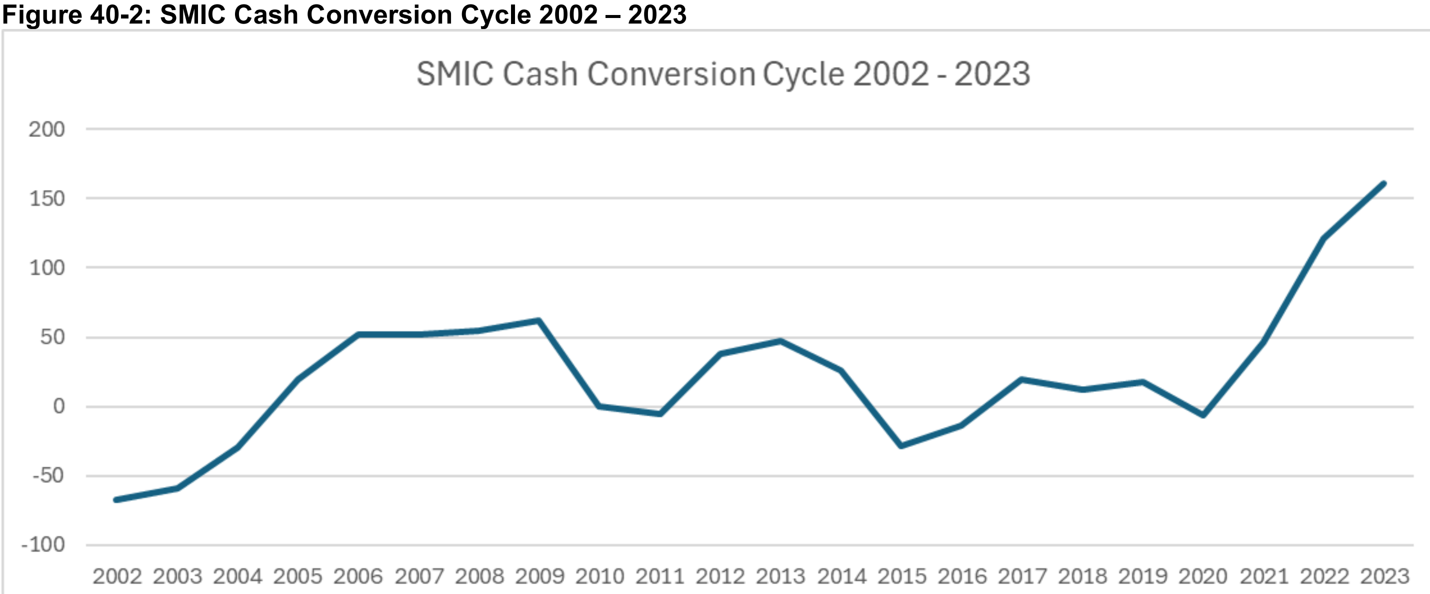
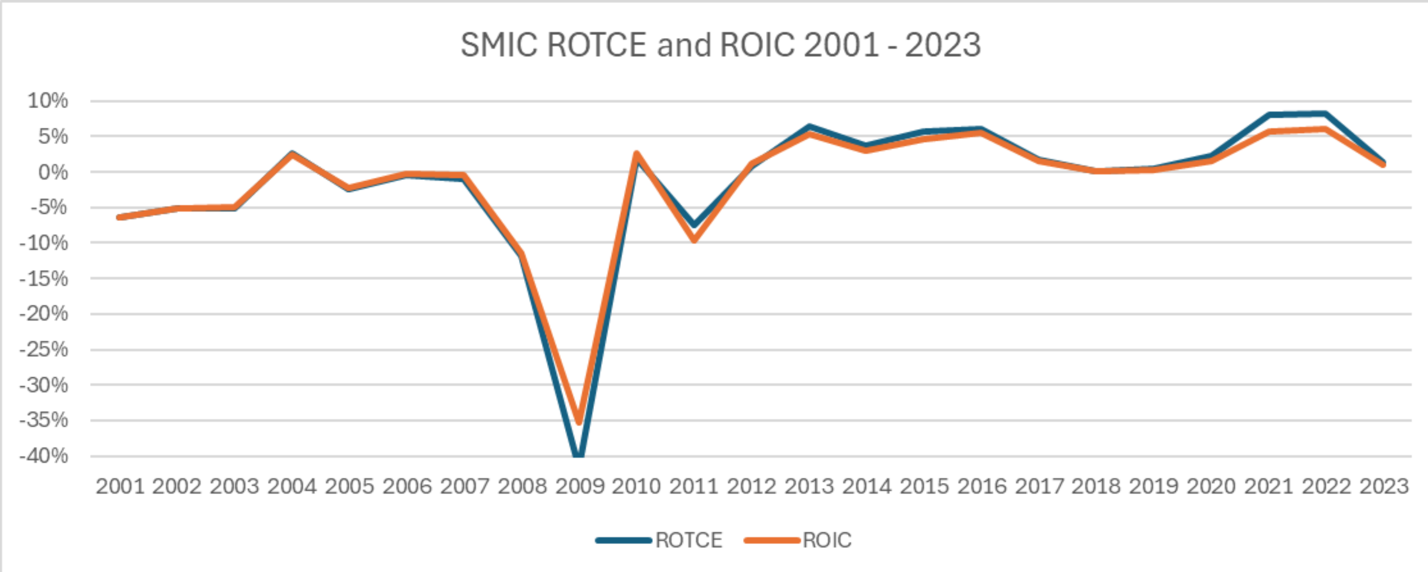


Figure 40-2: SMIC Cash Conversion Cycle 2002 – 2023



[337] SMIC Annual Report 2009.

Figure 41: GlobalFoundries ROTCE and ROIC 2018 – 2023



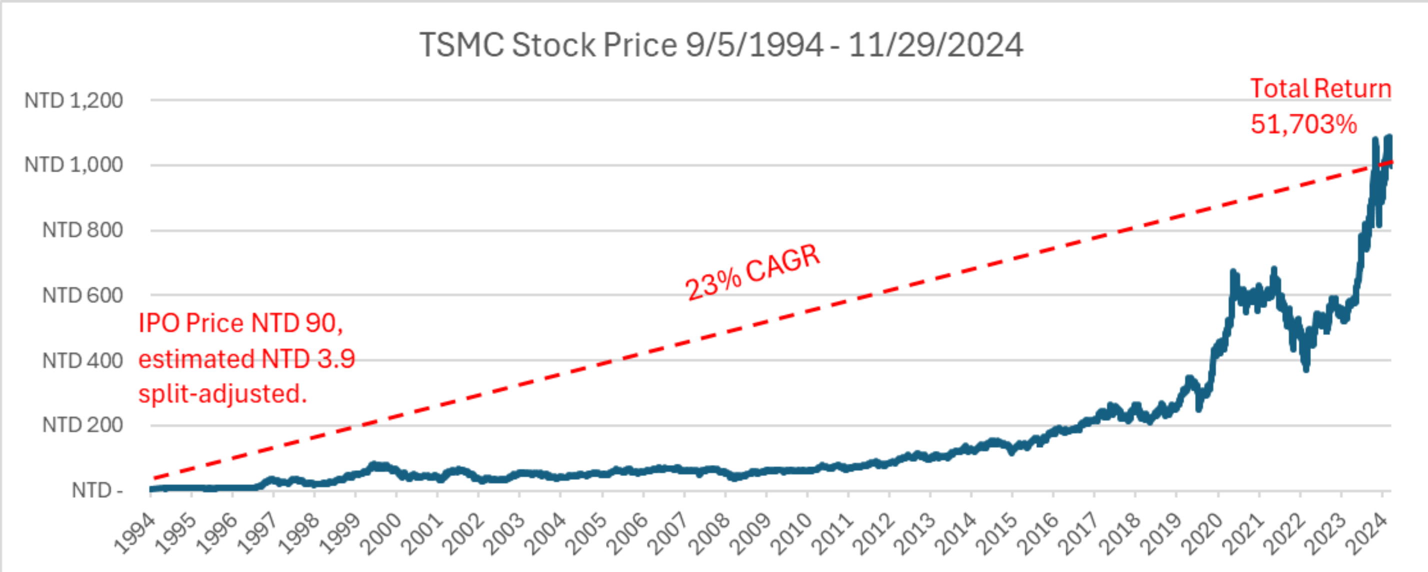
Note:

1. In 2009, SMIC's ROTCE and ROIC decreased significantly due expanding operating losses resulting from 1) a reduced gross margin resulting from the aftermath of the 2008 Global Financial Crisis, which led to continued losses while the company increased its R&D and marketing expenditure despite the market downturn, and 2) a $269.6 million expense related to the settlement of litigation with TSMC.[338] The lawsuit, filed in 2003, alleged infringement of certain patents and misappropriation of trade secrets related to semiconductor fabrication methods and integrated circuit manufacturing. SMIC settled all pending litigation with TSMC in 2009. After adjusting for litigation expenses, the company's ROTCE and ROIC would have been approximately -30% and -25%, respectively.

[338] SMIC Annual Report 2009.

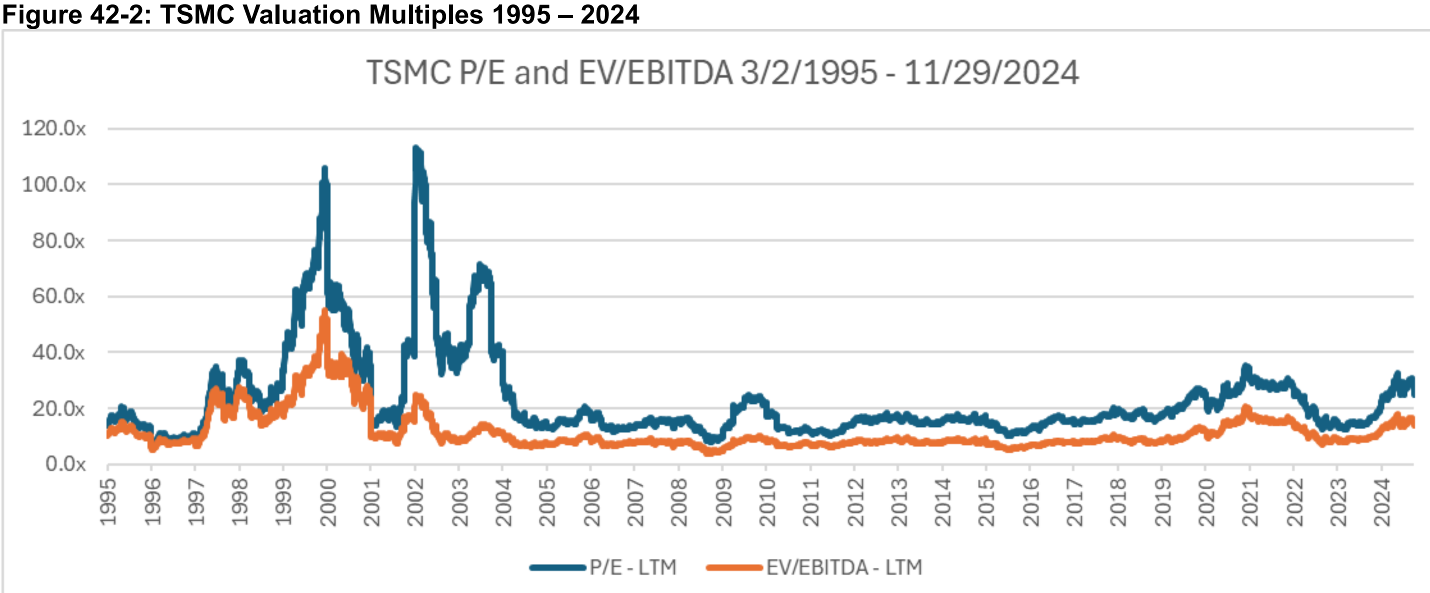
Is The Stock Cheap?

