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GLOBAL INSIGHT

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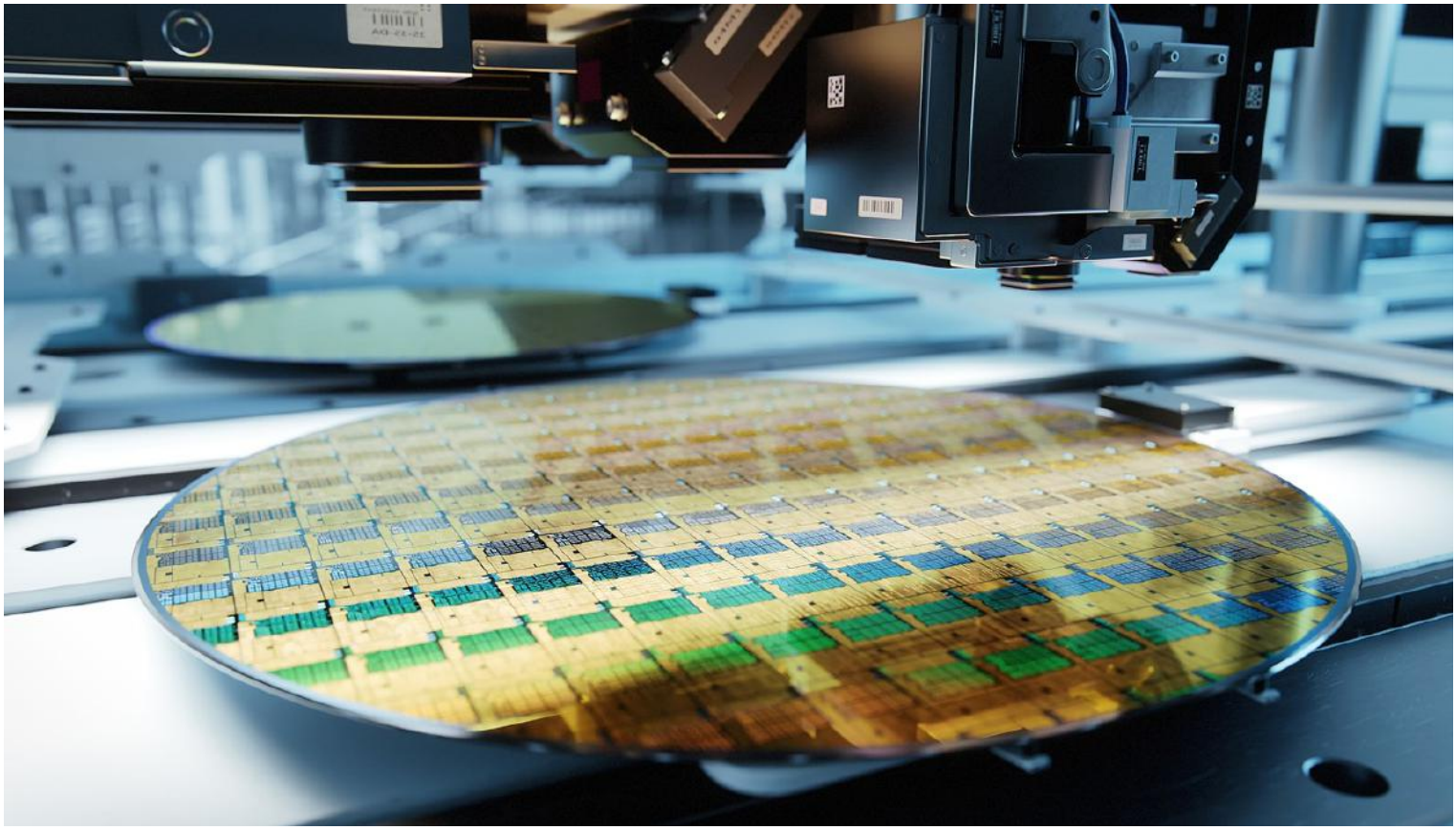
Global Technology

Clash of Chips – TSMC, Samsung, and Intel

The paths of these three companies will undoubtedly intersect as the competitive landscape for foundries continues to evolve, with TSMC and Samsung claiming the leading edge and Intel rejoining the race. We see TSMC and Samsung benefiting from the growing HPC segment, with Intel's role less certain.



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Clash of Chips – TSMC, Samsung, and Intel

We see a changing of the guard taking place in technologydriven by several forces:

- New end-market leadership vs. past cycles,
- Changes brought on by high performance computing (HPC),
- Near-shoring manufacturing, and
- Higher growth opportunities in cutting-edge semiconductor wafers to advanced packaging.

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Leading-edge integrated circuit (IC) process technology will likely be the cornerstone for all the advanced consumer, business, and military electronic systems of the future. The foundry industry surpassed the US$100bn mark for the first time in 2021, and we forecast an 8% CAGR to reach US$146bn by 2026e, with leading-edge growth significantly outpacing the market.

At the same time, moats are being built. There are only three capable leading-edge logic producers today (down from 28 in 2001) – TSMC, Samsung, and Intel (though Intel still has progress to make and currently appears to be a happy customer of TSMC). All of them are generating exceptional profits, possess staying power, and are dominating in the new normal.

Asia to dominate in leading-edge competition in the next 5-10 years: TSMC and Samsung's advanced technology leadership via provision of the backbone for global semiconductor manufacturing for leading edge chips is unmatched. These leading-edge foundry vendors are gearing up for high-stakes spending and a technology race, setting the stage for a possible shake-up across the semiconductor manufacturing landscape. The investment and operational excellence required to implement the most advanced process technologies for logic devices have driven out all but three companies.

From TSMC's perspective, Intel is at the same time an important customer (collaborate in some areas) and competitor (in other areas). Both Samsung and Intel aim to overtake TSMC's dominant share in chip manufacturing, which is getting exponentially more difficult and more costly.

However, do not lose sight of the long term. We think investors should consider a downturn as an opportunity to invest in some great companies at attractive prices. As the liquidity tightens and brings out the most speculative elements of the market, inevitably there is collateral damage to the broader market, including TSMC and Samsung. With maximum negativity, it is often a good strategy to find leading companies whose stock prices have in the short term diverged significantly from fundamentals.

Growth is easy to measure, but durability isn't: We have undertaken both quantitative and qualitative comparisons of Samsung, Intel, and TSMC's foundry portfolio. There are areas of strength and weaknesses, but we conclude the following:

- TSMC's higher multiple will be sustained.
- Samsung may catch up to some degree – a "free option" to reduce cyclicality and drive a higher valuation.
- Intel has laid out a three- to five-year path to win support and return to process leadership, requiring a steep investment period in an attempt to catch up to competitors.

In all, these stocks come with risks affected by global recessions, supply chain issues, Moore's Law, and geopolitical risk. The good news is that TSMC and Samsung revenues tend to hold up better during recessions and have also held up well relative to the tech sector and the broader market, especially in a downturn.

Overweight on Samsung and TSMC: TSMC offers superior ROIC in high-quality businesses with exposure to attractive growth segments. However, Samsung is hanging on vs. TSMC with potential to add at a relatively attractive valuation. Our price targets offer higher upside in TSMC but P/B is closer to trough (ex-cash) for Samsung. If we assume both stocks return to their five-year average relative P/E to the Asian tech sector, Samsung shows 22% upside potential and TSMC 12%.

Underweight on Intel: We cite its strong capex plan to support the foundry strategy despite weakening core end-market demand, leaving negative ex-dividend FCF over the next several years.

Contents

Executive Summary

At the leading edge, we expect TSMC and Samsung to continue to dominate advanced semiconductor manufacturing in the next decade, capitalizing on the large and rapidly growing foundry opportunity. Not losing sight of the long term, today's fear in the market has created an opportunity to invest in some of the highest quality and most dominant global semiconductor companies at attractive prices.

The investment and operational excellence required to implement the most advanced process technologies for semiconductor chips has driven out all but three companies from the industry. The key question is how many players will still be left standing at the end of this decade.

- **TSMC's future looks secure.**
- **We believe its only competitor manufacturing leading-edge chips, Samsung, should also be able to hang on.**
- **Intel is embracing a flexible foundry business model again as part of a tactical change amid geopolitical tensions but also to outsource its manufacturing.**

Overweight on TSMC and Samsung

We think now is a great time to accumulate TSMC stock:

TSMC has made a further breakthrough in 3nm production yield over the past two months. Its technology leadership is now even more solid.

However, a monopoly may not be in anyone's best interest, as anti-trust could present a long-term operational risk. We also think semi customers would prefer multiple sources, hence, Intel and Samsung need to be viable alternatives for leading-edge foundry services.

Samsung is trading on trough DRAM cycle multiples with no implied value for its foundry business:

1. Samsung is currently trading near book value (ex-cash) and could benefit from a cyclical upturn in memory on a 6-12 month horizon.
2. We expect renewed growth via M&A and a growing TAM.
3. We also see potential for better execution on foundry, thus regaining share. Its plan to commercialize a 2nm transistor process technology by 2025 will be a key swing factor in narrowing the market share gap with TSMC.
4. Its ROIC of 12% now vs. TSMC 25% (UMC 18%) implies the more they invest in foundries the higher potential for ROIC to move higher, hence, a re-rating assuming they execute.
5. If Samsung's current foundry division were valued on 6x sales today (TSMC long-term average multiple), its foundry business would be 11% higher than its entire current market cap.

Underweight on Intel

Negative ex-dividend FCF and limited core business upside keep us UW on Intel: The company's current pursuit of new growth opportunities (foundry, graphics) will keep expenses high, while providing a potential distraction to core business turnaround efforts. Weakness in notebooks and further share loss in servers adds more downside risk.

Our decade-long view: follow the money

For Samsung and TSMC, we think this presents a decade-long driver of stock prices well beyond the near-term macro/cyclical events (rate hikes, supply chain disruption risks) that are currently priced in. We think TSMC and Samsung are destined to claim the leading edge for themselves, with no other company able to match – let alone top – their spending:

1. TSMC is investing US$100bn in R&D and manufacturing capacity expansion over the next two to three years.
2. Samsung is investing US$150bn by 2030, a number that does not include investments in its already-dominant memory business.

Each of these high-quality stocks presents a large index weighting for tech investors …

… but we suggest considering this decade-long theme as follows:

- **TSMC** – a cut above the other growth cyclicals and our favored long-term semiconductor stock to own.
- **Samsung** – a distant second to TSMC among the cheap value cyclicals, but already trading at 2018 cycle trough levels with a substantial FCF yield and the best relative risk-reward in the next 6-12 months.
- **Intel** – a budding foundry business that will take time to catch up to leading-edge competition.

Again, we believe the technology race for leading-edge foundry is a marathon, not a sprint. Who can continue to invest in R&D and execute well in the coming decade should win the greatest reward.

What is the market missing?

We believe a few trends are not well understood by investors:

1. Moore's Law is indeed getting more expensive. However, we believe ISP (internet service providers) and HPC customers are willing to pay for 3nm/2nm, better transistor performance, and lower power consumption.
2. Even for consumer brands like Apple, we expect the company to adopt TSMC's 2nm in 2025.
3. The market is overly focused on the technology race. However, we think Samsung's strategic value as a viable second source is underappreciated.
4. We believe Asian foundries' cost structures are still much more competitive as a whole when compared with US manufacturing. TSMC's founder, Dr. Morris Chang, recently cited that manufacturing cost is 50% higher in the US than in Asia.
5. The market may have also overly simplified the foundry industry's oversupply risk for 2023. We think demand for mature nodes is still strong from automotive, and Chinese foundries' wafer output may not be as effective as the bears believe.

Milestones and foundry tracker

1. There is a technology race to gain a leadership position among leading edge foundry vendors via unprecedented capex. Wafer prices are increasing at each node. Both factors are influencing long-term returns. The delivery of 2nm by 2025 is the key check point.
2. The ongoing geopolitical tensions present a long-term risk of disruption of access to technology.
3. Intel's re-entry in the foundry business could fill its technology gap – but it has a lot to prove about its capabilities. How many US customers end up using Intel's service remains to be seen.
4. The market will need to see that investments in advanced packaging developments can provide significantly better power/performance improvements than scaling alone.
5. We need to gauge returns in relation to escalating chip manufacturing costs and incremental demand at 2nm and beyond. We may get a sense about capex per unit of 2nm from TSMC's 2023 capex guidance.

In sum, we forecast the foundry industry to generate a 8% CAGR to reach a market size of US$146bn by 2026e, with leading edge growth significantly outpacing other areas.

Chip demand from HPC (cloud, AI) should grow to match that from smartphones within a few years, making the logic foundry business less dependent on the smartphone product cycle.

In the following sections, we cover these topics:

We then present Face-Off – Samsung vs. TSMC – in Depth .

For a deeper dive into the background, we provide Foundry Industry Analysis and Outlook , followed by TSMC – Foundry Overview , Samsung – Foundry Overview , and Intel – Foundry Overview .

Finally, we offer a view from Quantech – Look for Sector-Neutral Alpha amid Macro Complexities .

Framing the Debate

Five months into a cyclical decline in the semiconductor sector and with PMIs weakening in most regions of the world, a common question we are asked is, "which quality defensive stock should I accumulate for 2022?" As we set out in our recent tech strategy report, *Boring is Beautiful,* we expect market positioning in tech to further rotate towards the highest quality stories that have good growth and cash flow.

Most important, however, is not to lose sight of the long term and consider a cycle downturn as an opportunity to invest in some great companies at attractive prices.

In this report, we compare Samsung and TSMC, both widely viewed as quality defensive stocks within Asian tech, but which are typically analyzed through different lenses – Samsung being a Value cyclical with an implied foundry value close to zero, and TSMC in the quality Growth segment.

We also provide context for Intel's objective to narrow the technology gap and regain its lead by 2025. It's a costly, ambitious goal, and Intel will have to prove that it can win support from customers.

The relative performance of these stocks over the past year or so makes a comparative analysis particularly interesting. TSMC's share price has outperformed Samsung's by 48ppt since the start of COVID in March 2020 – but TSMC's five-year average EV/sales valuation premium of mid-teens versus Samsung began to fade entering 2022. Looking at the companies through the same lens, comparing fundamentals and running our Quant analysis of share price drivers favors Samsung Value with a high FCF tilt in the near term. While both stocks are preferred from a sector-neutral perspective, this suggests rotation from TSMC to Samsung in the current late-cycle market environment.

End market outlook looks much stronger for TSMC than for Samsung given its exposure to higher growth markets (HPC, Auto).

Growth rate in TSMC's traditional business was nearly the same as Samsung's in 2011-21– 14% vs. 13% CAGR.

Quant analysis suggests that Samsung is more driven by Quality Value positioning.

Pricing power is greater at TSMC (widely viewed as the gold standard), at an average of 1.5% growth over the last 10 years.

However, further economic risk of a slowdown could be more advantageous for TSMC from an earnings perspective given the secular drivers of HPC revenue growth, although the multiple does not look like it is pricing in a potential recession vs. Samsung's multiple which does. Intel has underperformed Samsung and TSMC in the same period. Investing now for a potential 2025 recovery likely means investing through an eventual downturn, which remains a big ask for investors.

Five Key Surprises from Our Analysis

Applying historical valuation premiums suggests that TSMC's upside is below mid-teens, while implying high teens upside for Samsung.

TSMC has significantly outperformed Samsung over the long term – can this performance be sustained? Per Exhibit 1, taking a 10-year view, Samsung shares have materially underperformed TSMC – by close to 360ppt. Looking forward, the question is whether this situation can sustainably reverse. We note that during the last year, Samsung has suffered a substantial de-rating already.

In this report, we take a look at the path to top quartile performance and sustainability for TSMC, and the degree to which something similar may be feasible for Samsung. Our price target for TSMC at NT$780 implies 55% upside, higher than Samsung's 31% upside. However, we are concerned by the memory cycle uncertainty in 2H22 and hence believe TSMC's fundamentals could be more favorable in the near term in view of relative pricing power.

From a valuation perspective, TSMC trades at a premium to its long-term average on P/E given falling competitive intensity and higher expected returns. Samsung is already pricing in a memory downturn

and its foundry business appears to offer "free option" value on top of its memory business.

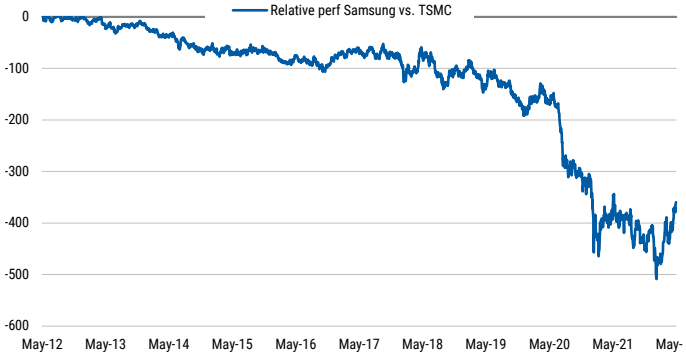
- *Hence, risk-reward appears more favorable to Samsung in the current volatile market environment. The cyclical downturn in memory is in the late stages vs. foundry, and is the reason Samsung is cheap… but the path to reward is nearer (Memory vs. Foundry – Divergence).*

Why be OW on Samsung in a memory down-cycle? We admit that the memory commodity cycle could remain challenging again in 2H22. However, a perceived cyclical downturn creates maximum anxiety and fear in the market, and we believe it is important to lean the other way when sentiment moves to extremes. Samsung's current valuation – back to book value (ex-net cash) – implies maximum negativity, and it is often a good strategy to try to allow for the possibility of positive surprises.

We do not believe that Samsung merits a premium multiple to TSMC in future… As mentioned in Face-Off – Samsung vs. TSMC – in Depth , by 2023 we expect TSMC's operating margin of 44% to be superior to Samsung's at 20%, and its average ROIC to be 21%, or ~8ppt higher than Samsung's. Even now, TSMC is operating in the 41-46% margin range, while Samsung has only two out of four divisions above the 30% level. We do see potential for slightly higher earnings growth at Samsung of 7% – but we would also "discount"' this a little, because in the past earnings have been volatile in a cyclical downturn.