Figure 42-1: TSMC Stock Price 1995 – 2024



Notes:
1. Return data from Bloomberg and FactSet, in local currency.
2. Total returns include dividends reinvested.
3. The start date for the return data above is 9/5/1994, which was the day of TSMC's IPO.
4. Lifetime end date is as of 11/29/2024.

Figure 42-2: TSMC Valuation Multiples 1995 – 2024



Notes:
1. The above daily data is from FactSet.
2. Neither FactSet nor Bloomberg has complete data on valuation multiples from TSMC's IPO date, 9/5/1994. It has been traded on the Taiwan Stock Exchange.
3. The valuation multiples in the chart above are based on the last twelve months.
4. From 1999 to 2000, the global semiconductor market experienced significant growth of 19% and 37%, respectively, following a slowdown over the previous three years. The market had declined by nearly 9% in 1996, grown by 4% in 1997, and declined again by 8% in 1998. Between December 1995 and December 2000, TSMC's market capitalization increased from approximately NTD 123 billion to NTD 930 billion, reflecting a nearly 50% CAGR, while its net profits grew by 34%.
5. In 2001, the global semiconductor market contracted by more than 30%. TSMC's revenue declined by 24%, and its gross margin fell from 46% in 2000 to 27% in 2001, resulting in a 77% drop in net profits.

6. During 2003 and 2004, the global semiconductor market grew by 18% and 28%, respectively. Between December 2002 and December 2004, TSMC's market capitalization increased from NTD 792 billion to NTD 1,170 billion, peaking at over NTD 1,350 billion in the second half of 2003, a CAGR of more than 40%.

In its 1994 annual report, TSMC expected that the global semiconductor market is expected to grow 15% to 20% by 1995, driven by strong demand from companies in the consumer electronics, telecommunications, networking, and automotive industries.[339] In May 1994, the Semiconductor Industry Association expected that the global semiconductor industry would reach $132.7 billion by 1997,[340] implying a 14% CAGR from 1993.

In a scenario analysis, we consider the possibility that at the time of TSMC's IPO, an investor believed the company could continue to outpace overall industry growth over the next five years, as it had in previous years. Although TSMC's growth rate had declined from roughly four times the market rate to around twice the market rate, the assumption is that over the next five years, TSMC would continue to grow at 1.5 times the overall market rate as it scaled further, resulting an estimated 21% CAGR growth rate over the next five years. Furthermore, if gross margins expanded to 50%, similar to its local competitor UMC, by the end of year five, the P/E ratio could fall to 5x, while the P/FCF ratio could decline to 10x.

Figure 43-1: TSMC's 5-Year Scenario at IPO

NTD Billion	1993	1998	5-Year CAGR
Total Revenue	NTD 12.3	NTD 33.3	22%
Gross Profit	NTD 5.7	NTD 16.7	24%
Gross Margin	*46%*	*50%*	
SG&A Expenses	NTD 1.0	NTD 2.7	22%
SG&A Expense as Percentage of Revenue	*8%*	*8%*	
R&D Expenses	NTD 0.3	NTD 1.0	26%
R&D Expense as Percentage of Revenue	*3%*	*3%*	
Operating Income	NTD 4.4	NTD 13.0	24%
Operating Margin	*36%*	*39%*	
Incremental Operating Margin		*41%*	
Earnings Before Tax	NTD 4.2	NTD 13.0	25%
Tax	NTD -	NTD -	
Tax Rate	*0%*	*0%*	
Net Income	NTD 4.2	NTD 13.0	25%
Net Margin	*34%*	*39%*	
FCF	NTD 2.3	NTD 6.8	24%
FCF/EBIT	*52%*	*52%*	
P/E	16.5x	5.4x	
P/FCF	30.8x	10.4x	

Notes:
1. The financial data for 1993 reflects TSMC's actual results from the last fiscal year prior to its IPO. Based on our discussions with TSMC, financial data referenced herein, sourced from the 1994 annual report, represents the earliest publicly available information.
2. The above scenario in 1998 assumes that TSMC's total revenue grew at 21%, or 1.5 times the global semiconductor industry CAGR of 14%, as projected by the Semiconductor Industry Association in 1994.[341] It also assumes gross margins expanded to 50%, following a similar trend to its local competitor, UMC, while operating expenses remained constant as a percentage of sales. In addition, the free cash flow (FCF) conversion rate (FCF/EBIT) is assumed to stay the same by year five.
3. FCF is calculated as CFO-CAPEX
4. At the time of its IPO, TSMC was tax-exempt, a status granted by the local government.
5. The market capitalization and enterprise value at the time of TSMC's IPO were approximately NTD 70 billion and NTD 71 billion, respectively.

339 TSMC Annual Report 1994.

340 Global Semiconductor Market Size 1994. Los Angeles Times. https://www.latimes.com/archives/la-xpm-1994-05-18-fi-59254-story.html

341 Global Semiconductor Market Size 1994. Los Angeles Times. https://www.latimes.com/archives/la-xpm-1994-05-18-fi-59254-story.html

Figure 43-2: TSMC's Actual Operating Results in 1998

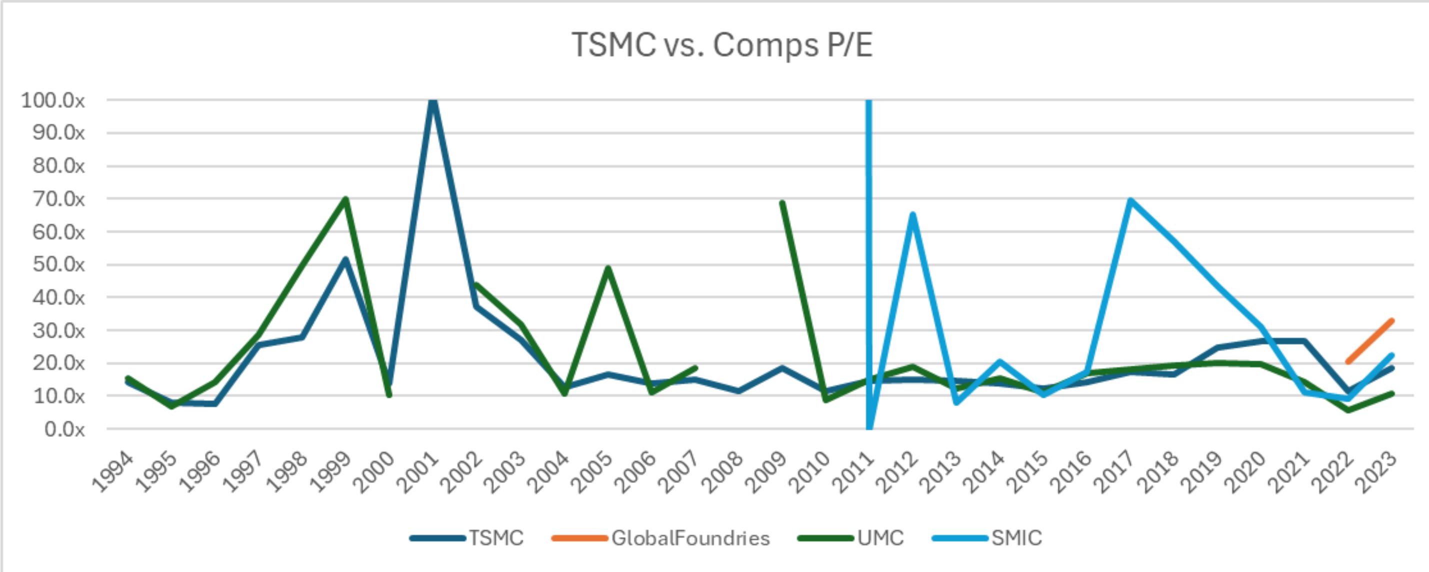
	1993	1998	5-Year CAGR
Total Revenue	NTD 12.3	NTD 50.4	33%
Gross Profit	NTD 5.7	NTD 19.3	31%
Gross Margin	*46%*	*38%*	
SG&A Expenses	NTD 1.0	NTD 2.3	18%
SG&A Expense as Percentage of Revenue	*8%*	*5%*	
R&D Expenses	NTD 0.3	NTD 3.2	60%
R&D Expense as Percentage of Revenue	*3%*	*6%*	
Operating Income	NTD 4.4	NTD 13.8	26%
Operating Margin	*36%*	*27%*	
Incremental Operating Margin		*25%*	
Earnings Before Tax	NTD 4.2	NTD 12.7	24%
Tax	NTD -	NTD (1.7)	
Tax Rate	*0%*	*-13%*	
Net Income	NTD 4.2	NTD 15.3	29%
Net Margin	*34%*	*30%*	
FCF	NTD 2.3	NTD 5.9	21%
FCF/EBIT	*52%*	*43%*	
P/E	16.5x	5.0x	
P/FCF	30.8x	13.2x	

Notes:

1. The financial data for 1993 reflects TSMC's actual results from the last fiscal year prior to its IPO. Based on our discussions with TSMC, financial data referenced herein, sourced from the 1994 annual report, represents the earliest publicly available information.
2. FCF is calculated as CFO-CAPEX
3. At the time of its IPO, TSMC was tax-exempt, a status granted by the local government.
4. Valuation multiples in 1998 are split-adjusted.
5. The market capitalization and enterprise value at the time of TSMC's IPO were approximately NTD 70 billion and NTD 71 billion, respectively.