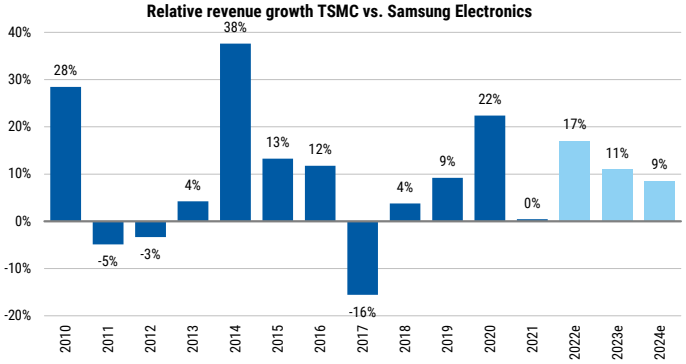
In principle, we think Samsung deserves some re-rating from levels which were too low owing to cyclical factors (memory). However, we are not convinced about the "structural case" here, and believe that TSMC should still command some form of relative premium.

Exhibit 1: Samsung has underperformed TSMC by 360ppt over the last decade…



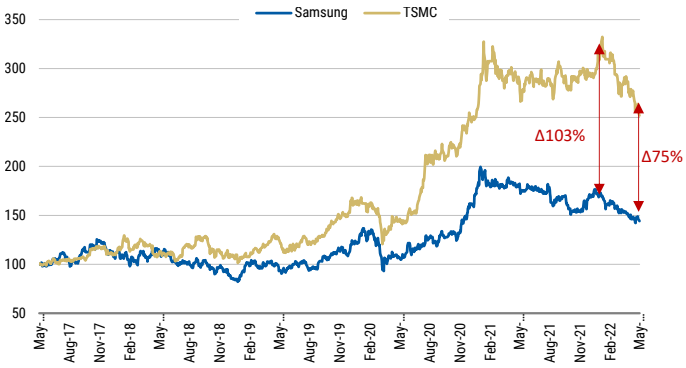
Source: Refinitiv, Morgan Stanley Research

Exhibit 2: …as TSMC's relative growth rate outpaced Samsung's



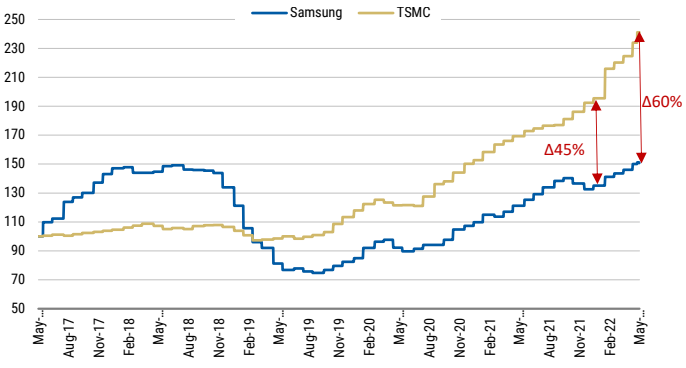
Source: Refinitiv, Morgan Stanley Research (e) estimates

Exhibit 3: Samsung vs. TSMC – indexed share performance



Source: Refinitiv, Morgan Stanley Research

Exhibit 4: Samsung vs. TSMC – indexed 12-month forward EPS



Source: Refinitiv, Morgan Stanley Research

…but on the other hand, Samsung's efforts could still be rewarded: Factors like the prospect of an ongoing memory downturn have weighed on sentiment (and hence the P/B multiple), but we believe that these factors will become increasingly less relevant and even reverse over the next 6-12 months.

For example, one reason for stagnant ROIC at Samsung, despite margin expansion, has been balance sheet deleverage and a mounting net cash position (>US$100bn). However, Samsung has signaled a more aggressive deployment strategy to achieve growth via M&A and this could lead to improving ROIC. On portfolio, we see significant optionality in Samsung making the right strategic M&A to increase its TAM, although our concern would be around paying steep prices.

- *As such, we see clear conditions for Samsung to re-rate.*

A relative re-rating has already occurred with TSMC now trading at 5.8x P/B vs. Samsung at 0.97x (ex-net cash): As the chart above shows, TSMC already re-rated substantially with the onset of COVID, in response to a succession of multiple supply chain disruptions causing chip shortages, earnings beats, and geopolitical tensions, with some evidence of structural margin improvement.

As such, we believe that relative performance from here must be driven by earnings factors – and specifically, execution. Hence, we have a preference for TSMC vs. Samsung, given the direction of earnings in the coming quarters.

However, looking beyond cyclical drivers, there are clear catalysts that could re-rate Samsung beyond commodity DRAM multiples via new TAM acquisitions, execution/catch-up in leading edge foundry, and increased capital returns.

Risk-Reward Considerations

What is the bull case?

We consider the upside the semiconductor business could provide three years from now: In the bull case, we think a major upside surprise for TSMC on a three-year time-frame would be Intel missing its target to deliver its internal 2nm (20A) process in 2025 (see report). Intel would then have to outsource its server CPUs to TSMC. In that case, we assume that TSMC's share price would double from here, exceeding NT$1,000.

For Samsung, a three-year bull case would be maturing its 2nm process and winning back previously lost share from Qualcomm, NVIDIA, and AMD for its 3nm customers. This could also help mitigate TSMC's antitrust risk, potentially establishing a win-win competitive environment. We assume Samsung's market cap doubles as well, given currently no implied value for its foundry business. Meanwhile, under this scenario its memory business continues to register higher lows and higher highs in terms of RoCE owing to complexity and broader applications, including Chinese entrants being unable to compete in mainstream DRAM markets.

For Intel, a three-year bull case would be that it clearly addresses issues with the pipeline, Sapphire Rapids arrives on time, and its roadmap delivers competitive performance that stabilizes share. Management execution on product roadmap would help investor sentiment and multiples.

One-year bull case scenario: For all three – Samsung, TSMC, and Intel – this would be from consumer tech demand turning better than feared from 2H22, which could be driven by macro events (e.g., end of China's lockdowns or the Russia/Ukraine conflict). Alternately, reopening tech demand could be stronger than expected, offsetting fading stay-at-home demand. In particular, the reset of expectations for mobile devices – whether smartphones or NB PCs – has overshot to the downside. We could see 2022 consensus estimates rise for Samsung and TSMC, and both stocks could exceed our price targets, with more than 50% one-year returns in the bull case.

Near-term risks

We see heightened cyclical risk to Samsung's and Intel's margin in contrast to stability at TSMC: The risks to Samsung's margin are skewed to the downside owing to memory exposure. We expect both revenue and margin to decline for Intel in 2022 as inventory accumulation in PCs makes the near-term outlook for Client Computing tougher than previously expected. We think TSMC could actually show gross margin expansion during this cycle. TSMC's gross margins have marched steadily higher through a combination of improving mix and leveraging its technology leadership. Furthermore, the company's predominantly customized manufacturing model should result in less variability in gross margin through the cycle relative to Samsung.

Long-term risks

Multipolarity ahead: Amid rising geopolitical tensions and an increasingly complicated macro environment, multipolarity and "slowbalization" could be on the way to becoming the new norm. Our bear case considers a "Competitive Confrontation" scenario where the US focuses more on unilateral, internal investments as a means of executing a domestic-focused "offensive strategy" that is bearish for Greater China semiconductors. In this scenario, we assume the US would likely promote re-onshoring/localization of semi production. Hitherto globalizing industries, such as semiconductors, could face reduced market access and/or export restrictions. Moreover, if the US strategy did move towards this outcome, we could see reduced reliance on imported components from East Asia, with a potentially negative impact on Taiwan, which has achieved unprecedented market share globally in recent years. We see engagement with traditional allies/partners as key to the Biden doctrine, and this includes a favorable perspective on friend-shoring, rather than re-shoring exclusively. The bear case would be a move to 'Fortress America', which could see more explicit support for made-in-America silicon, even at the expense of hardware/consumers.

What is the bear case?

TSMC: In the bear case, we think a major source of downside for TSMC would be if no customers were willing to pay for more expensive 3nm and 2nm wafers. Over the next few years, it is debatable whether Moore's Law will finally run out of steam. What is more certain is that cost has been increasing with complexity of leading edge foundry processes, and the amount of capex/R&D required is increasing significantly from node to node. Moore's Law limitations present a significant challenge to costs, chip manufacturing, and TSMC's ability to lead on advanced nodes, allowing Samsung to catch up and chip away returns.

We assume TSMC's stock falls to NT$400 in this scenario, or 13x through-cycle EPS.

Samsung: A three-year bear case would entail inability of 2nm/3nm capacity to reach scale given the ongoing yield challenge, and hence lack of customers. In this scenario, the memory business also faces Chinese competition (in particular from YMTC on 3D NAND), affecting returns over a cycle and potentially leading Samsung stock to go below book value.

Intel: In the bear case, PC growth subsides after a strong 2021 helped by work and learn from home. Data-centric revenue underwhelms owing to lackluster results in the Data Center Group. Mis-execution on or delays in the roadmap weigh on investor sentiment and valuation. In this scenario, AMD continues to take share in the consumer and cloud segments, with delays in the Intel products portfolio that create risk of erosion in the previously protected enterprise space.

A "tech hard landing" scenario: Such a hard landing – with the cloud, Apple, and automotive segments all starting to face end demand pressures and order cuts – would certainly be a major bear case on a one-year time frame. However, we believe investors have started to discount this potential risk in Samsung and TSMC stocks currently, and believe that risk-reward is skewed to the upside on a one-year time frame, especially relative to the MSCI Asia IT Index and stocks.

In terms of three-year risk-reward balance, we think both TSMC and Samsung look attractive currently: However, we would discount a higher beta in Samsung's stock given a more volatile memory cycle than TSMC's logic semi business. Intel looks unattractive on value-conscious metrics given its cost burden from supporting new growth initiatives.

What We Have Learned

Quantitative approach

Both stocks' metrics highlight Quality with a Value tilt favoring Samsung: Our quant analysis of factors driving both stocks shows that Samsung is skewed to Quality factors, while TSMC's drivers are more mixed – some Quality factors, but also Growth. We think this, as well as very active share gains, contributed to TSMC's outsized outperformance in 2021. However, sector momentum may ease and growth could start to slow against tougher comps, so we could see a return to a Value cyclical bias, which would favour Samsung.

Qualitative approach

TSMC's future looks brighter: TSMC's advantage is its ability to execute and exploit Moore's Law, which has been unmatched. It has built a dynasty by becoming the backbone of the semiconductor industry and runs the largest semiconductor foundry in the world, with formidable customers. Samsung's vertical and horizontal integration give it a unique edge by making both devices and components, ensuring a supply of the best chips for its device businesses, while guaranteeing an anchor customer to help maintain high capacity utilization in its component businesses. Costs borne and lessons learned when adopting a new generation of logic technology often spill over to benefit memory, giving Samsung a head start in the race to perfect and ramp up the next generation of memory-manufacturing technology.

Fundamentals suggest superior earnings growth at TSMC: Both are high quality businesses with exposure to attractive growth segments, but TSMC has generated higher organic growth and overall earnings growth through the cycle (10% 2015-20 sales CAGR vs. 7% at Samsung), and we expect this to continue (22% for 2021-23e vs. 15% at Samsung). Samsung's portfolio repositioning has brought greater diversification from its core memory business and exposure to faster-growing segments (5G, logic, cloud). Pricing power is similar, even though TSMC is often viewed as the gold standard. But Samsung's FCF generation is best-in-class helped by its non-foundry cash flow contributions in memory and mobile businesses.

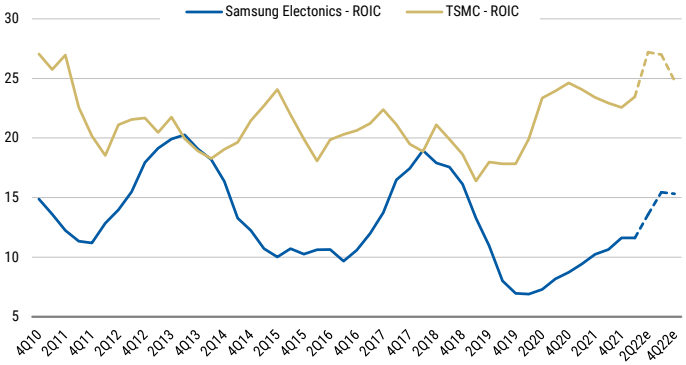
Samsung de-rating vs. TSMC re-rating – is it well supported? Samsung and TSMC have premier franchises, but we expect a global slowdown to shed light on key differences in cyclicality. Most importantly, both have high fixed costs in manufacturing: 47% for TSMC and 49% for Samsung. TSMC management deserves credit for better execution and significant action on its portfolio (aggressive capital deployment in the US and Japan), while gross margins have been stable at ~50% since 2014.

Samsung's return opportunities are significant (in view of higher leading edge foundry exposure, likely M&A and recovery in the memory cycle from 2023), but we believe that TSMC may do better on sustaining higher growth and penetrating new TAM opportunities (HPC, geographical expansion, mix shift). By our estimates, from 2022-24, operating margins at TSMC will normalize to 42% from the peak of 46% in 2022 versus Samsung remaining stable at around 20%, while average RoCE of 19% for Samsung will remain below 29% for TSMC. Samsung also has the advantage of generating massive amounts of FCF (US$30bn+ FCF in 2021-23e, FCF yielding 8%, and a more than US$100bn net cash position as of 1Q22). This large pile of cash is also a reason for Samsung's low multiples given its impact on depressing ROE.

Samsung's foundry opportunity is significant and underestimated: With Samsung having underperformed TSMC (and certain other global megatech stocks) by 45ppt since 2020, investors question whether there is room for it to re-rate significantly and catch up with global peers. In our view, secular long-term tailwinds in leading edge foundry and M&A in areas like auto semiconductors will contribute to a higher TAM and could be a powerful additional leg of growth. We see an underpenetrated and underestimated total market opportunity for Samsung of US$1.4tr, well ahead of the ~US$1.1tr industry TAM today. Samsung's returns have changed little in a decade but significant greenfield investment opportunities in leading edge foundries support higher returns on invested capital given its ROIC of 12% now vs. foundries generating 18-25% returns.

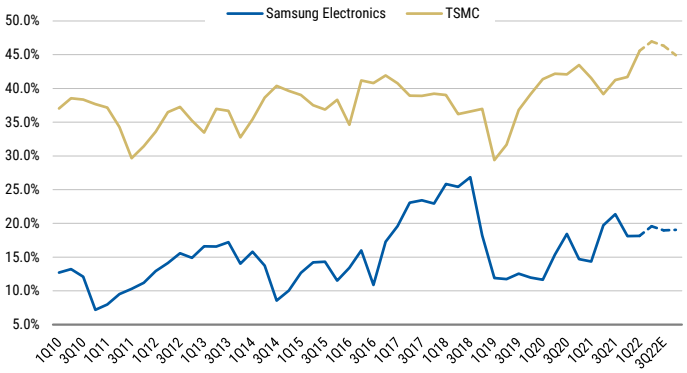
What drove TSMC's historical outperformance? TSMC has been riding on multiple semi industry megatrends, such as 5G, AI, HPC, and digitalization. All of those applications are heavily dependent on leading edge foundry process technologies, where TSMC currently has the lion's share. That is to say, TSMC's dominance in leading edge technologies is also a major reason why it has been able to outgrow its foundry peers in the past two years, without a significant pricing hike in wafers.

Exhibit 5: Samsung vs. TSMC ROIC – Cyclical and Lacks Step Improvement



Source: Company data, Morgan Stanley Research (e) estimates

Exhibit 6: Samsung vs. TSMC OPM



Source: Company data, Morgan Stanley Research (e) estimates

The stocks and market sentiment no longer discount a positive scenario

Samsung's de-rating at 9x 12-month forward P/E vs. TSMC at 16x offers an opportunity to add positions in Samsung at a relatively attractive valuation. Samsung has lagged YTD, with relative underperformance even greater over the last one and five years. This mostly reflects multiple expansion for TSMC; Samsung has failed to participate in this expansion in view of questions over its strategy on growth and holding too much cash on the balance sheet.

However, given TSMC's much higher multiple combined with similar cyclical risks, we see a strong argument that Samsung can reverse this relative underperformance over the next 3-6 months. Looking back over a longer time period, TSMC has outperformed Samsung over five years, driven by significantly stronger earnings growth that has more than outweighed multiple expansion for TSMC.

Book value multiples for Samsung have retreated to historical mid-cycle levels.

However, this in itself is insufficient without a second-derivative cyclical catalyst – an earnings uptick – for the market to call for a fundamental upturn: In previous corrections, Samsung has consistently outperformed the memory group and often the MSCI Asia benchmark, and we believe the business attributes are fundamentally more appealing in the current environment given cost/product leadership as well as optionality on seizing new addressable markets. Cash conversion, growth and RoCE characteristics are close to best-in-class among quality tech – we think the valuation along with high and secure dividend yield/cash returns are supportive in a down-cycle. Samsung's 12-month forward P/E has declined from a peak of 15.0x in 2020 to 8.5x now, reflecting the company's capital-intensive business model and slower revenue growth coming off a recent peak of the memory cycle and Covid affecting end-markets.

Limited re-rating upside for TSMC ahead in terms of P/E valuation.

TSMC may do better on sustaining higher growth and penetrating new TAM opportunities in HPC, geographical expansion, and mix shift. However, its operating margin is likely to normalize to 42% from the peak level of 46% in 2022 with the benefits from the pandemic fading away.

If we assume both stocks return to their five-year average P/E valuation relative to the Asian tech sector, Samsung offers 22% upside potential while TSMC is close to 12%.

What else did we learn?

Financial metrics are clearly stronger for TSMC – but there are also qualitative elements to consider when comparing these two foundry businesses. TSMC and Samsung spend around US$28bn each on manufacturing facilities and billions on R&D, and it is extremely hard for a commercial company to catch up with these chipmakers. According to IC Insight, governments would need to spend at least $30 billion per year for a minimum of five years to have any reasonable chance of success.

Intel's management has been very confident about its ambitions in the foundry market and aims at mid-/high-single-digit growth in 2023-24 and double-digit growth beyond that. However, it is going to take large investment well in advance of generating returns and we have been unable to confirm serious traction from the market for IFS (Intel Foundry Services). We remain skeptical and believe that the company has years of sacrifice and learning ahead before the foundry service becomes an asset.

The Story in Charts

Exhibit 7: Qualitative factors and business model comparison

	Samsung Electronics	Intel	TSMC
Company information			
Year of establishment	1969	1968	1987
Foundry service	2005	2013	1987
Number of employees	287,439	121,100	65,440
Foundry strategy	**Become the #1 foundry by 2030.**	**Leverage Intel's scale to meet growing foundry demand.**	**Everyone's foundry; values entegrity.**
Multi-year capex plan	US$151bn capex for foundry from mid-2021 to 2030.	US$108bn capex for Europe and US fab expansion.	US$100bn capex for 2021 to 2023.
Industry position (as of 2021)			
Total semi revenue size (US$bn)	94	79	57
Global semi market share	17%	14%	10%
Global semi revenue rank	#1	#2	#3
Global foundry market share	17%	<1%	51%
Capital market position			
Ticker	005930.KS	INTC.O	2330.TW
Market cap (US$ bn)	349	181	455
QFII holding	71%		73%
% of respective local indices	20%	9% of SOX	28%

Source: Company data, Morgan Stanley Research estimates

Exhibit 8: Comparison on quantitative factors

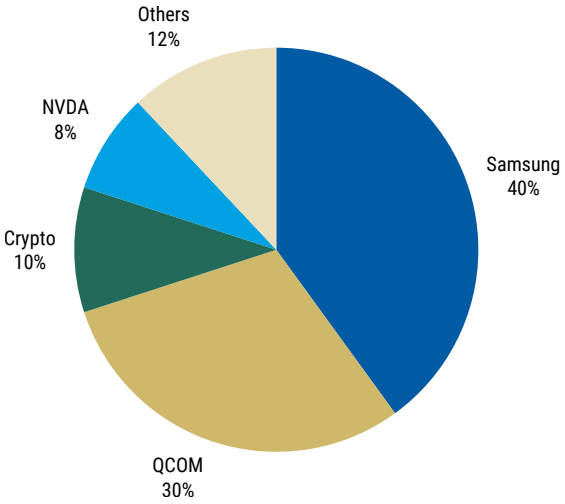
	Samsung Electronics	Intel	TSMC	Foundry industry avg.
Operational comparison (2022e)				
Revenue (US$ bn)	247	74	72	
Samsung LSI	*28*			
Samsung Memory	*93*			
Fab capacity (12" equiv.)	1,775	387	1,300	215
Samsung LSI	460			
Samsung Memory	1,315			
R&D (US$ bn)	17.3	16.4	5.7	
Profitibility				
Gross margin	45%	50%	56%	37%
Operating margin	19%	21%	46%	27%
Samsung LSI	*15%*			
Samsung Memory	*39%*			
EBITDA margin	29%	40%	69%	44%
Productivity				
Sales/R&D	14.3	4.5	12.6	13.8
Operating profits/R&D	2.7	1.0	5.8	3.8
Sales/Employee (US$k)	860	612	1,101	432
EBITDA profit per k wafers (US$ mn)	41.0	76.4	38.1	10.5
Growth potential (2022-24e)				
Revenue Growth	15%	8%	37%	8%
Adjusted EBITDA Growth	12%	21%	40%	2%
Comparable RoCE	19%	10%	29%	15%
EPS Growth	14%	18%	26%	-18%
2023 Net Debt/EBITDA	-130%	95%	-10%	56%
Valuation (2023e)				
P/B (x)	1.11	1.44	4.13	2.18
EV/Sales (x)	0.81	2.37	5.61	2.85
ROE	14%	14%	34%	20%
ROIC	13%	10%	41%	11%
FCF yield	9%	4%	3%	2%
Cash dividend yield	5%	3%	3%	4%
Dividend Payout ratio	43%	0%	41%	57%

Source: Company data, Morgan Stanley Research estimates

Comparative analysis

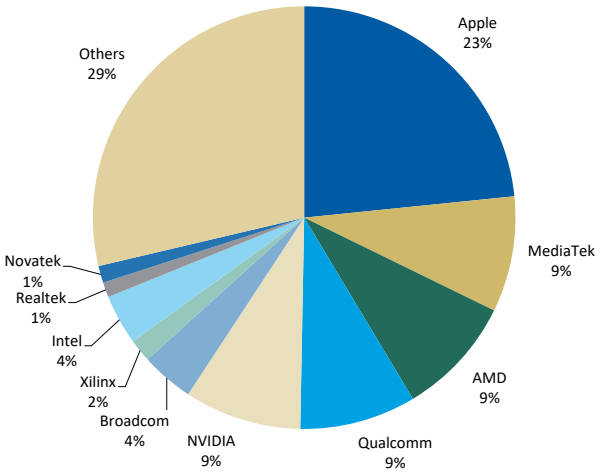
Foundry

Exhibit 9: Samsung foundry's key customers, 2022e



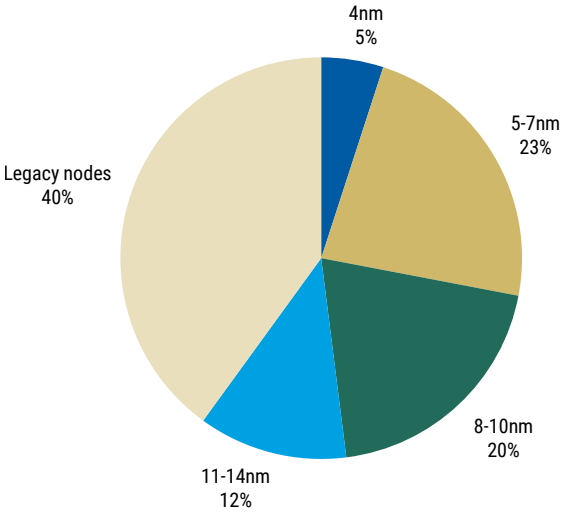
Source: Company Data, Morgan Stanley Research estimates

Exhibit 10: TSMC's key customers, 2022e



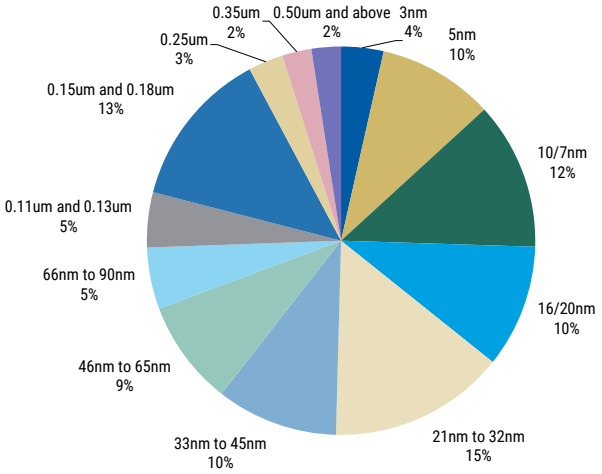
Source: Company Data, Morgan Stanley Research estimates

Exhibit 11: Samsung's capacity mix by nodes, 2022e



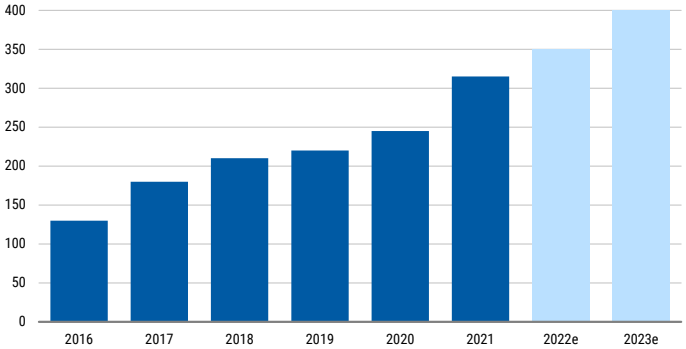
Source: Company data, Morgan Stanley estimates

Exhibit 12: TSMC's capacity mix by nodes, 2022e



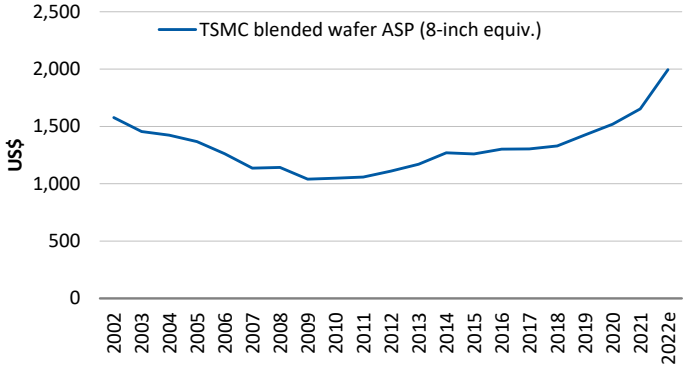
Source: Company data, Morgan Stanley estimates

Exhibit 13: Samsung's 12-inch wafer capacity



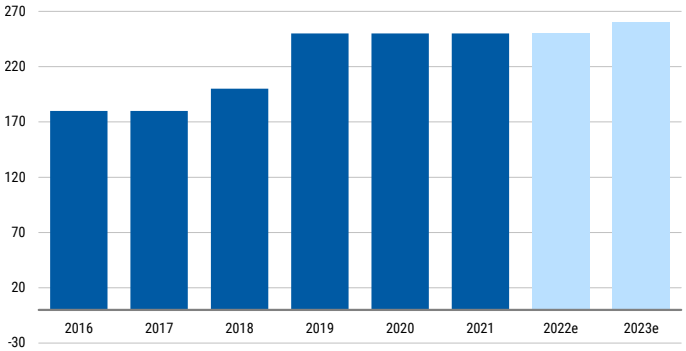
Source: Company data, Morgan Stanley estimates

Exhibit 14: TSMC's 8-inch equivalent wafer blended ASP trend



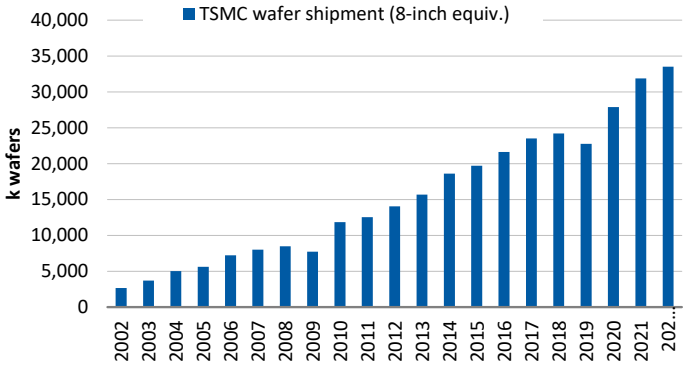
Source: Company data, Morgan Stanley Research estimates

Exhibit 15: Samsung's 8-inch wafer capacity



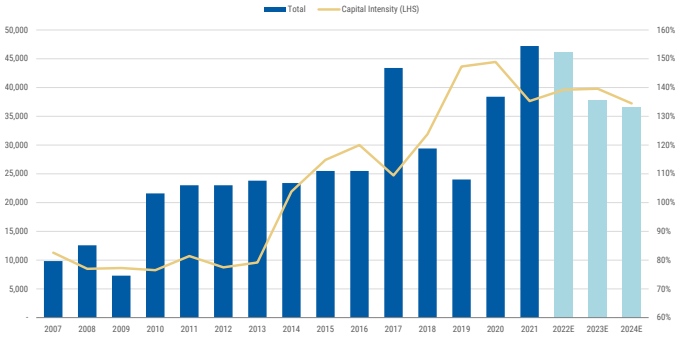
Source: Company data, Morgan Stanley estimates

Exhibit 16: TSMC's 8-inch equivalent wafer shipment trend



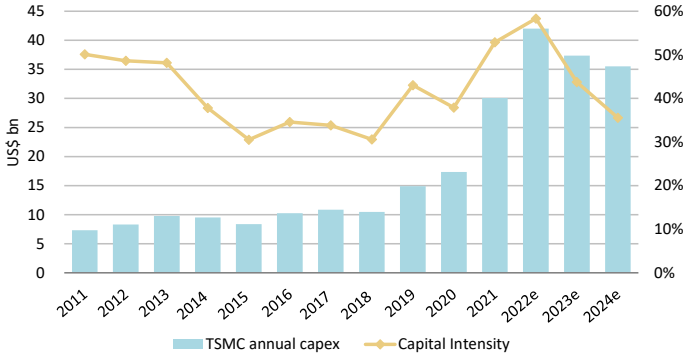
Source: Company data, Morgan Stanley Research estimates

Exhibit 17: Samsung – total capex vs. capital intensity



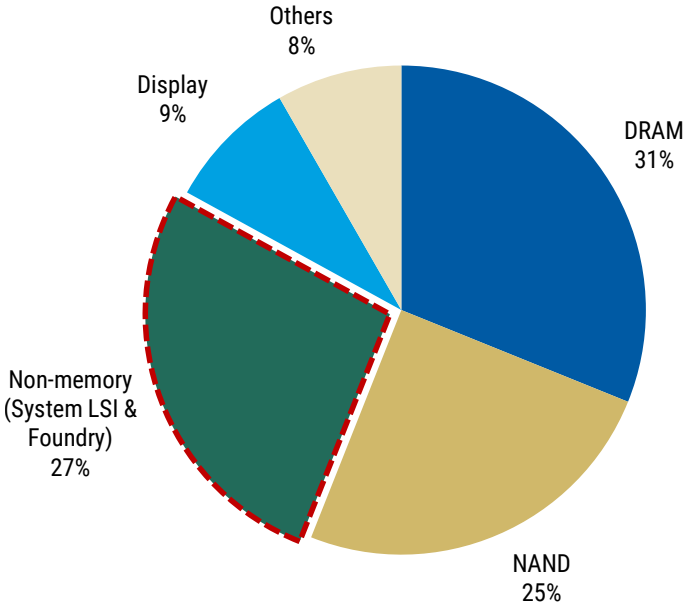
Source: Company data, Morgan Stanley Research estimate

Exhibit 18: TSMC – annual capex vs. capital intensity



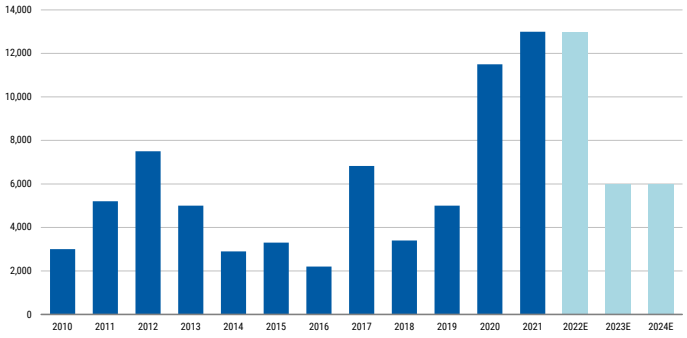
Source: Company data, Morgan Stanley Research estimate

Exhibit 19: Samsung – capex breakdown 2022e



Source: Company data, Morgan Stanley Research estimates

Exhibit 20: Samsung – system LSI & foundry capex trend

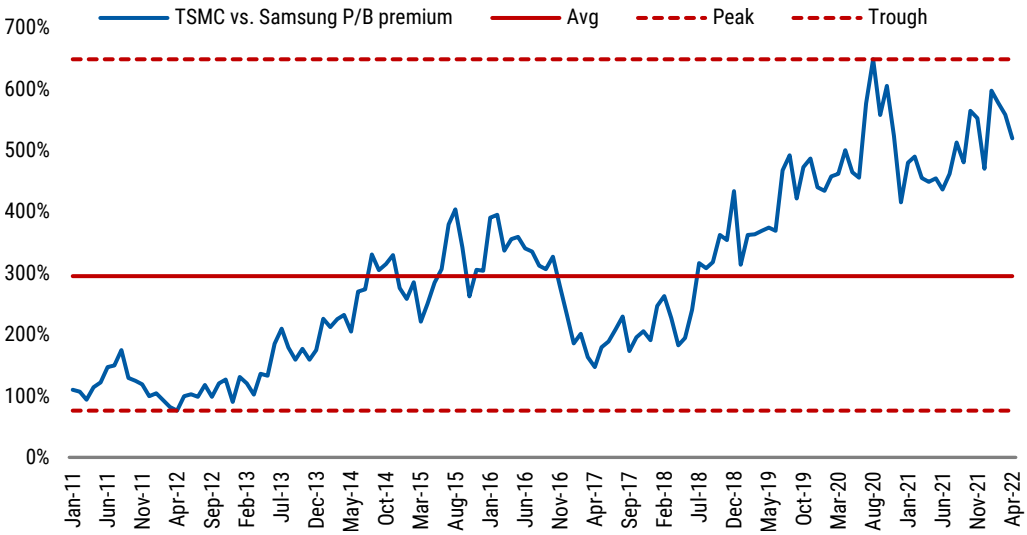


Source: Company data, Morgan Stanley Research estimates

Valuation

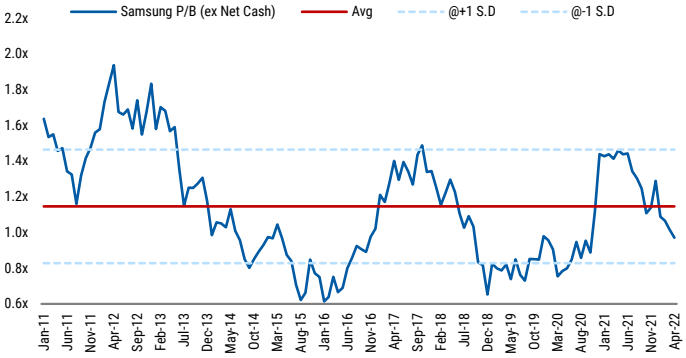
Relative valuation – Samsung's de-rating offers an opportunity: Over the past 18 months, TSMC's premium on P/E has narrowed versus Samsung (~4% relative re-rating) but widened versus the Asian tech sector P/E (~5% de-rating). We expect this trend to mean-revert – at our price targets, Samsung regains its historical average discount to TSMC. Looked at another way, if we assume both stocks return to their average valuation over the last five years, Samsung shows 22% upside potential while TSMC is close to 12%.