The following summarizes the annual valuation multiples and financial metrics of pure-play competitors in the semiconductor foundry industry.

Figure 44-1 TSMC vs. Comps P/E



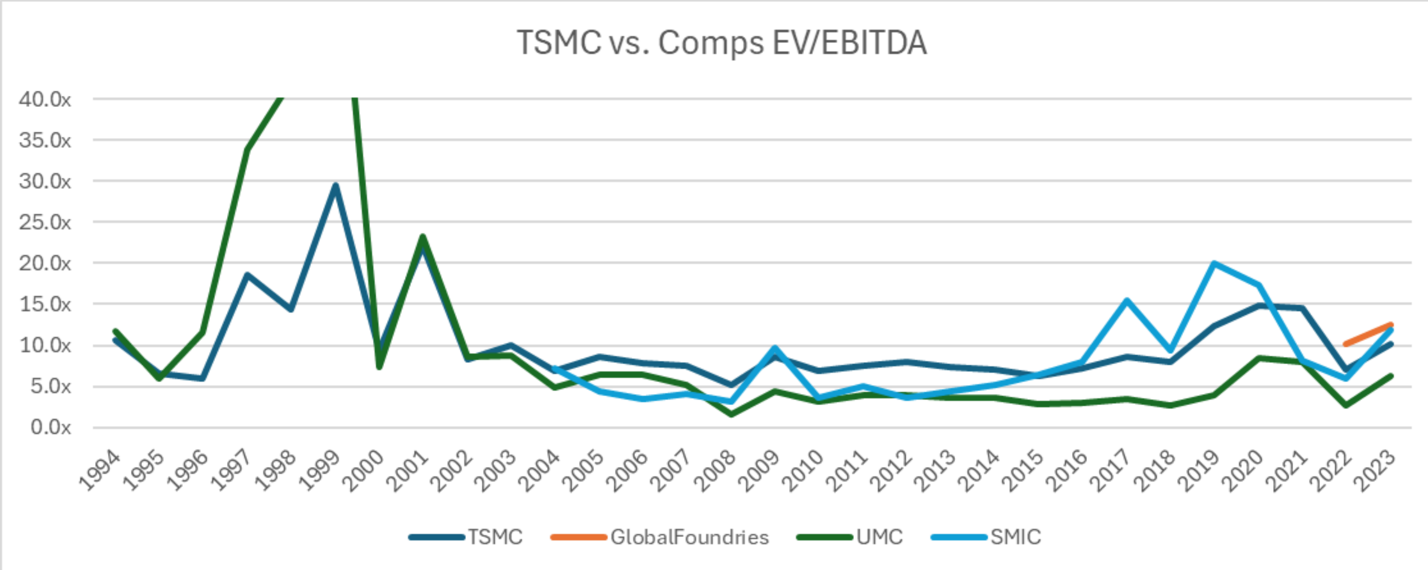
P/E	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
TSMC	14.4x	8.2x	7.7x	25.5x	28.0x	51.5x	13.9x	101.7x	37.4x	27.3x	12.7x	16.5x	13.9x	15.0x	11.5x	18.7x
GlobalFoundries																
UMC	15.6x	6.8x	14.4x	28.4x	49.8x	70.0x	10.2x		44.0x	31.6x	10.9x	49.0x	11.2x	18.5x		68.8x
SMIC																

P/E	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	Median
TSMC	11.4x	14.6x	15.1x	14.5x	13.9x	12.1x	14.1x	17.4x	16.7x	24.9x	26.5x	26.7x	11.4x	18.3x	**15.1x**
GlobalFoundries													20.5x	32.8x	**26.7x**
UMC	8.6x	15.1x	18.9x	12.2x	15.2x	11.2x	16.8x	18.0x	19.3x	20.0x	19.5x	14.2x	5.7x	10.7x	**16.2x**
SMIC	7000.0x	N/A	65.3x	7.9x	20.3x	10.2x	17.4x	69.6x	57.2x	43.4x	31.0x	11.2x	9.3x	22.3x	**22.3x**

Notes:

1. Data from FactSet.
2. Empty cells indicate unavailable or negative values.
3. P/E ratios are calculated by dividing the company's stock market price at the end of the fiscal year by its net profit for that same year.
4. From 1999 to 2000, the global semiconductor market experienced significant growth of 19% and 37%, respectively, following a slowdown over the previous three years. The market had declined by nearly 9% in 1996, grown by 4% in 1997, and declined again by 8% in 1998. Between December 1995 and December 2000, TSMC's market capitalization increased from approximately NTD 123 billion to NTD 930 billion, reflecting a nearly 50% CAGR, while its net profits grew by 34%.
5. In 2001, the global semiconductor market contracted by more than 30%. TSMC's revenue declined by 24%, and its gross margin fell from 46% in 2000 to 27% in 2001, resulting in a 77% drop in net profits.

Figure 44-2: TSMC vs. Comps EV/EBITDA

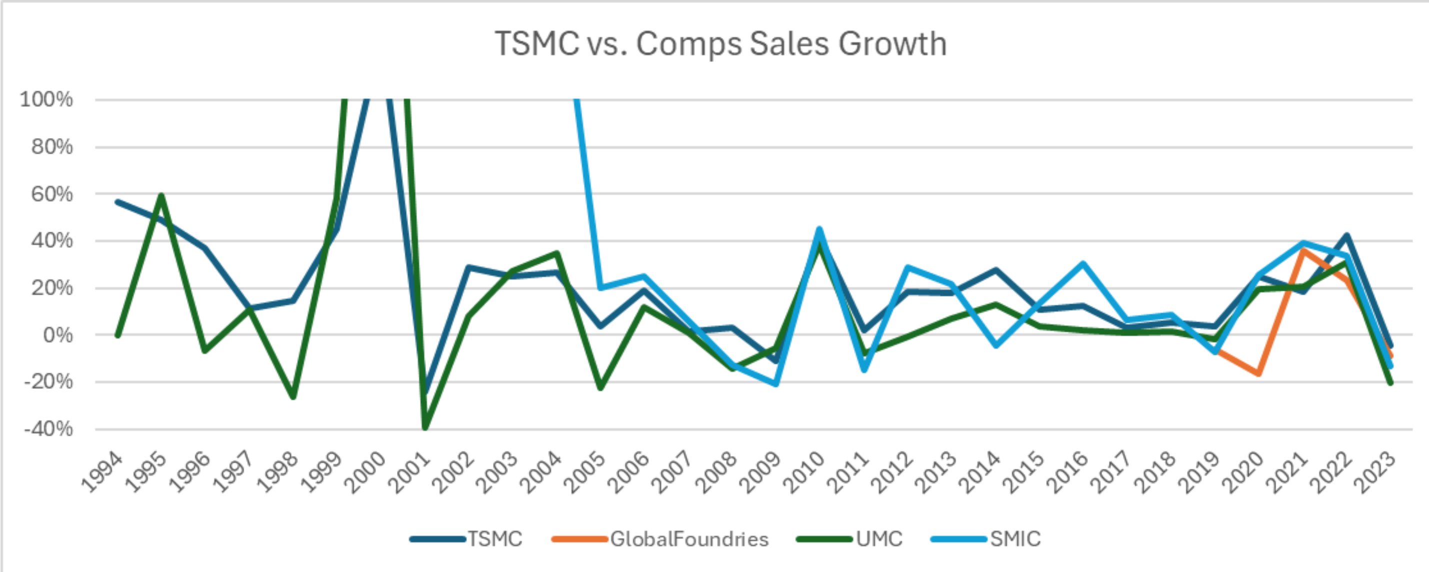


EV/EBITDA	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
TSMC	10.6x	6.7x	5.9x	18.6x	14.3x	29.4x	9.3x	22.1x	8.2x	10.1x	6.9x	8.5x	7.8x	7.5x	5.1x	8.6x
GlobalFoundries																
UMC	11.8x	6.0x	11.5x	33.9x	42.2x	65.5x	7.4x	23.2x	8.6x	8.7x	4.8x	6.5x	6.5x	5.2x	1.6x	4.4x
SMIC											7.2x	4.4x	3.5x	4.1x	3.2x	9.7x

EV/EBITDA	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	Median
TSMC	6.9x	7.5x	7.9x	7.4x	7.0x	6.2x	7.2x	8.5x	8.0x	12.4x	14.8x	14.5x	7.0x	10.1x	**8.1x**
GlobalFoundries													10.2x	12.4x	**11.3x**
UMC	3.2x	4.0x	3.9x	3.7x	3.6x	2.8x	3.0x	3.5x	2.7x	3.9x	8.5x	8.0x	2.7x	6.3x	**5.6x**
SMIC	3.6x	5.0x	3.6x	4.5x	5.2x	6.5x	8.0x	15.5x	9.3x	19.9x	17.3x	8.2x	5.9x	11.8x	**6.2x**

Notes:
1. Data from FactSet.
2. Empty cells indicate unavailable or negative values.
3. EV/EBITDA ratios are calculated by dividing the company's enterprise value at the end of the fiscal year by its EBITDA for that same year.
4. From 1999 to 2000, the global semiconductor market experienced significant growth of 19% and 37%, respectively, following a slowdown over the previous three years. The market had declined by nearly 9% in 1996, grown by 4% in 1997, and declined again by 8% in 1998. Between December 1995 and December 2000, TSMC's market capitalization increased from approximately NTD 123 billion to NTD 930 billion, reflecting a nearly 50% CAGR, while its net profits grew by 34%.
5. In 2001, the global semiconductor market contracted by more than 30%. TSMC's revenue declined by 24%, and its gross margin fell from 46% in 2000 to 27% in 2001, resulting in a 77% drop in net profits.