Exhibit 21: TSMC vs. Samsung – P/B premium



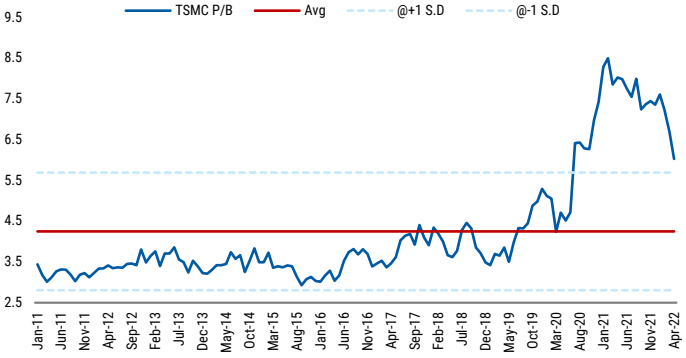
Source: Refinitiv, Morgan Stanley Research

Exhibit 22: Samsung: P/B



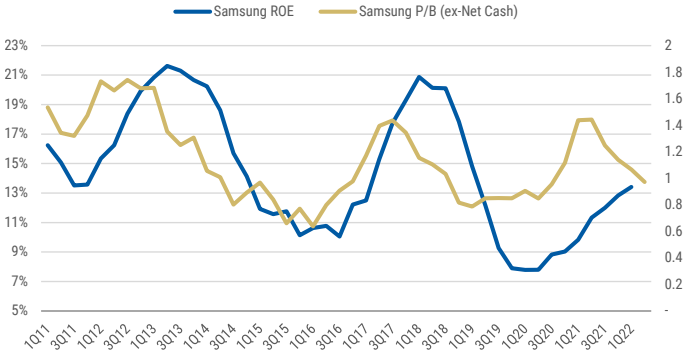
Source: Refinitiv, Morgan Stanley Research

Exhibit 23: TSMC: P/B



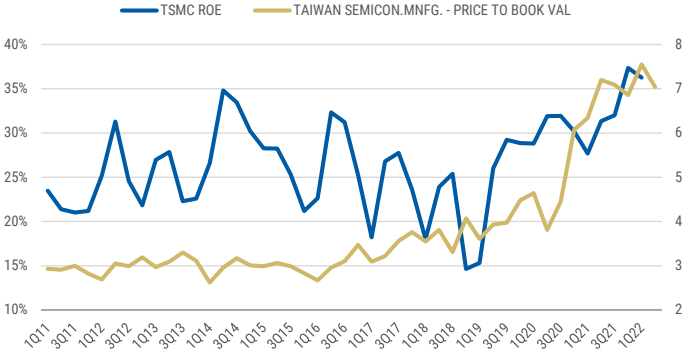
Source: Refinitiv, Morgan Stanley Research

Exhibit 24: Samsung: P/B vs. ROE



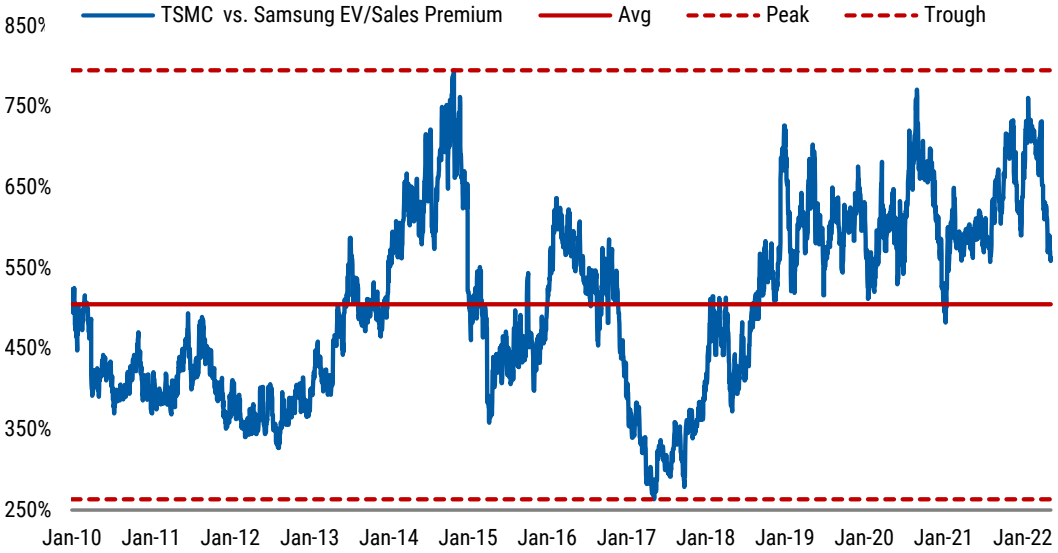
Source: Refinitiv, Morgan Stanley Research

Exhibit 25: TSMC: P/B vs. ROE



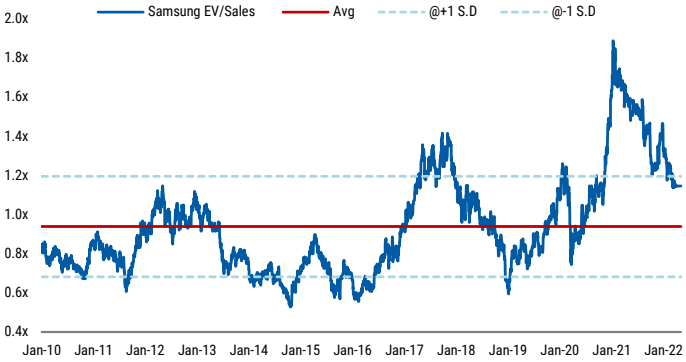
Source: Refinitiv, Morgan Stanley Research

Exhibit 26: TSMC vs. Samsung: EV/Sales premium



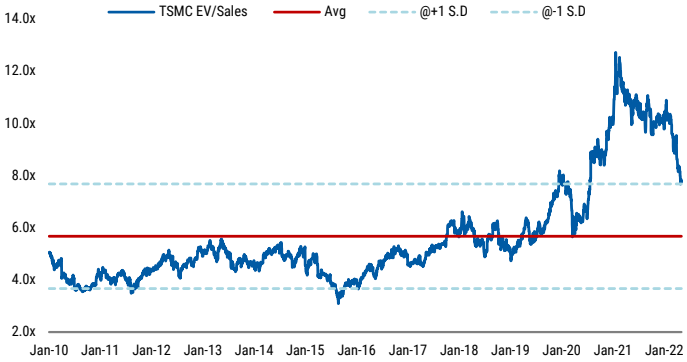
Source: Refinitiv, Morgan Stanley Research

Exhibit 27: Samsung: EV/Sales



Source: Refinitiv, Morgan Stanley Research

Exhibit 28: TSMC: EV/Sales



Source: Refinitiv, Morgan Stanley Research

Analyst Takeaways from the Other Side

Our impression of TSMC is that it is at a much earlier stage of its journey than Samsung in that investment actions have been a lot more aggressive. This could explain the divergent margin trends vs. Samsung.

For Samsung, it is hard to drive a re-rating in its existing diversified businesses, and additional new TAM may be required to drive growth and higher returns.

In terms of comparative returns, we think that Samsung stacked up reasonably well against TSMC with one exception: operating margins.

Charlie's view on Samsung

The market tends to simplify foundry competition by technology comparisons, Moore's Law, etc. We do think technology is an important factor, but not the only one. We should also consider semi customers' needs (e.g., vendor diversification), geopolitical risks, etc. We think TSMC's management has never underestimated the competition from Samsung. The company founder, Dr. Morris Chang, called Samsung Foundry a "formidable competitor," so TSMC investors should also be mindful of competition from Samsung as well, in our view.

Historically, Samsung Foundry used to be the major supplier of Apple-designed processors (2012). And in 2014, Samsung's 14nm technology was superior to TSMC's 20nm and 16nm in terms of logic transistor density. In addition, Samsung generates huge cash flow from its dominating memory business, which can continue to fund its foundry operations and enhance its competitive position. If we compare Samsung's overall semi division vs. TSMC's corporate operating margin, the gap may not be as big as some investors think – 45.9% for TSMC and 34.4% for Samsung's semi division, both in 2022e.

Strategic position – TSMC also doesn't want a solo dance

Importantly, semi customers normally need a second source behind TSMC in leading edge. The first wave of 4nm and 3nm chip projects may go to TSMC, but once Samsung's 3nm GAA is more mature, we would expect key customers like Qualcomm and NVIDIA to keep the outsourcing relationship with Samsung. At least for Qualcomm, Samsung Mobile is also an important customer for its high-end Snapdragon SoC.

On the other hand, TSMC has been careful about potential antitrust issues. Back in September 2017, GlobalFoundries called for an investigation into TSMC for manipulating wafer prices in Europe (Reuters).

That said, according to the company's press release on September 6, 2017, "*TSMC has received no official request for information from any legal authority regarding the allegation.*" Although reaching near-monopoly in future at 3nm and 2nm would be positive for TSMC, we believe competition would keep the industry structure healthy, in particular amid current geopolitical risks.

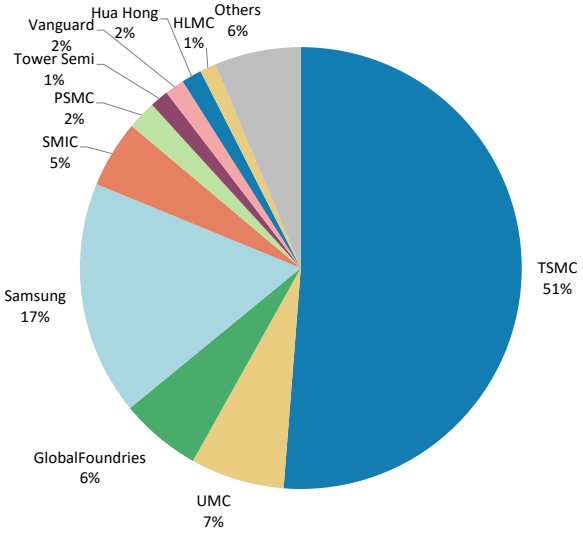
Is customer conflict a real issue? Samsung has its audience

"Customer interest conflict" has been seen as a significant counterpoint to Samsung's foundry business success. Indeed, major consumer IC vendors MediaTek and Novatek don't use Samsung's foundry service given the overlap with Samsung LSI's TV SoC and OLED display driver IC designs. However, there are still major HPC semi vendors, such as NVIDIA, that outsource to Samsung given limited business overlap. Tesla's autonomous driving chip using Samsung's 5nm is another example. Some customers are even happy to use Samsung as the major source, for example, Amberrella and Chinese crypto mining customers, given Samsung's cheaper wafer prices. China's GalaxyCore also uses Samsung as its major foundry partner, because it cannot get similar support from TSMC.

Technology race – a marathon, not a sprint

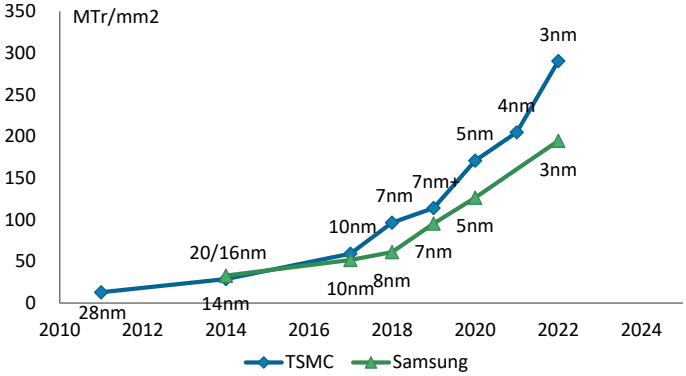
Regarding the possibility of Samsung's technology catching up with TSMC's in the coming years, we don't have clear answers. We don't have sufficient knowledge to explain why Samsung at times has experienced production yield issues at 7nm and 5nm. Some investors have said that Samsung's decision for fan-out advanced packaging came too late, while changes in materials in the front-end process were too aggressive. Whatever the case, if and when Moore's Law migration hits the physical or economical limit, we believe there will be a chance for Samsung to close the technology gap and become a viable leading-edge foundry source.

Exhibit 29: Foundry market share – Samsung likely needs to be a viable second source in foundry, or TSMC's dominance could prompt antitrust issues



Source: Company data, Gartner, Morgan Stanley Research. Note: Data as of 2021.

Exhibit 30: Logic transistor density comparison: Samsung's and TSMC's technology competition was very tight during 2015-2019 at 14nm and 7nm



Source: Company data, Morgan Stanley Research

Shawn's view on TSMC

TSMC is the backbone of the semiconductor industry: It runs the largest semiconductor foundry in the world, with formidable customers including Apple, NVIDIA, Qualcomm, and many more. The company is even supplying competitor Intel, which fell behind on the latest 7nm chip. It is also earning a consistently high return on equity of 25%, pays a dividend yield of approximately 3.3%, and its balance sheet is a fortress with US$42 billion in cash and maintainable debt.

TSMC is the archetype of a company that exploits Moore's Law: The company has a strong technology roadmap and it is set to continue introducing improved leading-edge nodes every year, thus offering its customers improvements at a predictable cadence. TSMC's high capital spending implies greater demand from Apple and Intel beyond 2023 for:

1. 3nm and 2nm nodes, in addition to the CPU/GPU growth from data centers;
2. 3D packaging, because of more demand from HPC clients; and
3. Specialty nodes at 28/22nm.

Its N3 and N5 nodes are not going to have competitors offering similar transistor densities and wafer starts. In the longer term, however, the end of Moore's Law means a physical limit to how many transistors we can place on a wafer, economically. This suggests that Samsung and Intel could catch up in the long term if the industry is no longer able to migrate to more advanced nodes.

Competition: There are incredible barriers to entry – only two companies, TSMC and Samsung, have even perfected the 7nm process. GF gave up; Intel needs to invest billions more and is still several years behind. Ironically, TSMC manufactures Intel's highest-end chips. The competitive position for TSMC is enviable. TSMC wisely supports its customers' growth rather than using its dominance to crank up margins; customers do not want TSMC to become a monopoly.

The biggest risk that Shawn can see for TSMC is China: China recently announced its ambition to become "Semiconductor Independent" as part of the "Made in China 2025" initiative with the goal to produce 70% of semiconductors domestically by 2025. There have even been news of China poaching Taiwanese semiconductor talent in order to enhance its indigenous technology. There is also the geopolitical risk, which has now been around for many years. The US has recognized the potential future threat from China in semiconductor technology and it has announced a new US$12 billion US semiconductor plant, which is expected to be TSMC's most advanced chip facility outside of Taiwan. This would also be TSMC's second manufacturing site in the US.

Industry experts' views on TSMC vs. Samsung

We interviewed several major foundry manufacturing experts, IC design customers and procurement managers.

Highlights:

What differentiates TSMC vs. Samsung? PPA (Power, Performance, and Area), costs, and schedule are three key aspects customers will consider when choosing foundry services. Currently, TSMC still surpasses Samsung in the overall evaluations. Samsung offers cheaper wafer prices than TSMC, but customers are concerned about scheduling delays and the lack of performance, which may cause them eventually to pay an even higher price.

More resources devoted to new technology development are likely lead to a higher yield: Compared to Samsung, TSMC is able to input more wafers and shorten the development cycle for a new technology with the investments and high requirements from Apple. This virtuous circle helps TSMC to gain better yields and attract more customers. Samsung's memory division generates strong cash flow to support its foundry business, but no other customers can compete with Apple in terms of willingness to use/push new technology.

Yield inferiority arising from architecture can be improved only to a limited extent once mass production starts: Different devices in an SoC require specific processes to wire in the functions. Once the chip is mass produced, it is hard for foundries to fundamentally change the design and therefore improve the yield rate. Samsung's aggressive push for mass production might be the reason behind its yield issue and delayed schedule.

Foundry customers prefer higher transparency and close collaborations: Industry experts suggest that Samsung's staff are as competitive as TSMC's – but culturally, TSMC staff may be more willing to communicate and collaborate, thus providing more assurance to customers in terms of project progress.

Samsung's foundry business has room to develop: This stems from:

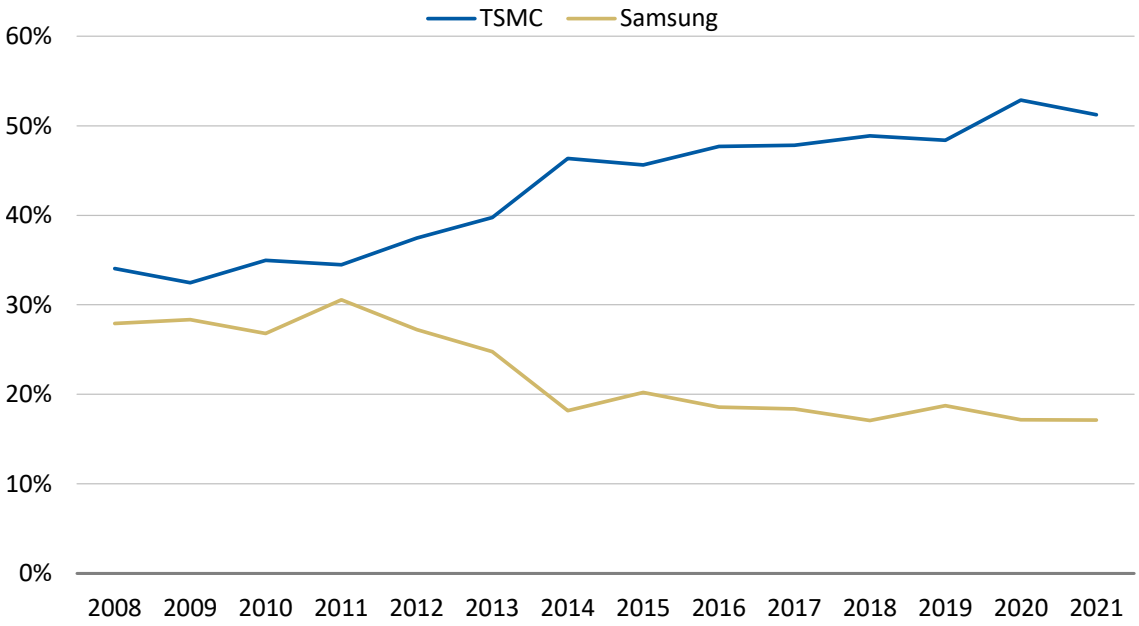
- Samsung's strong LSI capacity: LSI provides the services to complete the missing block to develop a new chip, which enables chip designs for companies like Google and Tesla.
- **Customers' concern over TSMC's near monopoly**
- **TSMC's prioritization of other big customers over them** – given capacity tightness

The latter two factors have encouraged customers to choose Samsung.

Face-Off – Samsung vs. TSMC – in Depth

Samsung has lost ground to TSMC in advanced semiconductors mass production and is losing market share in contract manufacturing. Based on our interviews with suppliers, the company was delayed in boosting the yield on the most advanced chips, with 5nm circuitry. It trailed TSMC by several months in the launch of 5nm mass production, and the technology gap has been widening ever since.

Exhibit 31: Foundry market share: TSMC vs. Samsung



Source: Company data, Gartner, Morgan Stanley Research

The foundry business model

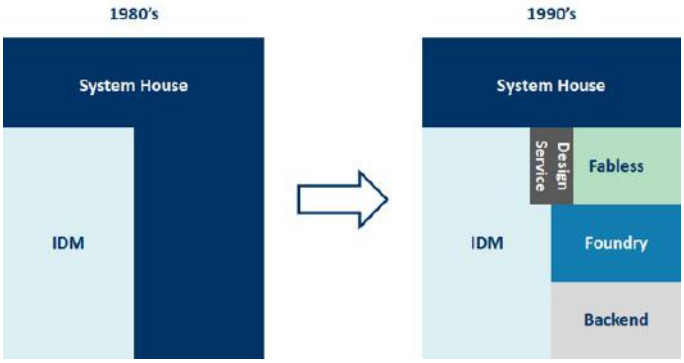
Semiconductors are made from silicon and other chemicals, which are readily available. Any country can build fab clean rooms to manufacture advanced chips, given no climate or space constraints. However, the manufacturing yield and quality can determine the success of the chip, as can the cost structure. Coupled with the growing capex intensity, the barriers to entry are high among the segments of hardware.

Asia's dominance: Wafer foundry outsourcing is a simple yet brilliant idea. It was conceived and developed by TSMC in the 1990s. According to VLSI, IC Insights, and SIA, the share of the US in semi manufacturing globally has shrunk from >30% in the 1990s to only 12-13% now. The dependency on major foundry TSMC in particular is high. If we include production at Samsung's 7nm and 5nm processes, essentially 100% of the advanced logic semis come from Asian foundries. The key reason that US semi customers have such high vendor concentration is Asian foundries' process leadership and operational efficiency in Taiwan and Korea.

Fabless IC design companies all use foundry services. But integrated design manufacturers (IDMs) use them only selectively. The IDM outsourcing trend started around 2001 and proliferated in 2004-06, as the foundry logic process became more competitive. By end products, most logic chips, such as smartphone chipsets, are designed by fabless IC design companies, and foundries should have acquired almost 100% of the outsourcing for this.

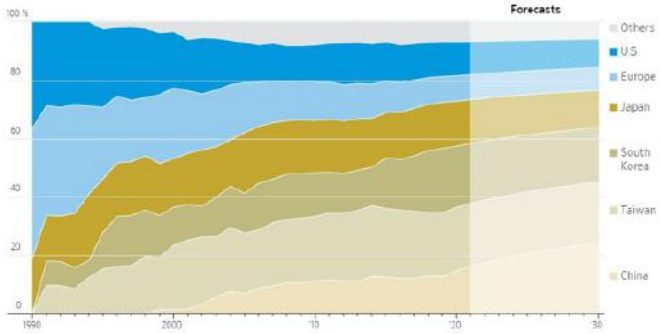
TSMC today produces 100% of Apple's iPhone processors, 90% of Xilinx's field-programmable gate arrays (FPGAs), and ~70% of NVIDIA's graphics processing units (GPUs).

Exhibit 32: Semiconductor industry specialization – foundry outsourcing



Source: Morgan Stanley Research

Exhibit 33: Global manufacturing capacity by region – shifting to Asia



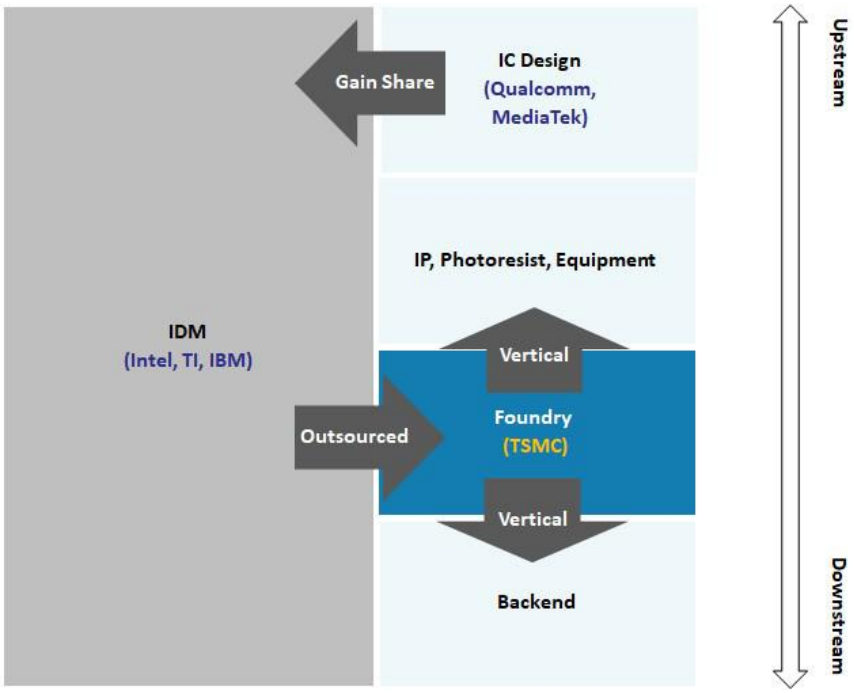
Source: VLSI Research projection, SEMI, BCG. Note: 2020 is an estimate, and 2021-2030 are forecasts.

Here is the framework we use to analyze foundry's current addressable market and long-term growth opportunities.

1. Share gain within the wafer foundry business
2. Vertical integration – advanced packaging (e.g., TSMC's 3DFabric) the key growth driver
3. Further outsourcing from IDMs (e.g., Sony sensors and Intel CPU outsourcing are key to TSMC)
4. IC design customers enter new addressable markets – ARM-based CPU
5. Organic growth of the semiconductor industry – data era and GDP growth

After three decades, TSMC acquired global foundry market share of 50%+. Samsung started its foundry services in 2005. Given the nature of foundry's business model, some foundry customers still see Samsung as an IDM with some conflict of interest with customers, whereas TSMC is a pure-play foundry. However, if Samsung can reverse that image, we believe more customers will choose it as the major foundry source. A good example is that Samsung LSI is doing more outsourcing to third-party foundries, such as UMC, to unbundle LSI and Samsung foundry.

Exhibit 34: Wafer foundry's growth opportunities



Source: Morgan Stanley Research

Competition and market share

Currently, it's a two-way race dominated by TSMC... Our profit analysis shows that Samsung's strong position in the memory business probably can support the Korean giant's foundry competition for another decade, and customers will always need a second supplier source. Intel now becomes a different animal with the US being much more aggressive in semi technology localization.

...but Intel is aiming to join: Intel launched "Intel Foundry Services" (IFS) last March. Previously, the Street expected TSMC and Samsung to be the duopoly in future leading-edge foundry services, including the US market. Intel now could be a choice for US hyperscalers' ASIC designs (e.g., Microsoft). Even if its foundry cost and technology are not as competitive as TSMC's, Intel could be favored from a US semi localization perspective. That's because TSMC keeps most know-how (or foundry recipes) in Taiwan, not in the US.

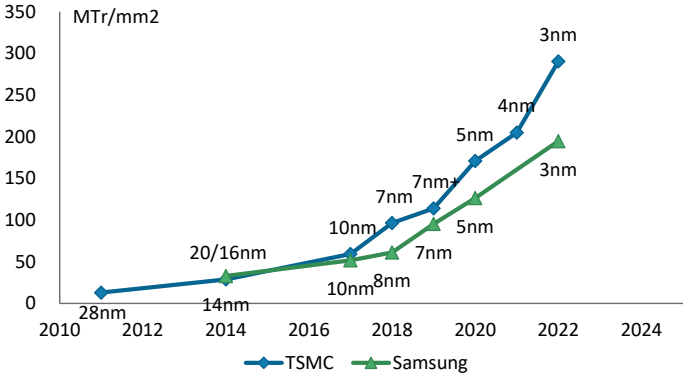
Intel could catch up in the long term... According to Intel, it is catching up with the 5nm EUV in terms of both tool supply and know-how. Should Intel (and the US semi industry) get more R&D support from the US government, TSMC's foundry service may be less competitive in terms of cost.

It is all about execution at this point. Intel clearly has some lofty goals and an ambitious turnaround plan in place, it remains to be seen if the company can successfully implement its strategy and meet the time lines it has set for itself. Advancing the company's technology and pivoting to manufacturing chips will not be easy.

Exhibit 35: Samsung's operating margin in memory is comparable with TSMC's in logic foundry but highly volatile

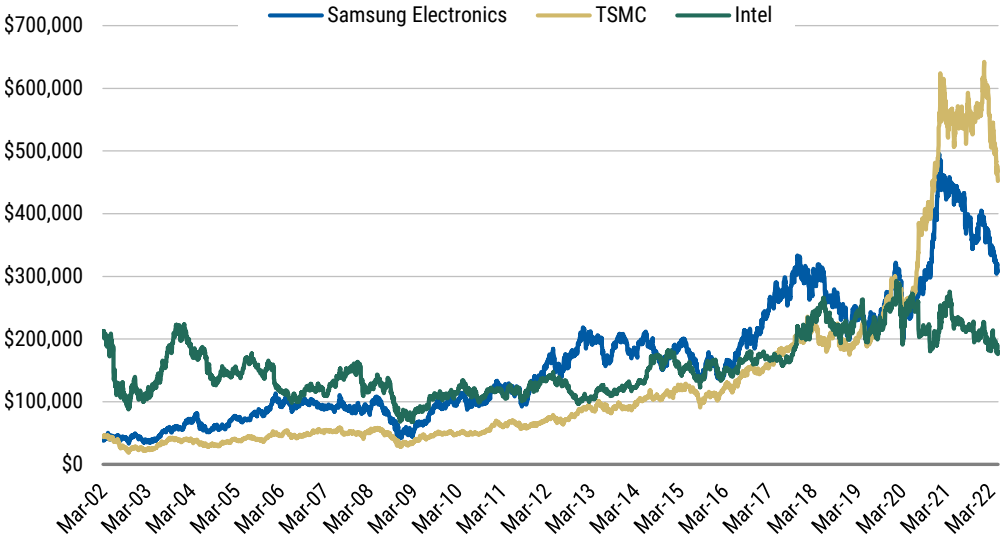
Source: IBM Research.

Exhibit 36: TSMC leads Samsung from 7nm in terms of logic density, but key customers need a viable second source



Source: SEMI, Morgan Stanley Research

Exhibit 37: Samsung vs. TSMC vs. Intel – market cap



Source: Refinitiv, Morgan Stanley Research; Note: Market cap in millions of USD as of May 4, 2022

…but the market remains a duopoly for now: Intent among key US customers such as Apple and Qualcomm to outsource some projects to Intel foundry would serve as a negative catalyst for TSMC stock. In fact, in his media interview on June 17, 2021, Intel's CEO, Pat Gelsinger, was appearing at a CNBC panel alongside Qualcomm CEO Cristiano Amon. Both started leading their companies in 2021. Though the companies are rivals, the CEOs downplayed the competition, and suggested that the two chipmakers could end up partnering in areas where they don't overlap. Qualcomm makes (among other things) chips that connect to 5G networks, while Intel mainly builds central processing units (CPUs) that provide base computing power.

What has gone right for both companies

TSMC

TSMC developed into the largest semiconductor market cap globally by leveraging Moore's Law: TSMC has been very good at commercializing "Moore's Law" (or chip scaling). The company consistently invests huge amounts in R&D, developing new processes day and night (the "Nighthawk Project"). With its superior technology, TSMC locks in a few select technology partners (e.g., Apple) for early adoption of advanced nodes (such as 7nm and 5nm), and serves as the key enabler for tech innovations such as 5G, AI, and IoT. Then, a second wave of customers come and use depreciated capacity and more mature production yields, which makes it hard for other foundry peers to compete.

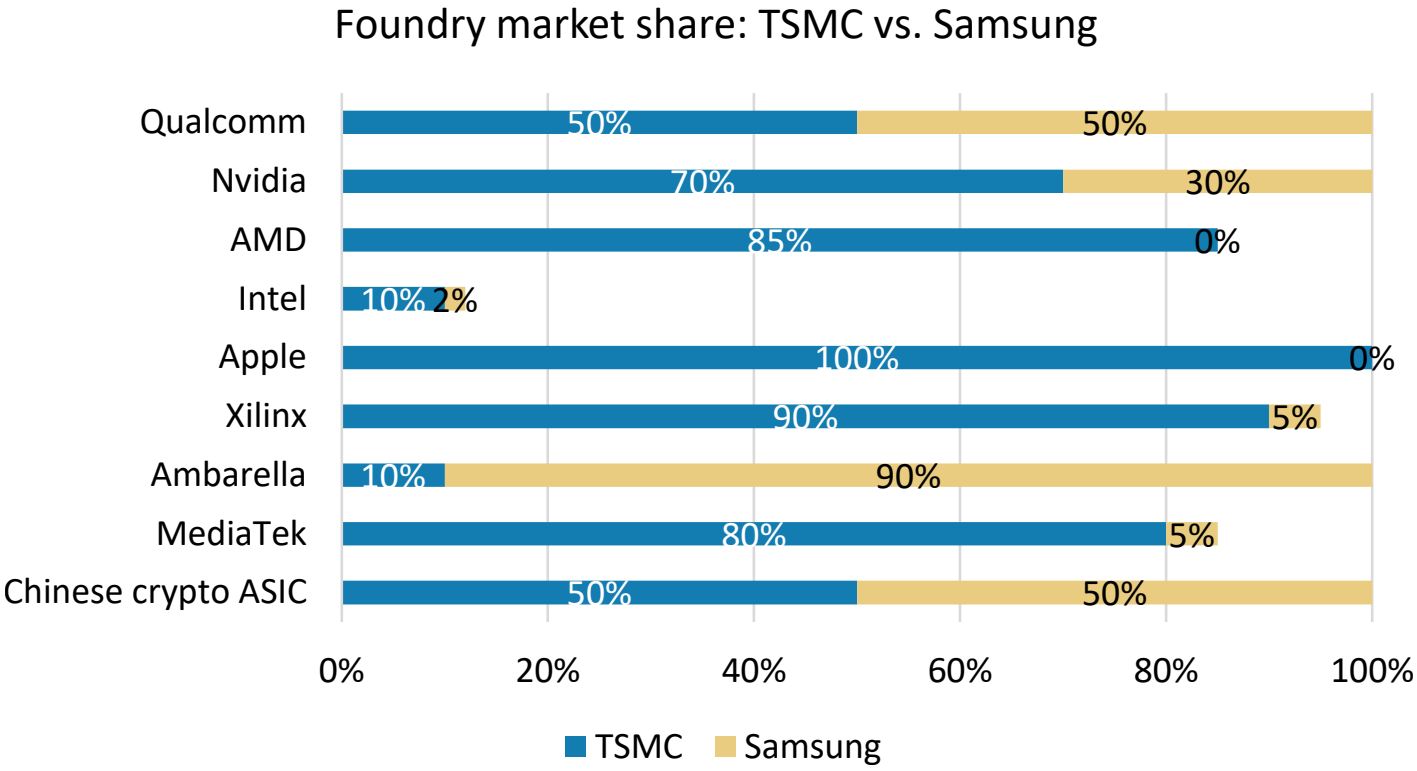
With its big scale, TSMC has also been able to obtain lower pricing from equipment and chemical suppliers for lower pricing.

Compounding this virtuous circle for 10-20 years, TSMC acquired global foundry market share of 50%+: Its operating margin reached 40%, around 25ppt higher than that of foundry industry peers at only 15%. This successful strategy has made TSMC the semiconductor stock with the biggest market cap in the world since 2020.

We attribute TSMC's high market share to:

- R&D intensity: Billions of dollars on R&D every year to test the limits of Moore's Law; its R&D spending is 10x vs. UMC.
- **Strong execution:** There has been consistent improvement in production yields, which is important for customers' tech cost structures.
- **Efficient supply chain in Taiwan:** This features a cluster of fabs and supporting infrastructure.
- **Fusion of global cultures and technologies:** These are drawn from from the US, Japan, and Europe.

Exhibit 38: TSMC and Samsung are the two major sources for leading edge customers



Source: Company data, Morgan Stanley Research estimates

- **Valuing integrity, trust, and partnership when working with customers:** TSMC doesn't compete with customers directly.
- **The corporate slogan "Everyone's foundry":** This signifies neutrality on the US/China debate.

Cost in Asia is still lower

TSMC founder Dr. Morris Chang, during his recent speech at Brookings Institution, said, *"We were extremely naïve in expecting comparable costs, but manufacturing chips in the US is 50 percent more expensive than in Taiwan."* According to the report, Chang said that US production will definitely increase, at least somewhat. *"There will be a high per-unit cost increase, and it will be hard for the US to compete internationally."*

The US's high manufacturing costs reaffirm our view that the US semi companies like Intel would need to outsource more CPU to TSMC in the coming 3-5 years. Back in February, one of our major reasons to upgrade TSMC to OW was the substantial CPU outsourcing opportunity from Intel. The US has to continue its chip manufacturing localization efforts, but that doesn't mean Taiwan's/TSMC's strategic position would be diluted. Indeed TSMC is building new fabs in both the US and Japan, but we think that was necessary to mitigate the geopolitical risks (so it is not totally forced by other governments)

Samsung

A dominant play on digitization:

1. We believe that it has meaningful exposure and the breadth of technologies to drive growth and leading share all its markets (5G, memory, OLED, CE).
2. We think the potential for foundry penetration is generally underestimated, in terms of perceived value ascribed to that business.
3. In most of its businesses, the company has significant scale advantages – and, more importantly, domain know-how: it is already #1 globally in all of its served end-markets, with the exception of foundry, where it is currently the #2 player.
4. With >US$100bn in net cash on its balance sheet, there is optionality to improve capital returns and/or expand its TAM via acquisitions in new areas such as automotive semis.
5. The shares remain significantly undervalued versus peers: 2022e EV/Sales is at 1.14x. On this basis, it trades at a discount to its main comparables in mobile, semi, and CE.