Figure 44-3: TSMC vs. Comps Sales Growth



Sales Growth	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
TSMC	56.8%	48.8%	37.0%	11.5%	14.8%	44.9%	127.5%	-24.3%	28.9%	25.1%	26.7%	3.6%	19.1%	1.6%	3.3%	-11.2%
GlobalFoundries																
UMC	0.0%	59.1%	-6.8%	11.0%	-26.5%	58.1%	296.6%	-39.6%	8.0%	26.9%	35.0%	-22.4%	11.7%	1.2%	-14.6%	-5.6%
SMIC										627.1%	166.4%	20.2%	25.1%	5.8%	-12.7%	-20.9%

Sales Growth	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	Median
TSMC	41.9%	1.8%	18.5%	17.9%	27.8%	10.6%	12.4%	3.1%	5.5%	3.7%	25.2%	18.5%	42.6%	-4.5%	**18.2%**
GlobalFoundries										-6.2%	-16.6%	35.8%	23.1%	-8.8%	**-6.2%**
UMC	38.4%	-7.7%	-0.9%	7.0%	13.1%	3.4%	2.1%	1.0%	1.3%	-2.0%	19.3%	20.5%	30.8%	-20.2%	**2.8%**
SMIC	45.3%	-15.1%	29.0%	21.6%	-4.8%	13.5%	30.3%	6.4%	8.3%	-7.3%	25.4%	39.3%	33.6%	-13.1%	**20.2%**

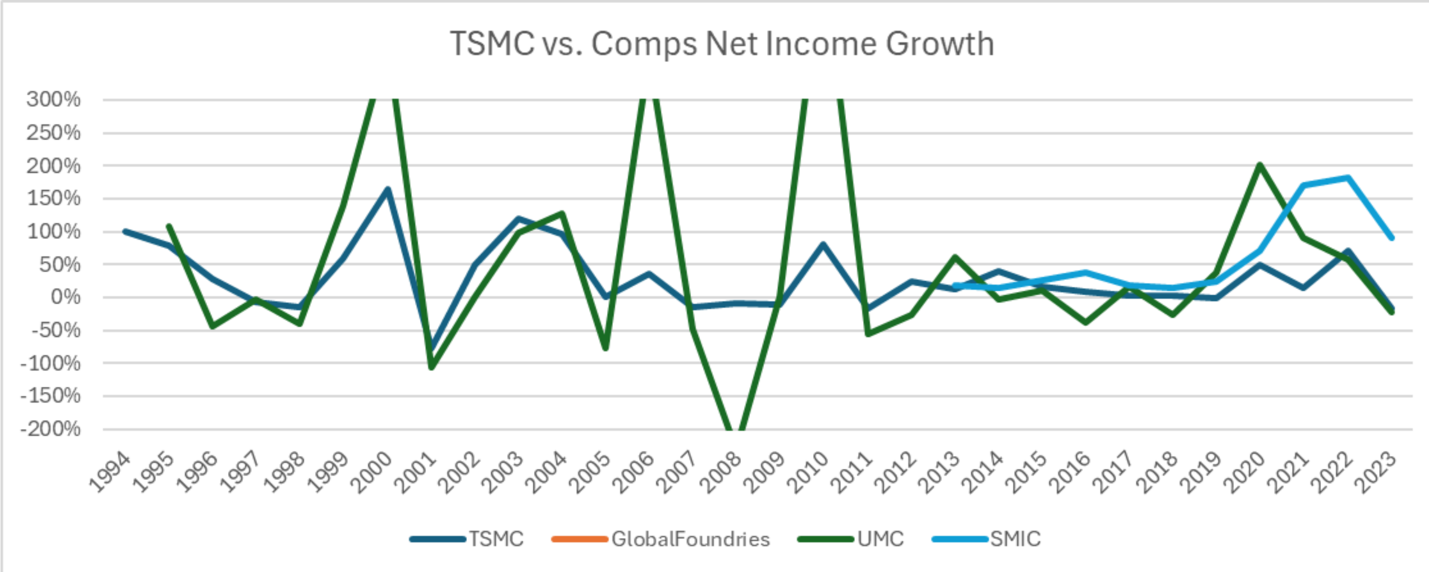
Notes:
1. Data from FactSet and company documents.
2. Empty cells indicate unavailable data.
3. From 1999 to 2000, the global semiconductor market experienced significant growth of 19% and 37%, respectively, following a slowdown over the previous three years. The market had declined by nearly 9% in 1996, grown by 4% in 1997, and declined again by 8% in 1998.
4. In 2001, the global semiconductor market contracted by more than 30%. TSMC's revenue declined by 24%, and its gross margin fell from 46% in 2000 to 27% in 2001, resulting in a 77% drop in net profits.
5. In 2005, global demand for semiconductors slowed to nearly 7% growth, following 18% growth in 2003 and 28% in 2004. Semiconductor foundries experienced lower capacity utilization as customers adjusted their inventories in response to weaker demand.[342] UMC faced a decline in sales volume and lower average selling prices. In 2006, the semiconductor market rebounded with 9% growth. As a result, UMC experienced higher capacity utilization, leading to improved gross margins driven by lower unit costs.[343]
6. During 2008 and 2009, amid the Global Financial Crisis, the global semiconductor market contracted by 3% and 9%, respectively. Semiconductor foundries were negatively impacted by the sharp decline in demand. In 2010, the global semiconductor market recovered and grew by nearly 32%. This recovery significantly boosted the sales and gross margins of foundries such as TSMC and UMC
7. SMIC generated its first sales in 2002.

---

[342] TSMC Annual Report 2005; UMC Annual Report 2005.

[343] UMC Annual Report 2006.

Figure 44-4: TSMC vs. Comps Net Income Growth



Net Income Growth	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
TSMC	99.6%	78.0%	28.6%	-7.4%	-14.6%	60.1%	165.1%	-77.7%	49.1%	118.7%	95.3%	1.4%	35.7%	-14.0%	-8.5%	-10.7%
GlobalFoundries																
UMC		107.0%	-43.1%	-3.3%	-40.4%	138.2%	383.7%	-106.2%		98.2%	127.1%	-77.9%	364.2%	-48.0%	-231.6%	
SMIC																

Net Income Growth	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	Median
TSMC	81.1%	-17.0%	23.8%	13.2%	40.3%	16.2%	9.0%	2.7%	2.3%	-1.7%	50.0%	15.2%	70.4%	-17.5%	**15.7%**
GlobalFoundries														-29.6%	**-29.6%**
UMC	516.9%	-55.6%	-26.3%	61.5%	-3.9%	10.8%	-38.2%	15.8%	-26.5%	37.2%	200.7%	91.1%	56.3%	-22.7%	**10.8%**
SMIC				17.3%	15.3%	25.3%	37.7%	18.0%	13.4%	23.5%	71.6%	170.2%	181.8%	90.3%	**25.3%**

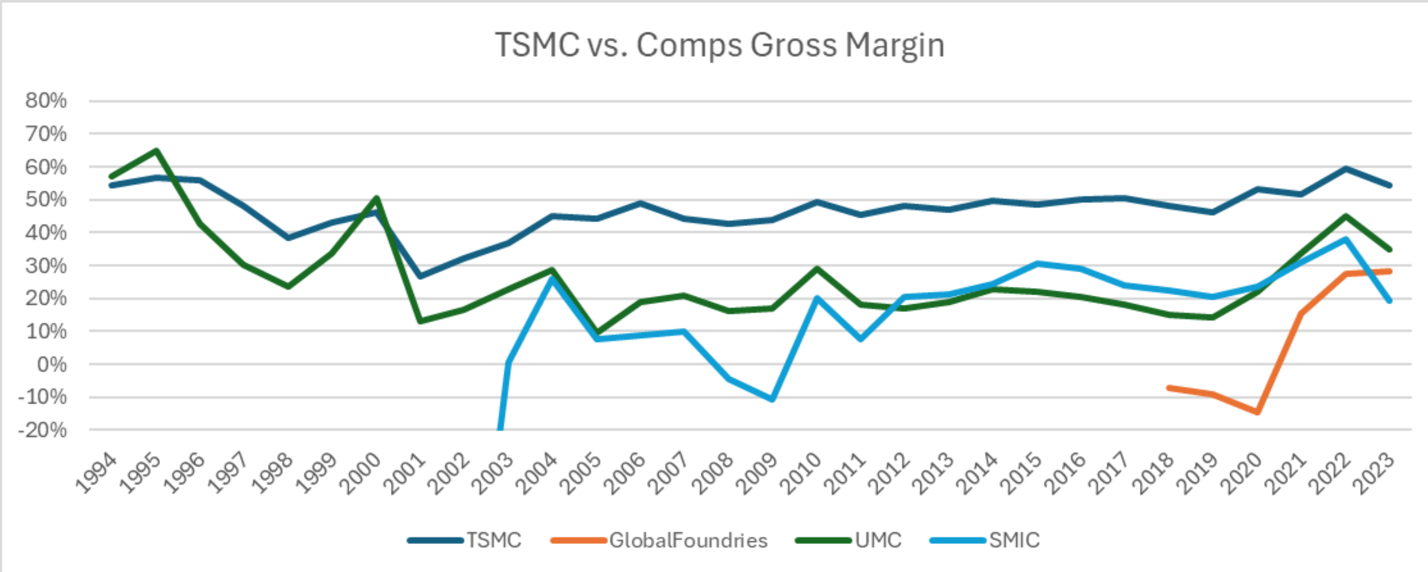
Notes:

1. Data from FactSet and company documents.
2. Empty cells indicate unavailable data.
3. From 1999 to 2000, the global semiconductor market experienced significant growth of 19% and 37%, respectively, following a slowdown over the previous three years. The market had declined by nearly 9% in 1996, grown by 4% in 1997, and declined again by 8% in 1998.
4. In 2001, the global semiconductor market contracted by more than 30%. TSMC's revenue declined by 24%, and its gross margin fell from 46% in 2000 to 27% in 2001, resulting in a 77% drop in net profits.
5. In 2005, global demand for semiconductors slowed to nearly 7% growth, following 18% growth in 2003 and 28% in 2004. Semiconductor foundries experienced lower capacity utilization as customers adjusted their inventories in response to weaker demand.[344] UMC faced a decline in sales volume and lower average selling prices. In 2006, the semiconductor market rebounded with 9% growth. As a result, UMC experienced higher capacity utilization, leading to improved gross margins driven by lower unit costs.[345]
6. During 2008 and 2009, amid the Global Financial Crisis, the global semiconductor market contracted by 3% and 9%, respectively. Semiconductor foundries were negatively impacted by the sharp decline in demand. In 2010, the global semiconductor market recovered and grew by nearly 32%. This recovery significantly boosted the sales and gross margins of foundries such as TSMC and UMC.

[344] TSMC Annual Report 2005; UMC Annual Report 2005.

[345] UMC Annual Report 2006.