Will the good times last?

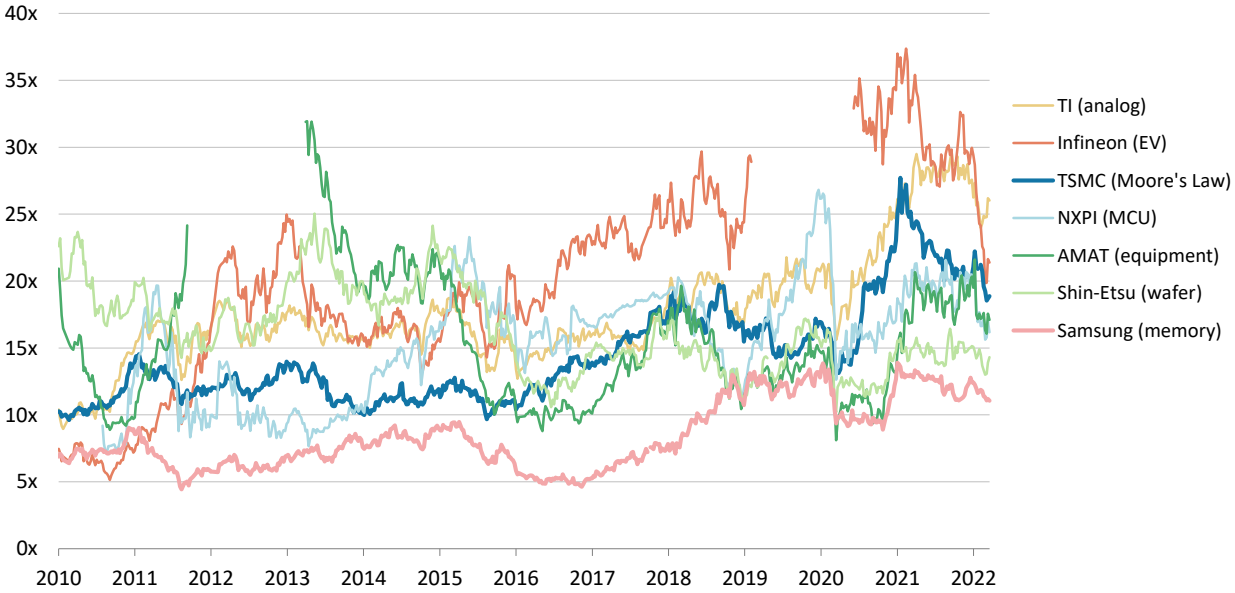
It has been a great journey for TSMC's re-rating since 2020 – but what P/E does it deserve now?

There are indeed some global semi stocks that can command 35-50x P/Es – we'd call them the "tech innovators": They are the true drivers behind the tech megatrends, or disruptive technologies. Examples include Infineon (EVs) and ASML (EUV lithography tools). These companies enjoy monopoly status and concentrate on new applications (AI and EVs), so they can easily generate 30-40% earnings CAGRs. Their stronger earnings growth in 2021 and 2022 also merits higher P/E multiples of 35-50x.

Another group we'd call the "tech enablers": They are also very important in the global tech supply chain, and probably proven as best-quality semiconductor companies. They supply general purpose semi components, services, or equipment. The market views Samsung as belonging to the "enabler" category given its depressed multiples. Other examples in this group include Texas Instruments in analog ICs, NXP in MCU, and Applied Materials in semi equipment. The group is currently trading at ~25x 2022e P/E.

Can TSMC trade at a premium to other "tech enablers"? TSMC should be included in the "tech enabler" group, in our view, given that it has continued to deliver on Moore's Law migration, which explains its re-rating to 20-25x over the past two years. However, with TSMC developing a monopoly over leading-edge processes (3nm and the future 2nm), we think the upper end of this range is deserved. TSMC's lead over rivals is growing. It is now moving to N3 – compared with Samsung's 3nm GAA and "Intel 4" – and will effectively have a monopoly once TSMC N3 enters mass production later this year.

Exhibit 39: Global tech enablers – P/E multiple comparison



Source: Company data, Refinitiv, Morgan Stanley Research estimates

Key risks

We see heightened cyclical risk to Samsung's margin in contrast to stability at TSMC: The risks to Samsung's margin are skewed to the downside, whereas we think TSMC could actually show gross margin expansion during this cycle. TSMC's gross margins have marched steadily higher through a combination of improving mix and leveraging its technology leadership. Furthermore, the company's predominantly customized manufacturing model should result in less variability for its gross margin through the cycle relative to Samsung's.

Portfolio and technology roadmap

Frequently asked questions from investors

How did TSMC wind up triumphant in global semiconductor manufacturing if the US invented semiconductors and provided the key equipment?

In a speech last year, TSMC founder Morris Chang mentioned cultural differences as one reason. We take this to mean that it is easier to drive engineers in Taiwan to achieve greater operational efficiency for fabs. Indeed, in 2014, TSMC started its "Nighthawk" initiatives, assigning two shifts of R&D engineers to work day and night to get the 10nm process to work. In 2018, TSMC's 7nm surpassed Intel's 14nm++ in terms of logic density, and now it is even winning CPU outsourcing from Intel at 3nm.

Given similar operations of Samsung and TSMC in Asia, why is Samsung's logic semi technology behind TSMC's?

Samsung was ahead of TSMC to introduce GAA at 3nm.

However, Samsung's 3nm Gate-All-Around (GAA) logic density is similar to that of TSMC's N4. Our latest checks suggest that Qualcomm and AMD will stick to TSMC's 3nm.

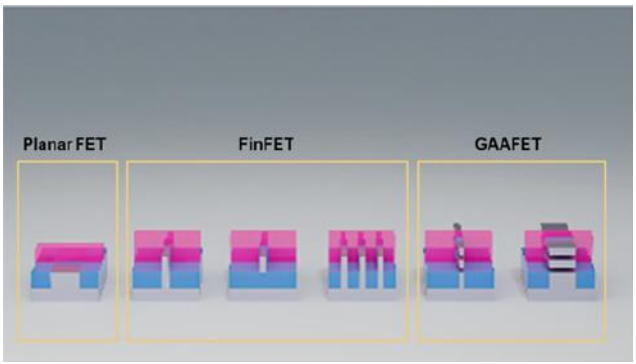
Our recent industry checks suggest that TSMC has made a breakthrough with its N3e process development, and that should make TSMC's 3nm more competitive in terms of cost.

2nm – the new key battle in 2025

TSMC is now moving on to N2 GAA development, and investors are asking whether N2 GAA will be as expensive and challenging as N3.The major benefit of TSMC's N2 should be the migration to GAA (gate-all-around). That reminds us of TSMC's migration from 20nm planar FET to 16nm FinFET. Back then, logic transistor density didn't improve much at 16nm, but the transistor performance and power consumption were enhanced.

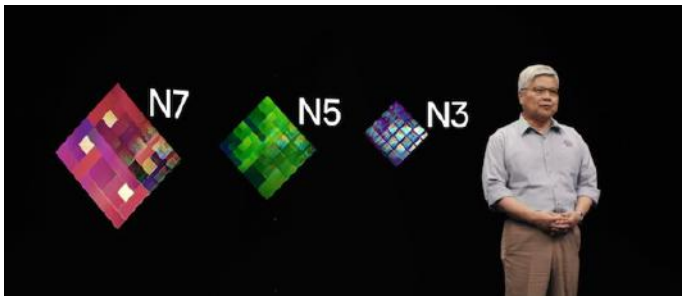
Intel will also switch from FinFET to Horizontally Stacked Gate-All-Around Nanosheets (Intel calls these RibbotFETs). TSMC may consider adding backside power rails at 2nm, like Intel's 20A PoweVia.

Exhibit 40: GAA (gate-all-around structure)



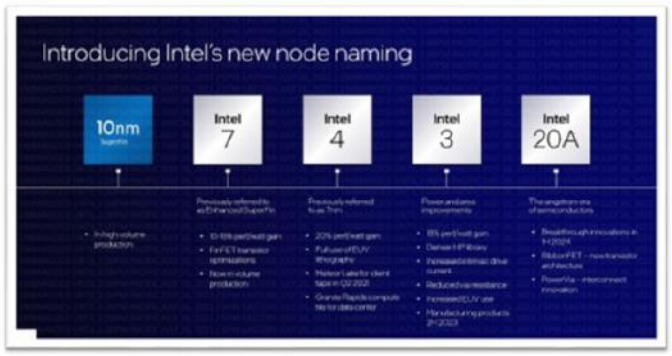
Source: Morgan Stanley Research

Exhibit 41: TSMC next node N2 should use GAA (gate-all-around) transistors



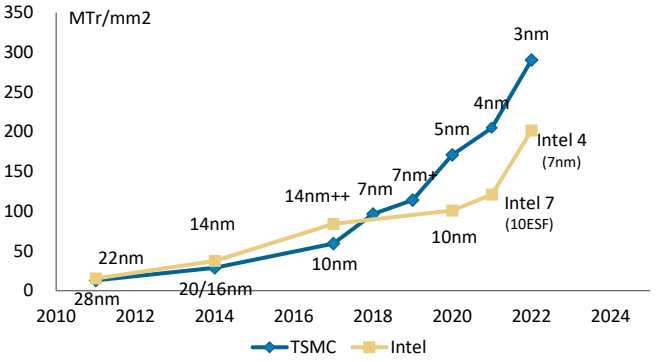
Source: TSMC

Exhibit 42: Intel has introduced a new node named Intel 20A (2nm)



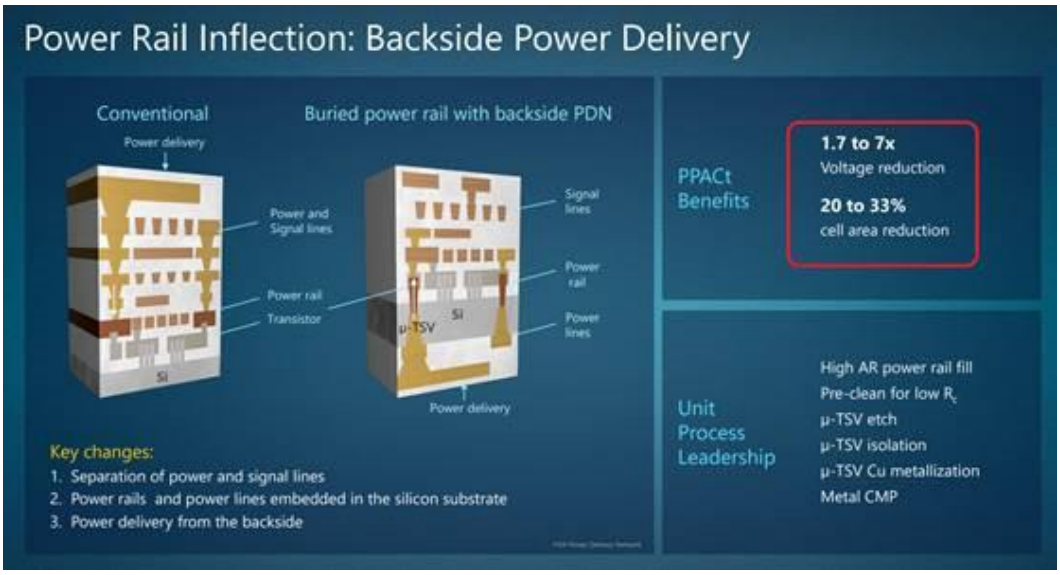
Source: Intel

Exhibit 43: TSMC's 3nm is far ahead of "Intel 4"



Source: Company data, Morgan Stanley Research estimates

Exhibit 44: "Power Rail" structure may be introduced at 2nm



Source: Company data, Morgan Stanley Research estimates

Exhibit 45: Leading-edge foundry process roadmap

CY	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021e	2022e	2023e	2024e	2025e
Intel		22nm FinFET		14nm FinFET					10nm FinFET	10nm	Intel 7 FinFET	Intel 4 (EUV)	Intel 3	5nm	Intel 20A GAA
TSMC	28nm			20nm	16nm FinFET	16nm+ FinFET	10nm FinFET	7nm	12nm	22nm	7nm Pro	5nm	5nm Pro	6nm	4nm	3nm FinFET	N3b	N3e	2nm GAA
Samsung	32nm	28nm			14nm FinFET	28FDS	10nm FinFET	8nm	28FDS-RF	14nm LPU	7nm (EUV)	28FDS-eMRAM	5nm	18FDS	4nm	3nm GAA			
GFS						14LPP	22FDX	12LP				12FDX							
SMIC					40nm		28nm HKC	28nm HKC+	14nm FinFET	N+1									
Hua Hong		0.13			0.11	65-	55nm												

Source: Company data, Morgan Stanley Research (e) estimates

Foundry's advanced packaging technology

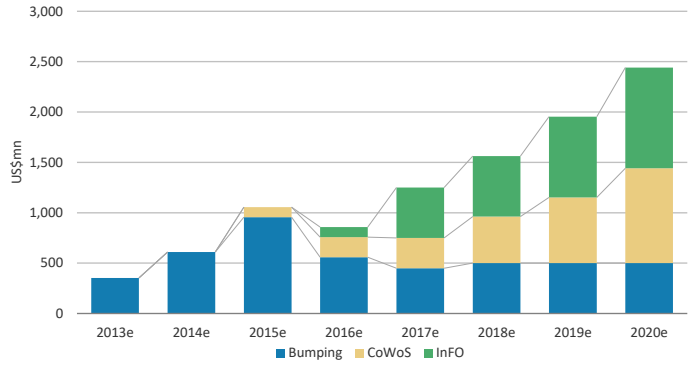
In TSMC's annual Technology Symposium in 2020, the company announced its "3D Fabric" platform, which aims to combine its front-end technology with a back-end process to achieve higher degree of integration, and thus better semiconductor performance. Coupled with TSMC's announcement that it will invest over US$10bn in an advanced packaging and testing plant in Taiwan, TSMC's ambition in semiconductor back-end is hard to overlook.

Intel has also been leveraging its back-end technology to improve its CPU performance. Samsung also started to pay more attention to advanced packaging after Apple's A-series AP (application processor) order loss to TSMC in 2016, thanks to the latter's InFO technology. As the progress of Moore's Law gets slower, we expect leading foundries to continue to expand their packaging portfolios and compete with OSATs, especially in higher-end markets. Here we discuss TSMC's and Samsung's advanced back-end technology offerings in more depth.

TSMC

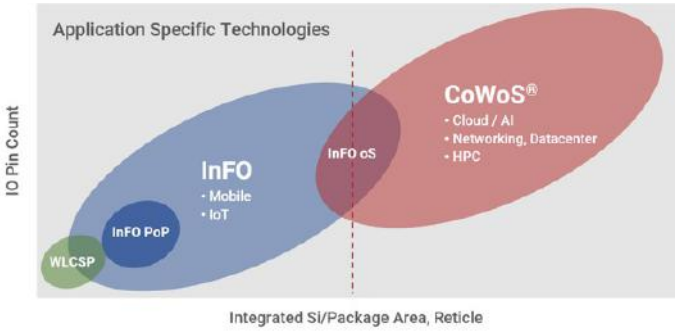
After 2013, TSMC started to develop more advanced packaging services, such as InFO and 2.5D CoWoS, which helped bring a strong revenue rebound. Leveraging its front-end and back-end technology, TSMC aims to provide high-level heterogeneous integration for high-end applications targeting secular megatrends, such as mobile 5G, HPC, automotive, and IoT. The introduction of the 3DFabric platform highlights TSMC's capability to incorporate its leading edge back-end and front-end solutions together for a system-level integration, and we believe TSMC's non-wafer business can grow similarly to its wafer foundry business in the coming years. TSMC's 3DFabric can be separated into two parts – front-end 3D chip stacking (SoIC) and back-end 3D advanced packaging (InFO and CoWoS).

Exhibit 46: TSMC back-end revenue trend up to 2020, by chip packaging technology



Source: Company data, Morgan Stanley Research estimates

Exhibit 47: TSMC's advanced packaging technology



Source: TSMC

Here we provide some introduction to each of them:

SoIC (System on Integrated Chips): This was first introduced by TSMC during the ECTC Conference in 2019. In 3DFabric, "front-end 3D" refers to SoIC, which is the chip-to-chip stacking for either CoW (chip-on-wafer) or WoW (wafer-on-wafer). It's called front-end 3D because SoIC is based on wafer processing, and the main goal of SoIC is to stack bits of silicon on top of each other without using bumping in the back-end process, as if it were a single piece of silicon to begin with.

SoIC enables chip-to-chip interconnect density to go down to <1um pitch, and thus could be a solution of fine pitch bonding that realizes chiplet partitioning and subsequent integration, thereby achieving smaller form factors. AMD should be one of the first-wave users of TSMC's SoIC technology, adopted on its high-end CPU with the so-called 'v-cache' or 3D vertical cache, which is expected to be launched in 2H22.

InFO (Integrated Fan-Out): This is TSMC's general FO-WLP (Fan-Out Wafer-Level Packaging) solution that comes in many different focuses depending on applications. This technology makes use of RDL (ReDistribution Layer) and TIV (Through-InFO Via) to achieve higher integration and semiconductor performance. Some extensions of the technology include InFO_MiM (InFO Multi-stack in Multi-stack) and InFO_AiP (InFO Antenna-in-Package). Currently, TSMC's InFO revenue is mostly contributed by Apple's iPhone processors, namely the A series chip.

CoWoS (Chip-on-Wafer-on-Substrate): This is a 2.5D advanced packaging technology developed by TSMC. Compared to 2D technology such as SiP, it adds silicon interposers by using TSV (Through Silicon Via) technology to ease the bottleneck of circuit density. CoWoS has been broadly adopted by high-end HPC customers that incorporate HBM (High Bandwidth Memory) technology. Major customers are: NVIDIA, AMD, and Xilinx. Other HPC customers, including Google, Intel, Fujitsu, and NEC are also using TSMC's CoWoS as packaging.

Exhibit 48: Some examples of TSMC's advanced packaging technologies

	Technology	End device	Major end customers	Key feature	Status
InFO_PoP (InFO Package-on-Package)	FO-WLP (Fan-Out Wafer-Level Packaging)	Mobile AP + DRAM (Smartphone, Smartwatch, Tablet)	Apple (A-series chips)	Finer L/S; thinner form factor vs. Flip-chip	High volume production for gen 3; now successful qualification for gen 4.
InFO_AiP (InFO Antenna-in-Package)	FO-WLP + SiP (System-in-Package)	mmWave wireless communication (5G, WiFi, Modem)		Lower transmission loss and higher antenna performance with thinner form factor	Currently under qualification.
InFO_SoW (InFO System on Wafer)	FO-WLP (Fan-Out Wafer-Level Packaging)	HPC (AI)	Cerebras (Wafer Scale Engine)	Pack known-good chips without substrate/PCB; low latency and low power consumption	Announced in 2020; expect to commercialize within 2 years.
InFO_LSI (aka. InFO_L; InFO Local Si Interconnect)	Embedded die + FO-WLP (Fan-Out Wafer-Level Packaging)	Networking, HPC	Apple (M1 Ultra?)	Integrate local silicon interconnection between chips with finer pad pitches and RDLs	An optional improved version of InFO_oS; to complete qualification in 1Q21.
CoWoS (Chip-on-Wafer-on-Substrate)	3D Stacking (2.5D)	HPC (AI, Cloud computing, Data center, Super computer, GPU) Networking	Nvidia (GPU) AMD (GPU) Xilinx (High-end FPGA)	Increase bandwidth and reduce power consumption with smaller form factor	Established in 2012, now capable of 7nm process with HBM2; a matured tech broadly used in high-end HPC.

Source: Company data, Morgan Stanley Research

Samsung

Samsung has demonstrated its packaging capabilities: Samsung has over two decades of experience in packaging, from memory to logic devices. It has demonstrated its packaging capabilities in the past – the world's first TSV (Through Silicon Via) for 3D memory, TSV SiP for mobile AP (application processor), and highest capacity NAND flash memory stacking, etc.

Loss of Apple's A-series order a major motive: TSMC's InFO_PoP solution for Apple's A10 processor was a major success, which led Apple to make the decision to have TSMC as its sole chip manufacturer from 2016. Since then, Samsung has never got back Apple's chipset orders thanks to TSMC's continued innovation in advanced packaging. As a response, Samsung and SEMCO (Samsung Electro-Mechanics) announced in June 2016 that they will collaborate to launch a solution to compete with TSMC's InFO.

Panel-level fan-out potentially an answer to TSMC's HD fan-out: In 2018, Samsung successfully incorporated its fan-out panel-level packaging to produce Exynos 9110, a combination of a PMIC, an AP, and a DRAM in the same package. Initially, Samsung invested US$200mn in SEMCO to convert a PCB line to a fan-out production line. Over the course of development, Samsung invested more than US$400mn to develop this technology. Currently adopted in Galaxy Watch, Samsung expects this technology to further evolve and to be used in its future smartphone AP production. "Panel-level" means the packaging can be done at higher efficiency with lower cost, compared to "wafer-level"' packaging. Though Samsung still has not won back Apple's order, this breakthrough is often perceived as a potential answer to compete with TSMC's InFO_PoP.

Exhibit 49: Some examples of Samsung's advanced packaging technologies

	Technology	End device	Major end customers	Key feature	Status
I-Cube (Interposer Cube)	3D Stacking (2.5D)	HPC (AI, GPU) Networking	Baidu (Kunlun AI chip)	Support higher memory bandwidth with a lower cost RDL structure	First adopted by Baidu's HPC chip in 2020; continue to explore multiple HBM integrateion with complex RDL
X-Cube (eXtended-Cube)	3D Stacking (3D)	HPC (AI) Networking (5G) Mobile/Wearable	Samsung	Stack SRAM with logic die through TSV, enabling shorter signal paths between dies	Now capable at 7nm and 5nm; will first be adopted in Samsung's products, and tries to help customer design in
ePLP (embedded Panel-Level-Packaging)	FO-PLP (Fan-Out Panel-Level-Packaging) + Embedded die	Mobile AP + DRAM (Smartphone, Smartwatch, Tablet)	Samsung (Exynos 9110 for Galaxy Watch)	High-density fan-out packaging at panel-level with lower cost and better production efficiency	First adopted on Samsung's smart watch in 2018, and expected to be used in Samsung's smartphone.
FO-SiP (Fan-Out System-in-Package)	Fan-out + SiP (System-in-Package)			Better memory bandwidth and thermal performance vs. FC-PoP	Currently under development.

Source: Company data, Morgan Stanley Research

Foundry Industry Analysis and Outlook

Foundries represent a very large total addressable market (TAM) to generate revenue growth and drive potentially significant future cash flows and returns: We estimate the size of the global foundry market to be similar to that of DRAM by 2022 – at ~US$90bn. The cyclical upturn in the foundry industry this year is driven by both multiple cyclical and structural positive drivers, which have largely been absent for the past two decades. Most segments, including automotive and industrial, are driving strong demand for the foundry market and support another consecutive leg of potential double-digit growth in 2022.

Moreover, with further IDM outsourcing, we expect the market to soon surpass US$140bn in size during 2025-26. In our view, Samsung is well positioned to increase market share as a strong No. 2 player, sharing a global duopoly in leading-edge foundry with TSMC.

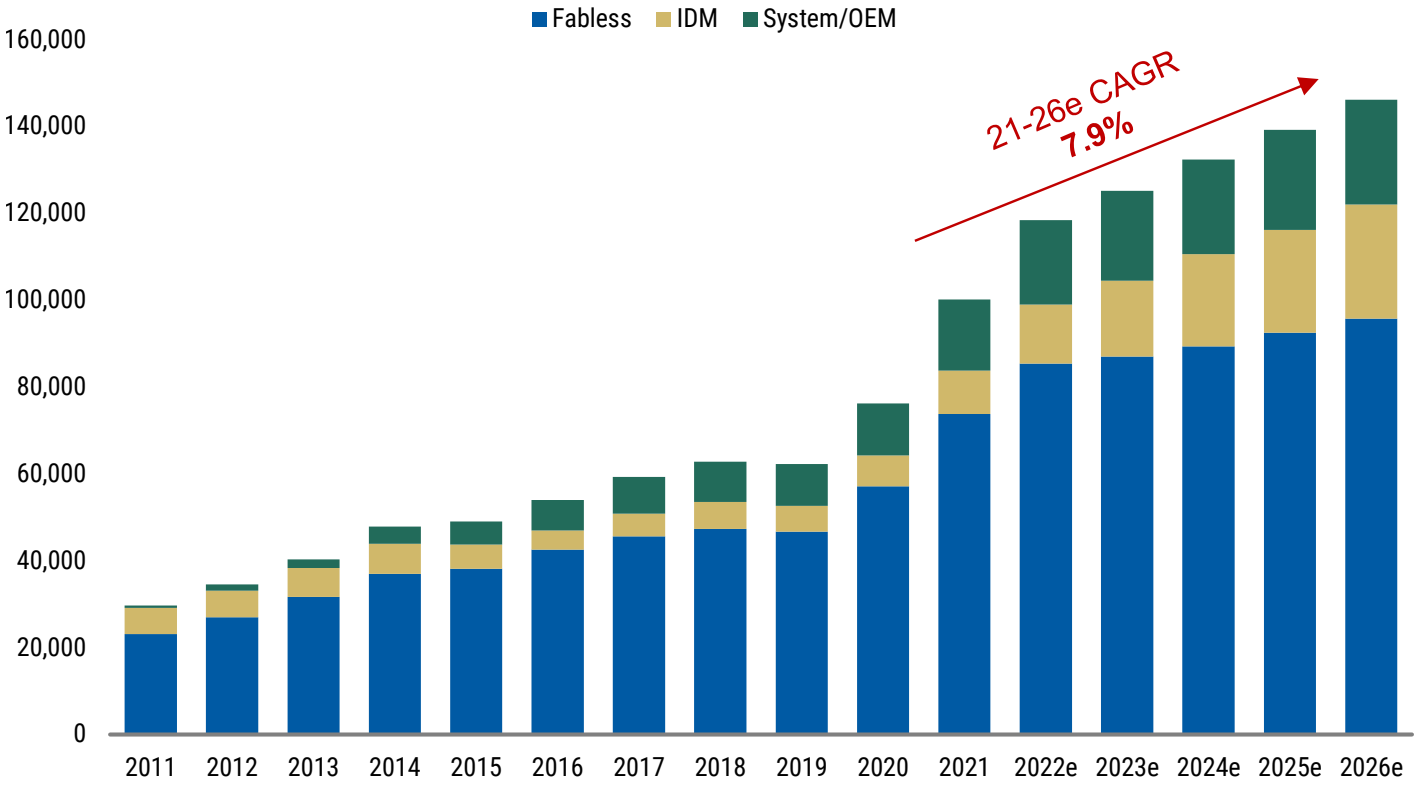
There is significant concentration of economic profit at the top... Profits across tech are concentrated, reflecting greater benefits of scale than in other sectors. This is seen in a range of TMT products and services, from smartphones to social media. In 2010-19, the top 20 companies captured roughly 54% of the profits in TMT industries (using NASDAQ as proxy).

...a rapidly rising middle tier of value-creating companies... While the largest companies in TMT capture the majority of the profits, they also nurture a middle tier of companies that benefit from their networks. For example, Samsung, Intel and TSMC have created a formidable ecosystem of leading companies ranging from cutting edge semiconductor equipment manufacturers globally to materials and components suppliers that have benefitted from outsized growth and profits.

...and considerable turnover among the bottom players: The capital investment to supply exponentially shrinking and increasing transistor counts and to push leading-edge research can only be supported by companies that have very large revenues.

Complexity increases to meet demand: Leading-edge foundry demand is driven by accelerating production ramp-ups of EUV-enabled nodes, at both 5nm and 7nm, after passing through the

Exhibit 50: Foundry market size and growth chart



Source: Gartner, IC Insights, Morgan Stanley Research estimates

initial stages of learning since 2019 and 2020.

For 5nm, TSMC started its mass production from 1Q20, and Samsung followed after 6-9 months. We estimate the total wafer shipment volume of 5nm will account for 5% of 12-inch wafers in the global foundry industry this year, up from less than 1% in 2020.

Smartphones dominate 5nm use this year. Apple is the top customer because of its A14/15 iPhone processors, with more than 50% of foundry capacity allocation, followed by Qualcomm for its modem and Samsung's own Exynos AP.

7nm applications are more diversified into AI/GPUs, CPUs, networking, and automotive processors, and should account for about 12% of total 12-inch wafers in foundries this year. The majority will be shipped to AMD (27%) and NVIDIA (21%), while smartphones also combine for 35% consumption.

Intel's potential CPU outsourcing presents another growth opportunity for both TSMC and Samsung: One indicator of future revenue growth confidence for chipmakers is the current high ratio of capex to sales, which was maintained at peak levels in 2021, with about 40% for TSMC and 70% for Samsung's foundry.

Moore's Law challenges

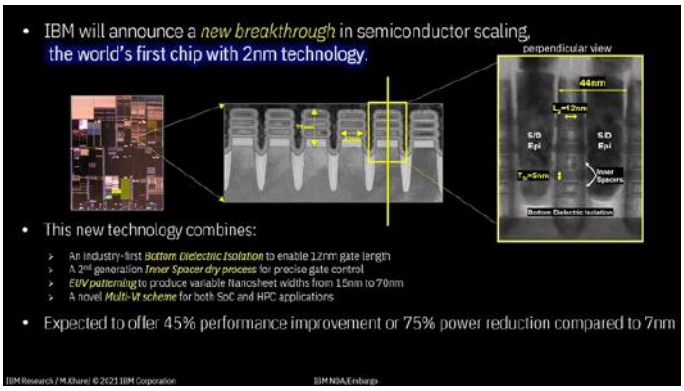
Scaling continues but cost is much higher: Moore's Law posits that the number of transistors on a computer chip should roughly double every two years. This in turn would mean that the speed and capability of computing technologies should double every two years. While the semiconductor industry, including TSMC, has fallen off the curve of Moore's Law in recent years, the demand for cutting-edge wafers remains high despite the increased costs, as evidenced by the rapid adoption of TSMC's 7nm and 5nm nodes. Challenging unit economics at more advanced nodes could pose a headwind down the road, but our base case assumption is that scaling will continue at a similar pace for at least the next few years with higher capex intensity, and as long as the demand for cutting edge wafers persists.

Pushing the physical limits: Two years ago, most industry experts believed 2nm was the physical limit of foundry process. This year both TSMC and IBM both unveiled 2nm technology and Apple appears to have started 2nm engagement with TSMC already. Furthermore, TSMC announced the technology path for 1nm by using new materials. Technically, Moore's Law appears to be extending.

- TSMC sees a path to 1nm utilizing new materials: "This technology unveils the potential of high-performance monolayer transistors that are on par with state-of-the-art three-dimensional semiconductors, enabling further device downscaling and extending Moore's Law." 2D atomic channels materials are the key for sub-2nm scaling. Please see the research source from the Nature website: https://www.nature.com/articles/s41586-021-03472-9
- **IBM has unveiled its 2nm process technology:** Here are IBM's assertions about how its 2nm technology can change the world: (1) Quadrupling cell phone battery life – this requires users to charge their devices only every four days. (2) Slashing the carbon footprint of data centers, which account for 1% of global energy usage. Changing all servers to 2nm-based processors could reduce that number significantly. Currently, the latest Power 10 chip by IBM is done by Samsung's 7nm. We therefore think IBM's technology may enable Samsung and Intel's 2nm production in the 2026/2027 time frame.

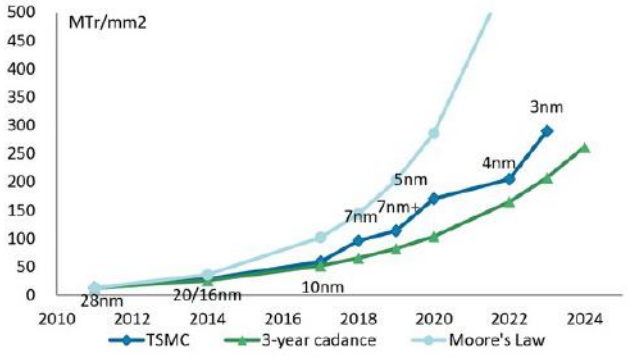
TSMC cannot keep up with the two-year migration cadence of Moore's Law, nor can competitors Samsung and Intel. We think the current full-node migration period for 3nm has become three years for TSMC.

Exhibit 51: IBM has unveiled its 2nm process technology



Source: IBM Research.

Exhibit 52: Lagging Moore's Law but a three-year cadence can be achieved

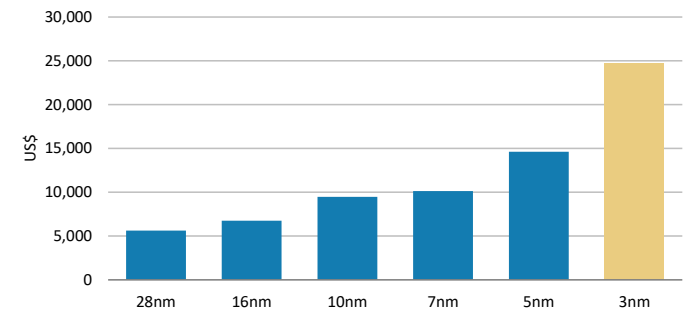


Source: SEMI, Morgan Stanley Research

Transistor costs curve is exhausted: Were it not for EUV, node migration should have stopped at 7nm. Although the capex for 5nm and 3nm was greater than expected, it is still positive for the semi industry overall. TSMC may suffer from higher capex and depreciation, but the further migration also helped ensure its outgrowth vs. foundry peers.

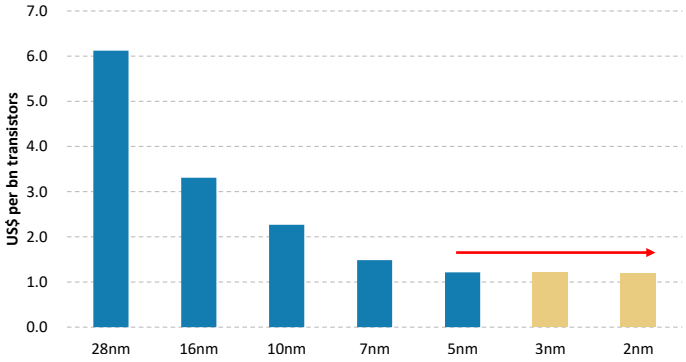
While the market could be excited about IBM's 2nm and the feasibility of TSMC's 1nm, we are concerned that no semi customers can really afford these nodes, given the expensive costs. Our analysis shows that per-transistor cost to TSMC's customers may not be able to decline at 3nm. We think this is a key reason why TSMC appears to have a dominant market share in leading-edge, but is reluctant to hike wafer prices in the current up-cycle. TSMC and its top customers are already facing the challenge of higher costs of 5nm and 3nm processes. Unless we see other killer apps beyond 5G, AI, and EV, it is getting harder to pass costs through to customers.

Exhibit 53: Wafer price by node: TSMC has to price 3nm wafers higher to pass through the capex cost



Source: SEMI, Morgan Stanley Research estimates

Exhibit 54: Transistor cost by node – the 3nm cost is almost identical to that of 5nm



Source: Morgan Stanley Research estimates

Moore's Law may continue till 1nm, but we see challenges in chip economy at 3nm starting in 2023. Beyond the burden of equipment costs on TSMC, growing IP/EDA tool costs also impose additional costs on customers in designing chips on advanced nodes. These all together result in higher development costs for leading-edge chip projects, limiting TSMC's wafer price upside.