Figure 44-5: TSMC vs. Comps Gross Margin

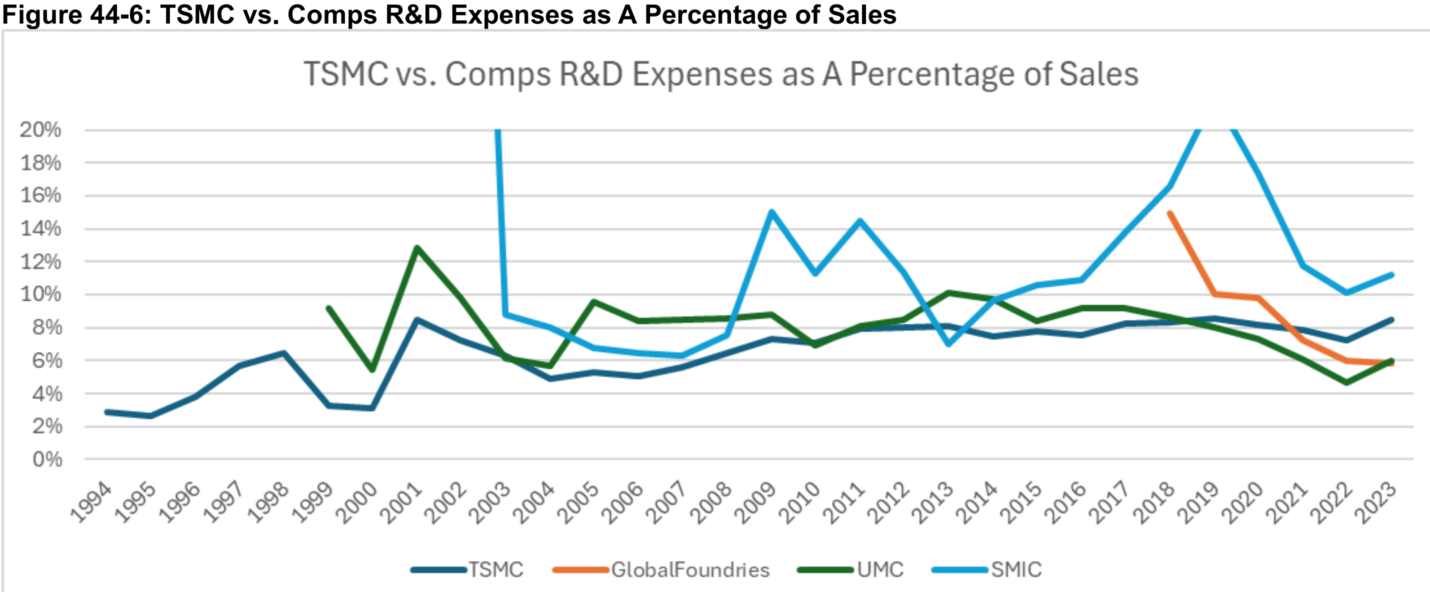


Gross Margin	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
TSMC	54.3%	56.8%	55.7%	48.0%	38.4%	43.1%	46.0%	26.7%	32.2%	36.9%	45.0%	44.3%	49.1%	44.1%	42.5%	43.7%
GlobalFoundries																
UMC	57.3%	64.9%	42.6%	30.1%	23.6%	33.7%	50.3%	13.2%	16.6%	22.7%	28.5%	9.6%	19.1%	20.8%	16.2%	16.9%
SMIC									-109.2%	0.7%	26.0%	7.7%	8.7%	9.9%	-4.4%	-10.7%

Gross Margin	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	Median
TSMC	49.4%	45.4%	48.1%	47.1%	49.5%	48.7%	50.1%	50.6%	48.3%	46.0%	53.1%	51.6%	59.6%	54.4%	**48.1%**
GlobalFoundries									-7.3%	-9.2%	-14.7%	15.4%	27.6%	28.4%	**4.1%**
UMC	29.2%	18.2%	16.8%	19.0%	22.7%	21.9%	20.5%	18.1%	15.1%	14.4%	22.1%	33.8%	45.1%	34.9%	**22.0%**
SMIC	19.9%	7.7%	20.5%	21.2%	24.5%	30.5%	29.2%	23.9%	22.2%	20.6%	23.6%	30.8%	38.0%	19.3%	**20.6%**

Notes:
1. Data from FactSet and company documents.
2. Empty cells indicate unavailable data.

Figure 44-6: TSMC vs. Comps R&D Expenses as A Percentage of Sales

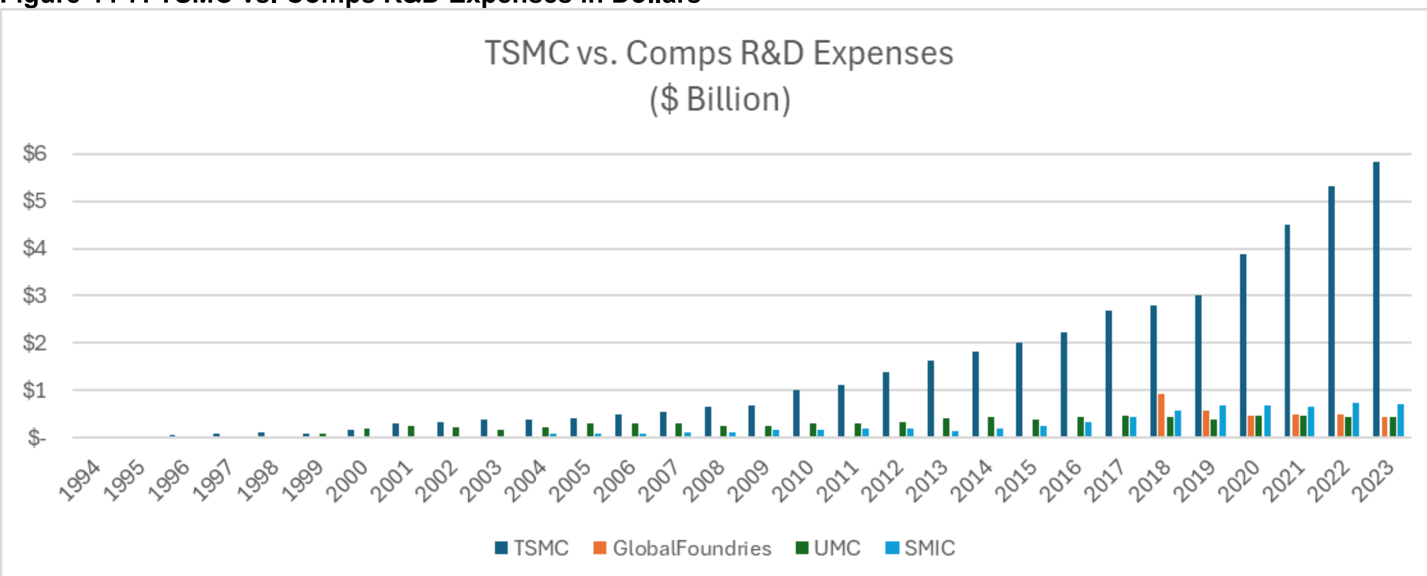


R&D to Sales	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
TSMC	2.8%	2.6%	3.8%	5.7%	6.4%	3.3%	3.1%	8.5%	7.2%	6.3%	4.9%	5.3%	5.1%	5.6%	6.4%	7.3%
GlobalFoundries																
UMC						9.2%	5.5%	12.8%	9.8%	6.1%	5.7%	9.6%	8.4%	8.5%	8.5%	8.8%
SMIC									74.4%	8.8%	8.0%	6.7%	6.4%	6.3%	7.6%	15.0%

R&D to Sales	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	Median
TSMC	7.1%	7.9%	8.0%	8.1%	7.4%	7.8%	7.5%	8.3%	8.3%	8.5%	8.2%	7.9%	7.2%	8.4%	**7.2%**
GlobalFoundries									14.9%	10.0%	9.8%	7.3%	5.9%	5.8%	**8.5%**
UMC	6.9%	8.1%	8.5%	10.1%	9.8%	8.4%	9.2%	9.2%	8.6%	8.0%	7.3%	6.1%	4.6%	6.0%	**8.5%**
SMIC	11.2%	14.5%	11.4%	7.0%	9.6%	10.6%	10.9%	13.8%	16.6%	22.1%	17.3%	11.7%	10.1%	11.2%	**11.1%**

Notes:
1. Data from company documents.
2. Empty cells indicate unavailable data.
3. SMIC generated its first sales in 2002.
4. In 2009, the sales of SMIC declined over 20% following the Global Financial Crisis while it continued to invest in R&D and SG&A.

Figure 44-7: TSMC vs. Comps R&D Expenses in Dollars



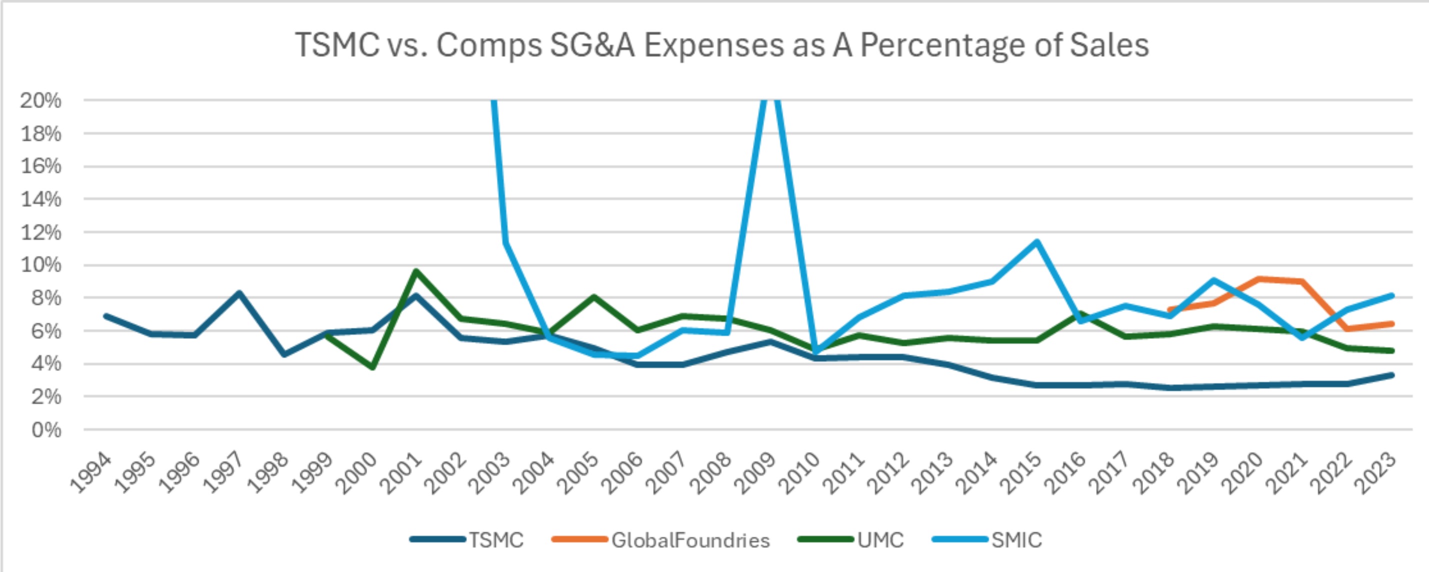
R&D ($ Billion)	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
TSMC	$ 0.02	$ 0.03	$ 0.05	$ 0.08	$ 0.10	$ 0.08	$ 0.15	$ 0.31	$ 0.34	$ 0.37	$ 0.39	$ 0.42	$ 0.49	$ 0.55	$ 0.65
GlobalFoundries															
UMC						$ 0.08	$ 0.19	$ 0.26	$ 0.21	$ 0.17	$ 0.23	$ 0.29	$ 0.29	$ 0.30	$ 0.25
SMIC								$ 0.01	$ 0.04	$ 0.03	$ 0.08	$ 0.08	$ 0.09	$ 0.10	$ 0.10

R&D ($ Billion)	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
TSMC	$ 0.67	$ 0.99	$ 1.12	$ 1.39	$ 1.62	$ 1.81	$ 2.00	$ 2.23	$ 2.70	$ 2.79	$ 3.02	$ 3.88	$ 4.50	$ 5.33	$ 5.84
GlobalFoundries										$ 0.93	$ 0.58	$ 0.48	$ 0.48	$ 0.48	$ 0.43
UMC	$ 0.25	$ 0.29	$ 0.31	$ 0.34	$ 0.42	$ 0.44	$ 0.37	$ 0.42	$ 0.46	$ 0.42	$ 0.39	$ 0.46	$ 0.47	$ 0.42	$ 0.43
SMIC	$ 0.16	$ 0.17	$ 0.19	$ 0.19	$ 0.15	$ 0.19	$ 0.24	$ 0.32	$ 0.43	$ 0.56	$ 0.69	$ 0.68	$ 0.64	$ 0.73	$ 0.71

Notes:
1. Data from company documents.
2. Empty cells indicate unavailable data.
3. The exchange rates for NTD/USD used to convert R&D expenses of TSMC and UMC were based on the December rates of each year, as provided by the Federal Reserve Bank of St. Louis.[346]

[346] Taiwan Dollars to U.S. Dollar Spot Exchange Rate (EXTAUS). Federal Reserve Bank of St. Louis. https://fred.stlouisfed.org/series/EXTAUS

Figure 44-8: TSMC vs. Comps SG&A Expenses as A Percentage of Sales

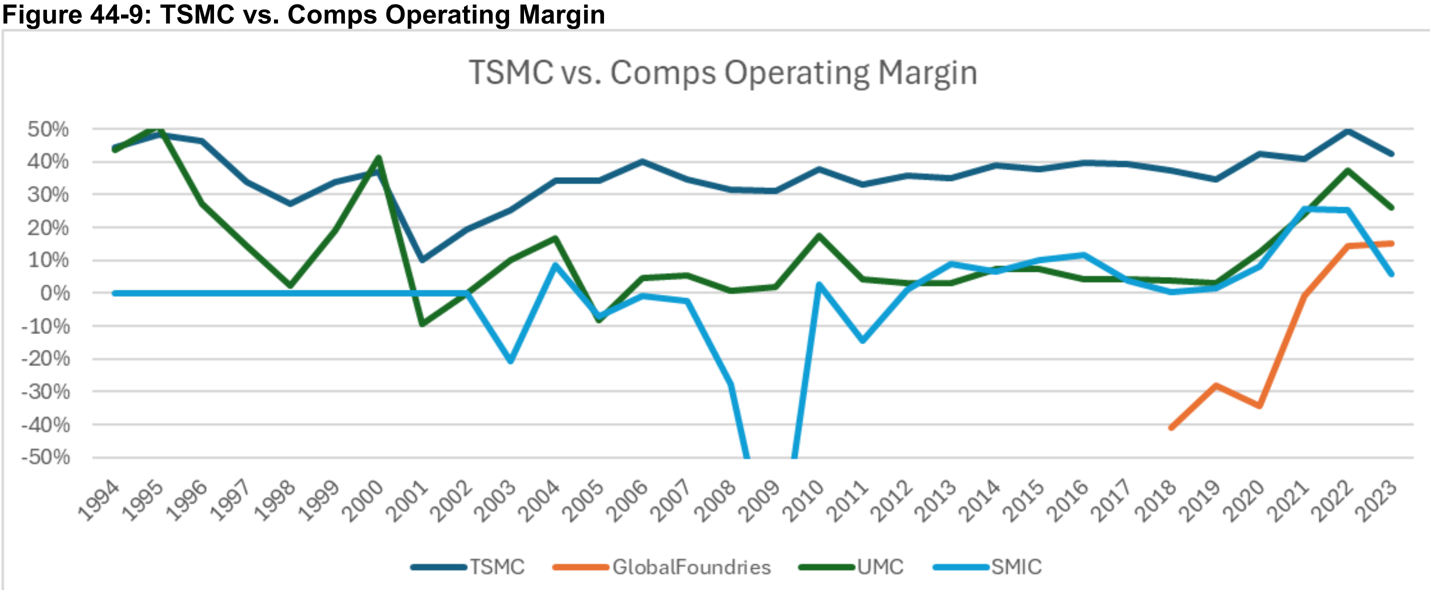


SG&A to Sales	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
TSMC	6.9%	5.8%	5.8%	8.3%	4.5%	5.9%	6.1%	8.1%	5.5%	5.4%	5.8%	5.0%	3.9%	3.9%	4.8%	5.3%
GlobalFoundries																
UMC						5.6%	3.8%	9.6%	6.7%	6.4%	5.9%	8.1%	6.1%	6.9%	6.8%	6.0%
SMIC									44.0%	11.3%	5.6%	4.6%	4.5%	6.0%	5.9%	22.6%

SG&A to Sales	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	Median
TSMC	4.3%	4.4%	4.4%	3.9%	3.1%	2.7%	2.7%	2.8%	2.5%	2.6%	2.7%	2.8%	2.8%	3.3%	**4.4%**
GlobalFoundries									7.3%	7.7%	9.2%	9.0%	6.1%	6.4%	**7.5%**
UMC	4.9%	5.8%	5.3%	5.6%	5.4%	5.4%	7.0%	5.7%	5.8%	6.2%	6.1%	5.9%	5.0%	4.8%	**5.9%**
SMIC	4.7%	6.8%	8.2%	8.4%	9.0%	11.4%	6.6%	7.5%	6.9%	9.1%	7.6%	5.6%	7.3%	8.2%	**7.4%**

Notes:
1. Data from company documents.
2. Empty cells indicate unavailable data.
3. SMIC generated its first sales in 2002.
4. In 2009, the sales of SMIC declined over 20% following the Global Financial Crisis while it continued to invest in R&D and SG&A.

Figure 44-9: TSMC vs. Comps Operating Margin

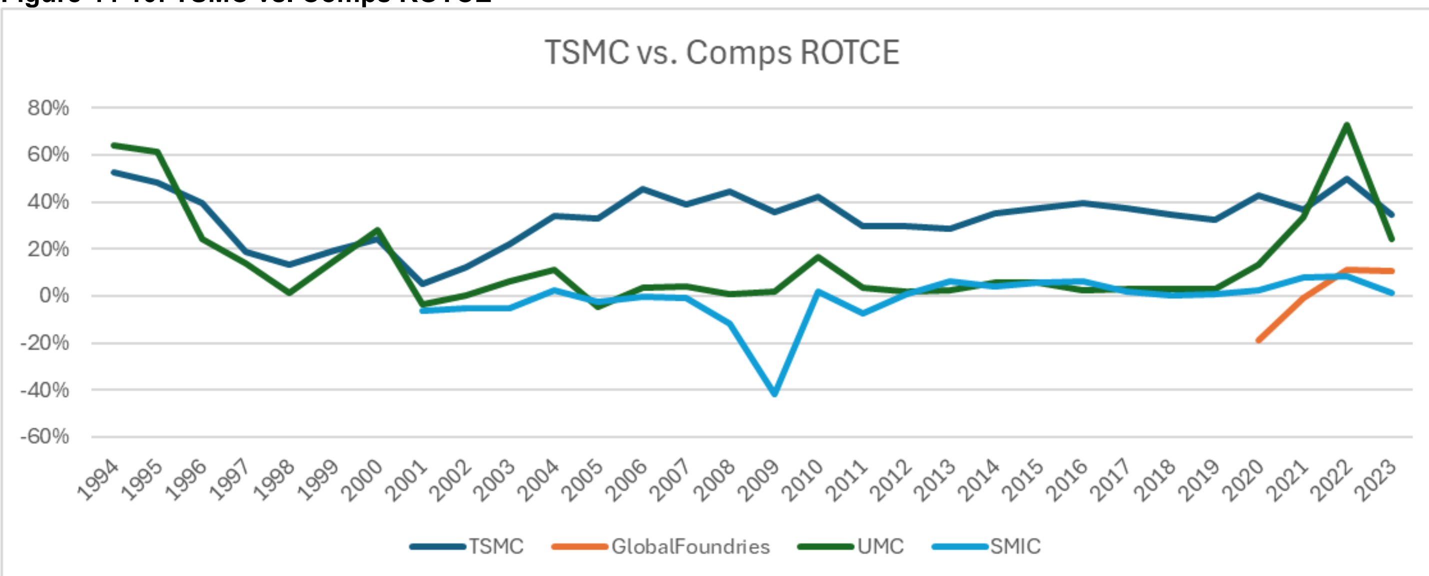


Operating Margin	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
TSMC	44.6%	48.3%	46.2%	34.0%	27.4%	34.0%	36.9%	10.2%	19.5%	25.3%	34.4%	34.1%	40.1%	34.6%	31.3%	31.1%
GlobalFoundries																
UMC	43.6%	51.2%	27.1%	14.3%	2.1%	18.9%	41.1%	-9.2%	0.1%	10.2%	16.9%	-8.1%	4.6%	5.4%	0.9%	2.0%
SMIC	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	-20.6%	8.5%	-7.2%	-0.9%	-2.3%	-27.8%	-90.1%

Operating Margin	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	Median
TSMC	37.9%	33.1%	35.8%	35.1%	38.8%	37.9%	39.9%	39.4%	37.2%	34.8%	42.3%	40.9%	49.5%	42.6%	**36.3%**
GlobalFoundries									-40.7%	-28.0%	-34.1%	-0.9%	14.4%	15.3%	**-14.4%**
UMC	17.4%	4.4%	3.0%	3.3%	7.2%	7.5%	4.2%	4.4%	3.8%	3.2%	12.4%	24.3%	37.4%	26.0%	**6.3%**
SMIC	2.8%	-14.5%	1.3%	9.0%	6.6%	9.9%	11.6%	4.0%	0.4%	1.6%	8.0%	25.6%	25.2%	5.7%	**2.8%**

Notes:
1. Data from FactSet and company documents.
2. Empty cells indicate unavailable data.

Figure 44-10: TSMC vs. Comps ROTCE

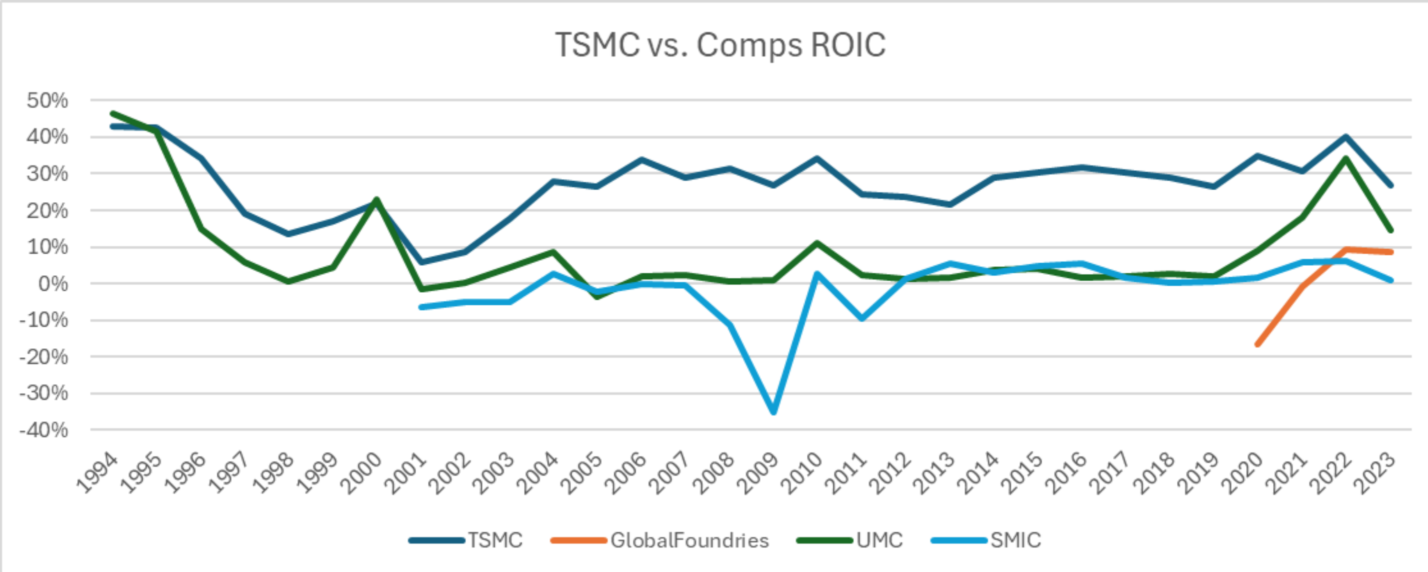


ROTCE	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
TSMC	52.8%	48.3%	39.7%	18.6%	13.4%	19.5%	24.2%	4.9%	12.5%	21.7%	33.8%	32.7%	45.5%	39.0%	44.2%	35.4%
GlobalFoundries																
UMC	63.8%	61.4%	23.9%	13.6%	1.4%	14.8%	28.2%	-3.8%	0.1%	6.0%	11.2%	-4.8%	3.4%	4.3%	0.8%	2.0%
SMIC								-6.3%	-5.1%	-5.1%	2.5%	-2.5%	-0.4%	-1.1%	-11.9%	-41.7%

ROTCE	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	Median
TSMC	42.3%	29.6%	29.6%	28.6%	35.1%	37.0%	39.3%	37.3%	34.5%	32.4%	42.6%	36.6%	49.6%	34.6%	**34.8%**
GlobalFoundries											-18.9%	-0.7%	11.3%	10.7%	**5.0%**
UMC	16.7%	3.4%	2.1%	2.4%	5.6%	5.7%	2.6%	2.9%	2.9%	2.7%	13.5%	33.4%	72.5%	24.0%	**4.9%**
SMIC	1.9%	-7.5%	0.9%	6.4%	3.8%	5.7%	6.0%	1.8%	0.2%	0.5%	2.2%	8.1%	8.3%	1.4%	**0.9%**

Notes:
1. Empty cells indicate unavailable data.
2. SMIC did not achieve consistent annual profitability until 2012.
3. The semiconductor chip shortage following the COVID-19 pandemic (after 2020) benefited foundries overall.

Figure 44-11: TSMC vs. Comps ROIC



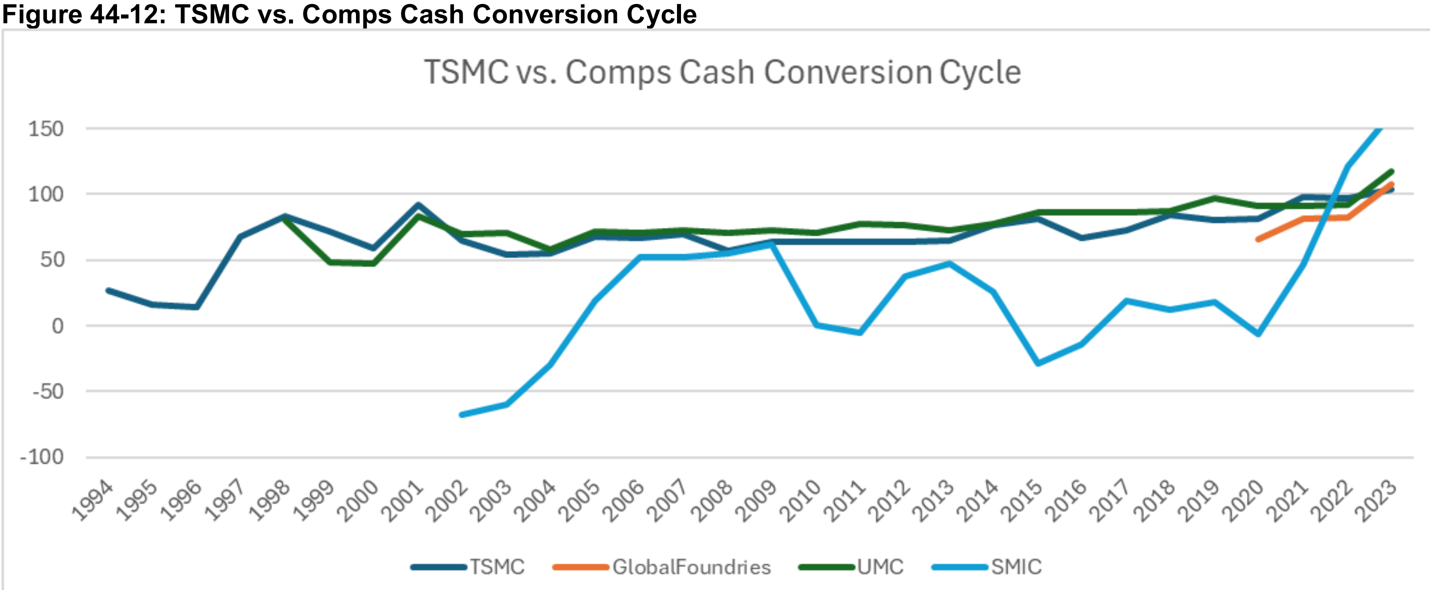
ROIC	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
TSMC	43.0%	42.6%	34.1%	19.1%	13.4%	17.0%	21.8%	5.6%	8.5%	17.9%	27.9%	26.5%	34.0%	29.0%	31.5%	26.9%
GlobalFoundries																
UMC	46.4%	41.4%	14.8%	5.9%	0.6%	4.4%	23.1%	-1.6%	0.0%	4.3%	8.7%	-3.8%	2.0%	2.3%	0.6%	0.7%
SMIC								-6.3%	-5.1%	-4.9%	2.5%	-2.3%	-0.2%	-0.4%	-11.5%	-35.4%

ROIC	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	Median
TSMC	34.0%	24.4%	23.8%	21.7%	28.9%	30.4%	31.7%	30.2%	28.8%	26.6%	34.8%	30.5%	40.2%	26.8%	**28.4%**
GlobalFoundries											-16.6%	-0.9%	9.4%	8.8%	**3.9%**
UMC	11.1%	2.4%	1.2%	1.6%	3.7%	4.1%	1.7%	2.0%	2.8%	2.1%	8.8%	18.0%	34.1%	14.5%	**3.3%**
SMIC	2.6%	-9.6%	1.3%	5.4%	3.0%	4.7%	5.4%	1.5%	0.1%	0.4%	1.5%	5.6%	6.0%	1.0%	**1.0%**

Notes:

1. Empty cells indicate unavailable data.
2. SMIC did not achieve consistent annual profitability until 2012.
3. The semiconductor chip shortage following the COVID-19 pandemic (after 2020) benefited foundries overall.

Figure 44-12: TSMC vs. Comps Cash Conversion Cycle

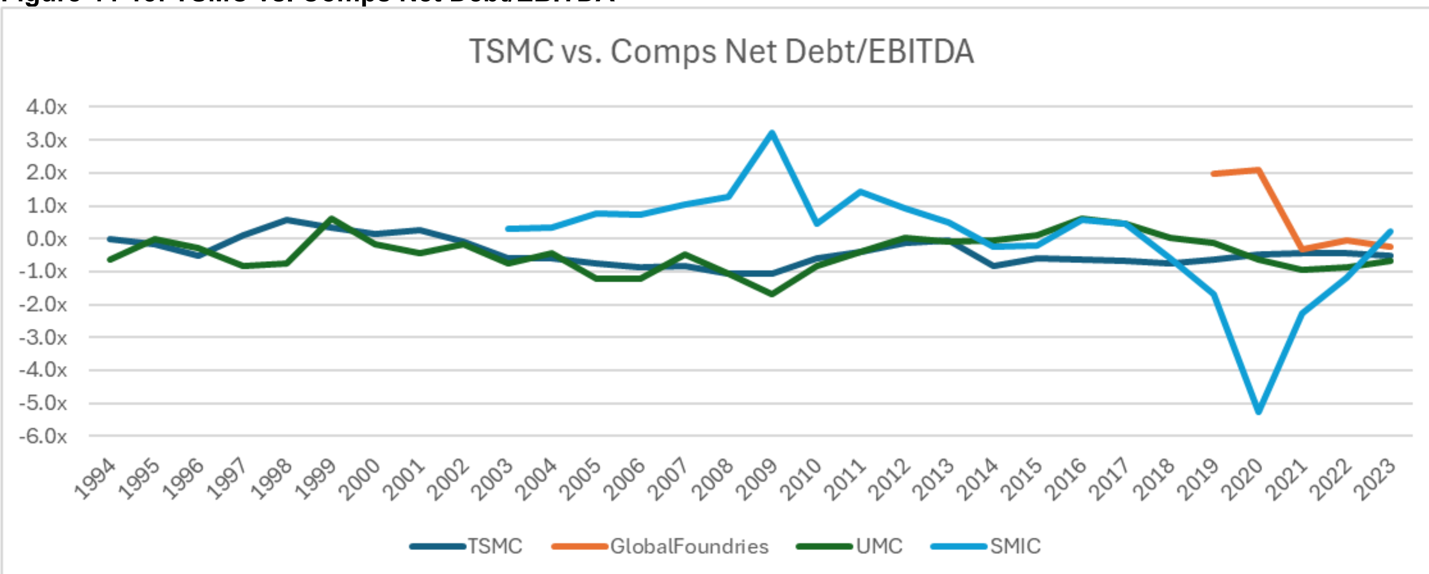


Cash Conversion Cycle	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
TSMC	27.3	16.1	14.4	67.5	83.5	71.3	58.7	92.0	65.0	54.3	55.2	67.7	66.5	69.6	57.4	63.5
GlobalFoundries																
UMC					80.4	47.9	47.4	83.4	69.5	71.2	57.7	71.5	70.5	72.9	70.5	72.6
SMIC									-67.7	-59.5	-29.4	19.2	51.7	51.8	54.7	62.4

Cash Conversion Cycle	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	Median
TSMC	63.5	63.6	63.5	65.1	76.4	81.5	67.1	72.7	84.2	80.3	81.2	98.2	96.9	103.5	**67.3**
GlobalFoundries											66.2	81.8	82.2	107.6	**82.0**
UMC	71.1	77.3	76.1	73.1	77.3	86.2	86.0	86.6	87.0	96.6	91.3	91.6	92.1	117.8	**76.7**
SMIC	0.5	-5.5	37.9	47.4	25.8	-28.9	-13.6	19.6	11.9	17.8	-6.1	46.8	121.5	160.9	**19.4**

Notes:
1. Data from FactSet and company documents.
2. Empty cells indicate unavailable data.

Figure 44-13: TSMC vs. Comps Net Debt/EBITDA

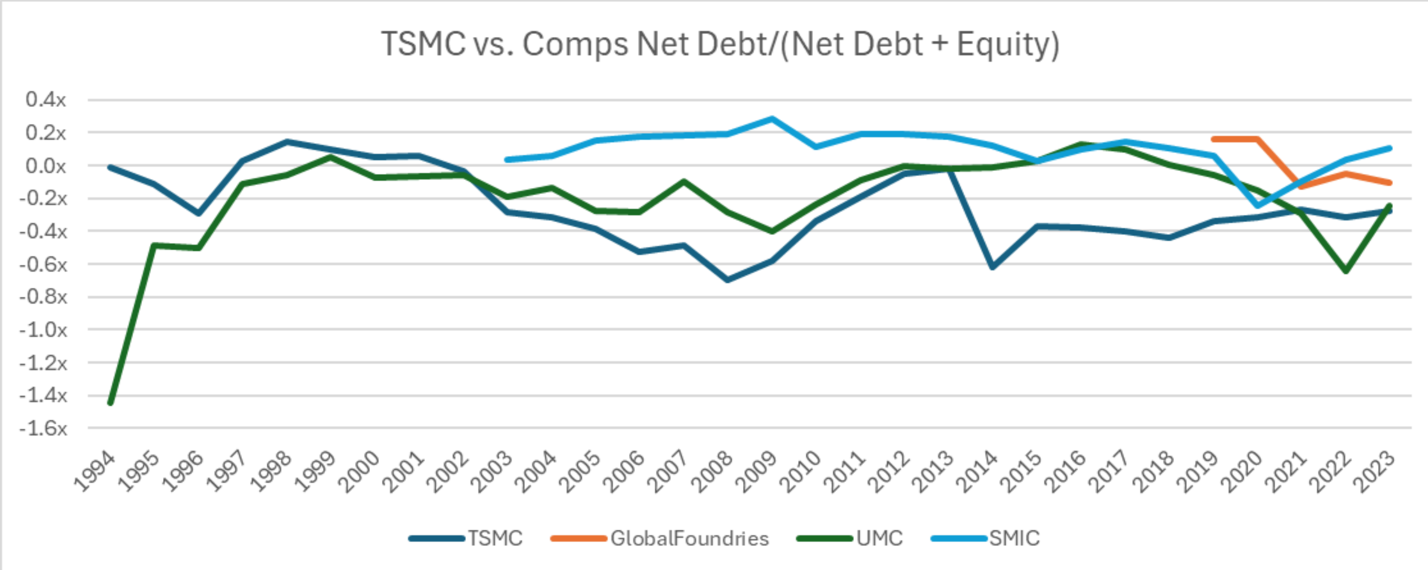


Net Debt/EBITDA	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
TSMC	0.0x	-0.2x	-0.5x	0.1x	0.6x	0.3x	0.1x	0.3x	-0.1x	-0.6x	-0.6x	-0.7x	-0.9x	-0.8x	-1.1x	-1.1x
GlobalFoundries																
UMC	-0.6x	0.0x	-0.3x	-0.8x	-0.7x	0.6x	-0.2x	-0.4x	-0.2x	-0.7x	-0.5x	-1.2x	-1.2x	-0.5x	-1.1x	-1.7x
SMIC										0.3x	0.3x	0.8x	0.7x	1.0x	1.3x	3.2x

Net Debt/EBITDA	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	Median
TSMC	-0.6x	-0.4x	-0.1x	-0.1x	-0.8x	-0.6x	-0.6x	-0.7x	-0.8x	-0.6x	-0.5x	-0.4x	-0.5x	-0.5x	**-0.5x**
GlobalFoundries										2.0x	2.1x	-0.3x	0.0x	-0.3x	**0.0x**
UMC	-0.8x	-0.4x	0.0x	-0.1x	-0.1x	0.1x	0.6x	0.4x	0.0x	-0.1x	-0.6x	-0.9x	-0.9x	-0.7x	**-0.5x**
SMIC	0.5x	1.4x	0.9x	0.5x	-0.2x	-0.2x	0.6x	0.5x	-0.6x	-1.7x	-5.3x	-2.3x	-1.2x	0.2x	**0.5x**

Notes:
1. Data from FactSet and company documents.
2. Empty cells indicate unavailable data.

Figure 44-14: TSMC vs. Comps Net Debt/(Net Debt + Equity)



Net Debt/(Net Debt + Equity)	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
TSMC	0.0x	-0.1x	-0.3x	0.0x	0.1x	0.1x	0.1x	0.1x	0.0x	-0.3x	-0.3x	-0.4x	-0.5x	-0.5x	-0.7x	-0.6x
GlobalFoundries																
UMC	-1.4x	-0.5x	-0.5x	-0.1x	-0.1x	0.1x	-0.1x	-0.1x	-0.1x	-0.2x	-0.1x	-0.3x	-0.3x	-0.1x	-0.3x	-0.4x
SMIC										0.0x	0.1x	0.1x	0.2x	0.2x	0.2x	0.3x

Net Debt/(Net Debt + Equity)	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	Median
TSMC	-0.3x	-0.2x	-0.1x	0.0x	-0.6x	-0.4x	-0.4x	-0.4x	-0.4x	-0.3x	-0.3x	-0.3x	-0.3x	-0.3x	**-0.3x**
GlobalFoundries										0.2x	0.2x	-0.1x	0.0x	-0.1x	**0.0x**
UMC	-0.2x	-0.1x	0.0x	0.0x	0.0x	0.0x	0.1x	0.1x	0.0x	-0.1x	-0.2x	-0.3x	-0.6x	-0.2x	**-0.1x**
SMIC	0.1x	0.2x	0.2x	0.2x	0.1x	0.0x	0.1x	0.1x	0.1x	0.1x	-0.2x	-0.1x	0.0x	0.1x	**0.1x**

Notes:
1. Data from FactSet and company documents.
2. Empty cells indicate unavailable data.

Disclosures

Worldly Partners, and its affiliates, do not have a financial interest in Taiwan Semiconductor Manufacturing Company (TSMC) or the securities, or derivatives thereof, issued by this company. This research report has been published on August 12, 2025 is for informational and educational purposes only and is not meant to provide information on any services or products connected to Worldly Partners and its affiliates. The statements or conclusions made are opinions only and should not be relied upon as fact. The report does not serve as an endorsement or as an investment recommendation. Worldly Partners did not receive compensation for creating or providing this research report. No investors in Worldly Partners or its affiliates or in its Funds requested that we produce this report or make the statements or conclusions included herein.

Data throughout this report is sourced from third-parties, including multiple levels of third-parties, unrelated to Worldly Partners. While we believe the sources to be reliable, we have not confirmed the accuracy of the data presented or the analyses or assumptions made by such third-parties in arriving at any projections shown or conclusions made. Accordingly, the actual data may be materially different from what is presented in the third-party reports. In addition, the projections included in the report as determined by such third-parties may not be achieved, and the actual results could be materially different from those projected by such third-parties. In addition, past performance is not an indication of future results. Comments made in the Notes section of charts or graphs throughout this research report include statements and concepts from companies' annual reports, including direct statements, summaries of statements, and, in some cases, interpretations, extrapolations, or analyses of statements contained therein. Notwithstanding anything to the contrary contained herein or in any Worldly Partners Fund's governing documents, nothing contained herein or in the Fund's governing documents shall restrict, amend, eliminate or waive any fiduciary duties of an indemnified party (or any rights of the Funds or the investors in respect thereof) under (A) the Advisers Act or (B) any other applicable Federal or U.S. state law to the extent (but only to the extent) that such restriction, amendment, elimination or waiver would be in violation of such other Federal or U.S. state law.

When comparing performance to an index, keep in mind that individuals cannot invest directly in any index, and index performance does not include transaction costs or other fees, which will affect actual investment performance. An individual investor's results will vary. The S&P 500 is an unmanaged index of 500 widely held stocks that is generally considered representative of the U.S. stock market. The NASDAQ Composite is a stock market index of the common stocks and similar securities listed on the NASDAQ stock market.

Much of the information throughout this report represents historical analysis or data which, if updated to periods closer to the report year or date, could result in materially different data and conclusions. Worldly Partners is not updating this report as new data is released or made available. The statements made are based upon information reviewed as of the date of the report.

This presentation is confidential and is intended solely for the information of the person to whom it has been delivered. This report is provided for the purpose of providing insight into the research approach used by Worldly Partners in its investment process. This document is not intended for general distribution and it may not be copied, quoted, or referenced without the prior written consent of Worldly Partners.