2nm could be just a minor upgrade with some lithography process savings

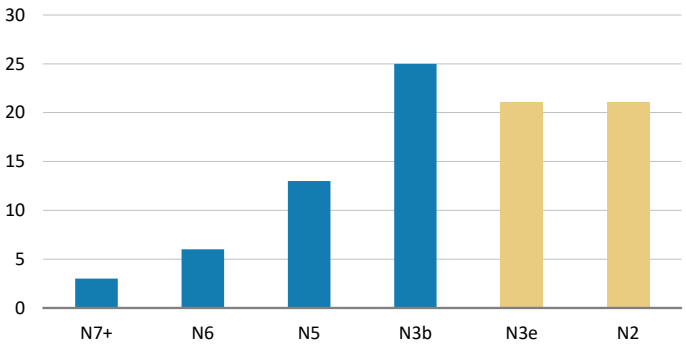
Our analysis shows that the per-transistor cost to TSMC's customers may not be able to decline at 3nm. TSMC and its top customers are already facing the challenge of higher costs of 3nm processes. Assuming a US$25,000 wafer price for N3, there are no transistor cost savings compared with N5.

In Feedback on the N3e process and auto semi output concerns (18 Oct 2021), we indicated that TSMC would introduce the N3e process in 2023 to cut manufacturing costs by reducing EUV layers by four (from 24 at N3b to 20 at N3e). Our latest industry checks suggest that TSMC's N2 will use similar EUV layers as N3e, and reuse some of the process for back-end circuits. Therefore, capex per k for N2 could be significantly lower than our previous estimate.

We expect TSMC's capex intensity to decrease in 2023 and 2024, given the reduced EUV use at N2. TSMC aims to introduce the N3e process in 2023 to cut manufacturing costs by reducing the number of EUV layers by four (from 24 at N3b to 20 at N3e). Oour latest industry checks suggest that TSMC's N2 will use a number of EUV layers similar to N3e. Meanwhile, TSMC can still keep its technology leadership with GAA migration at N2. To semi customers, the N2 transistor cost should be affordable for consumer tech such as smartphones, given the flattish transistor cost trend.

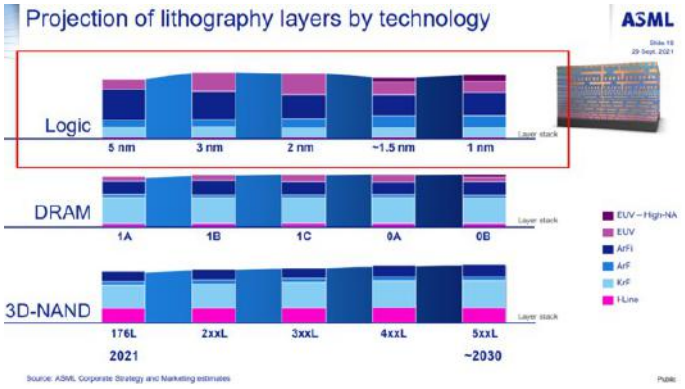
Exhibit 55: EUV adoption slows down at N3e and N2

Number of EUV layers for each TSMC node



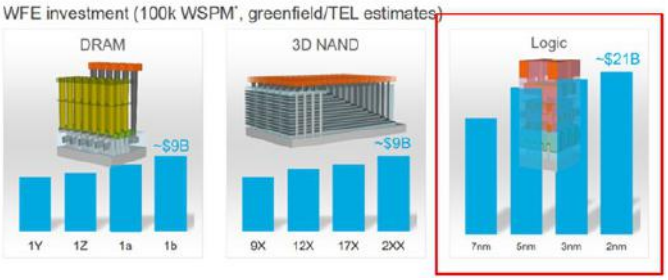
Source: Morgan Stanley Research estimates

Exhibit 56: ASML also projects flattish lithography layer use from 3nm to 2nm



Source: ASML

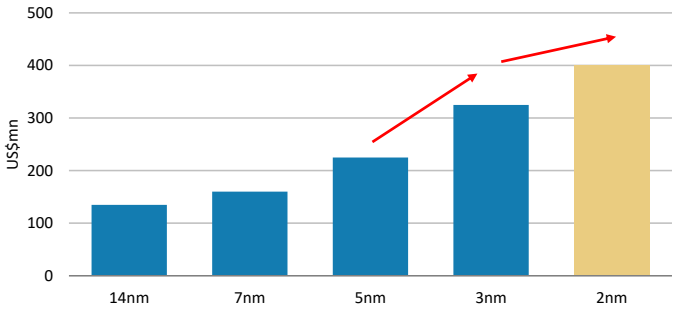
Exhibit 57: The new assessment for 2nm logic semi capex is better than we thought



Source: Tokyo Electron

Exhibit 58: With N2, capex per wafer should not increase much

Capex per k wafers by process node



Source: SEMI, Morgan Stanley Research

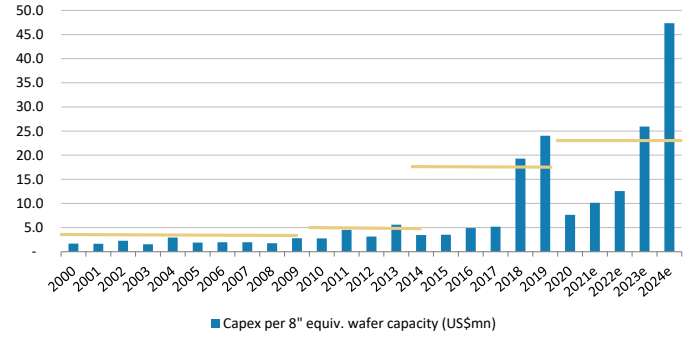
TSMC's overall ROIC is improving even though the payback period of leading-edge is longer

Assuming most of the capex is for leading-edge capacity expansion (TSMC commented that it takes up 80% of capex), we calculate the wafer ASP/capex (or the "pro forma ROI") to understand how much revenue TSMC can earn for each dollar of capex. The leading-edge pro forma ROI is showing a secular downtrend based on the wafer ASP data we have. In other words, the payback period of leading-edge (such as N5 and N3) is longer.

The reason TSMC can maintain its ROIC (return on invested capital) is its fully depreciated mature-node capacity, which is considered invested capital. Those mature nodes (16nm or above) have gone through a five-year depreciation period and their gross margin is about 5ppt higher than the corporate average.

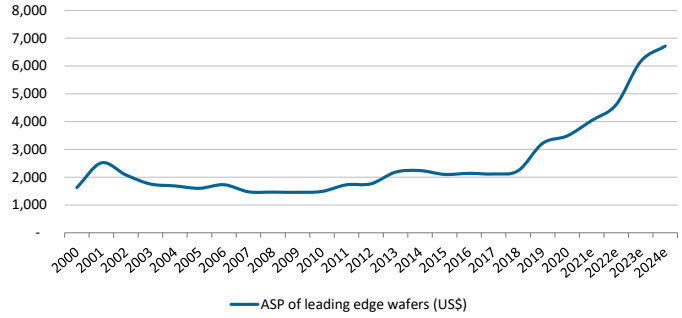
After the 5-20% wafer price hikes last year, TSMC's ROIC should start to trend up in 2022.

Exhibit 59: TSMC's capex per k trend (8-inch wafer equivalent)



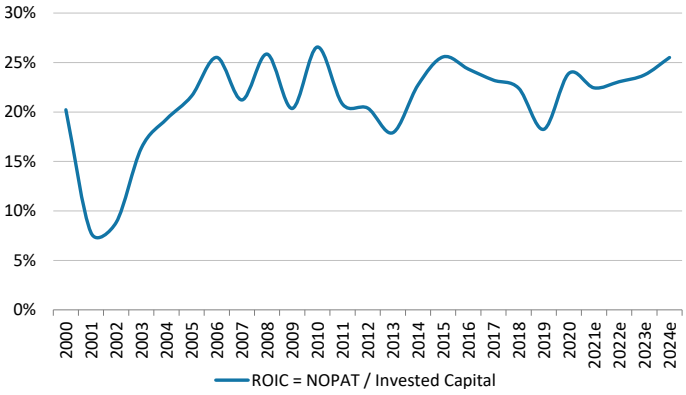
Source: Company data, Morgan Stanley Research estimates

Exhibit 60: TSMC's leading-edge wafer ASP



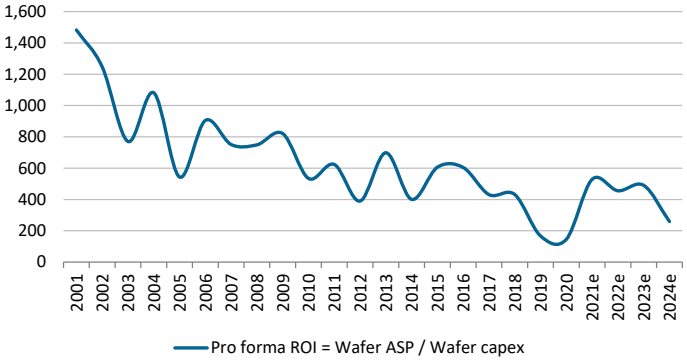
Source: Company data, Morgan Stanley Research estimates

Exhibit 61: TSMC's corporate ROIC to improve with wafer price hikes



Source: Company data, Morgan Stanley Research estimates

Exhibit 62: TSMC's ROI on leading-edge nodes to stabilize in 2021-24



Source: Company data, Morgan Stanley Research estimates

Moore's Law migration is more than cost-saving, but maybe only big customers can afford the performance and power efficiency advantages beyond 3nm.

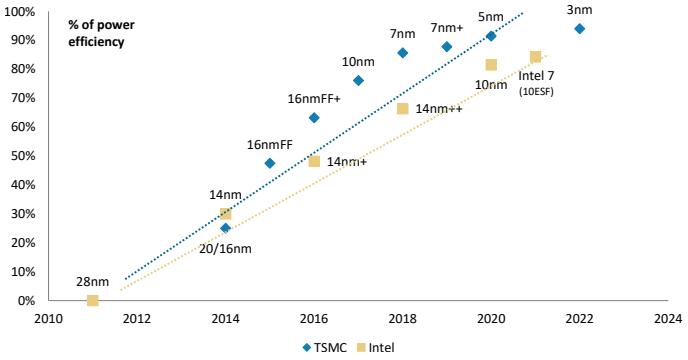
The transistor cost doesn't appear to be going down further at 3nm, but the node may still be cost-effective given energy savings.

TSMC's leading-edge process is key to saving power in tech products and data centers. For TSMC's data center customers, total ownership cost is the key metric, which includes not just chip costs but also electricity and space.

Here are the benefits IBM sees for its 2nm technology:

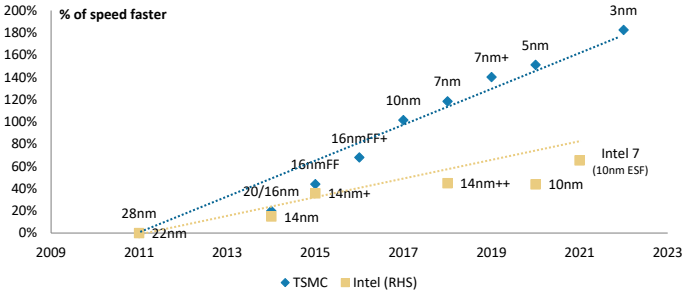
- **Quadrupling cell phone battery life** – requiring users to charge their devices only every four days.
- **Slashing the carbon footprint of data centers** – these account for one percent of global energy use. Changing all of their servers to 2nm-based processors could reduce that number significantly.

Exhibit 63: TSMC's power efficiency improvement is only 15-20% every node generation, helping to save electricity costs



Source: Company data, Morgan Stanley Research estimates

Exhibit 64: TSMC's technology also improves the chip speed, saving space in datacenters



Source: Company data, Morgan Stanley Research estimates

TSMC – Foundry Overview

TSMC is a leading player in global semiconductors as a pure play foundry – and is now dominating in leading edge semiconductor manufacturing in terms of technology and market share.

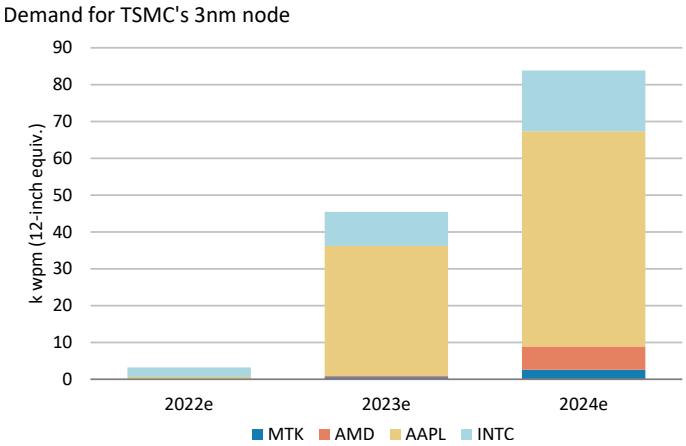
- TSMC is the major, if not sole, foundry vendor for the biggest leading edge customers – 100% market share at Apple, 90% at Xilinx, and 70% at NVIDIA.
- **We think TSMC is the key enabler for multiple tech megatrends:** These include 5G, artificial intelligence (AI), and high performance computing (HPC). All of these applications require leading edge foundry technologies to produce the related semiconductor chips.
- **TSMC is shifting its major growth driver from the more cyclical smartphone to the more secular HPC:** 1Q22 marked the first quarter that the contribution from HPC-related business exceeded that from smartphones. We expect HPC continue to outgrow TSMC's smartphone business, underpinned by Intel's CPU outsourcing, Apple's in-house designs, and the proliferation of AI ASIC.
- **Where TSMC is different:** It is the biggest pure-play foundry in the world, and does not compete with its own customers. With its technology leadership and expertise in the foundry services, TSMC has built deep relationships with its suppliers and customers, such as Apple, AMD, and MediaTek.
- **We expect TSMC's technology leadership in semiconductor manufacturing to continue:** We cite continued R&D investment and strong execution. The company's dominance may not be limited to front-end processes; it could also apply to back-end advanced packaging.

Continuous outgrowth driven by dominance in the leading edge

Most TSMC's 5nm customers will migrate to 3nm, with Intel as a new customer

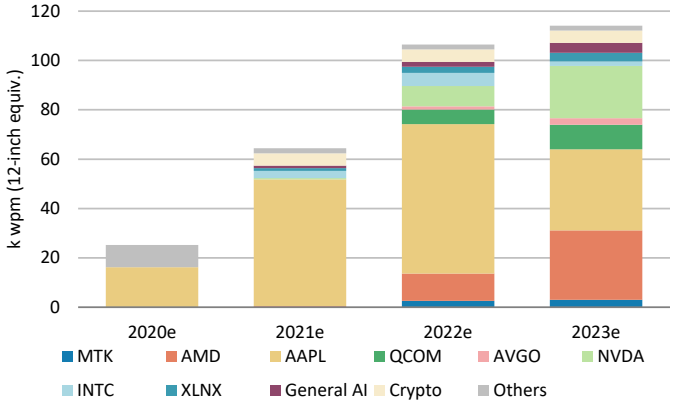
We believe foundry process will become the key factor in the competition between Intel and AMD in the CPU market in 2023 and onwards. Also, MediaTek aims to catch up to Qualcomm in terms of technology, and TSMC's 3nm appears to be a necessary move. Our checks suggest that both Qualcomm and AMD are not choosing Samsung's 3nm GAA given performance and yield rate issues. We therefore believe leading-edge will help TSMC outgrow the foundry industry in terms of both revenue and earnings.

Exhibit 65: TSMC: Customer demand for 3nm node capacity – Apple and Intel are first-wave 3nm customers in 2023



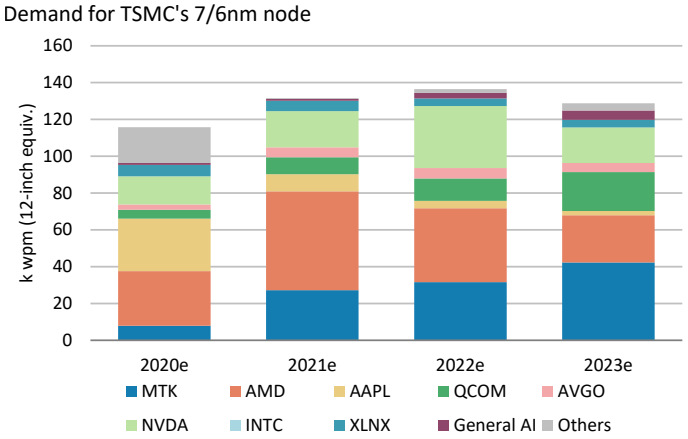
Source: Morgan Stanley Research estimates

Exhibit 66: TSMC: Customer demand for 5n and 4nm node capacity



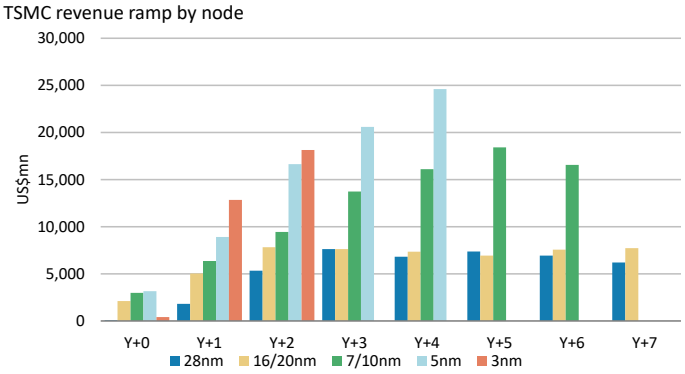
Source: Morgan Stanley Research estimates. Note: 2020 estimates include HiSilicon.

Exhibit 67: TSMC: Customer demand for 7nm and 6nm node capacity



Source: Morgan Stanley Research estimates. Note: 2020 estimates include HiSilicon.

Exhibit 68: TSMC's revenue ramp by node – each new node contributes higher revenue than before



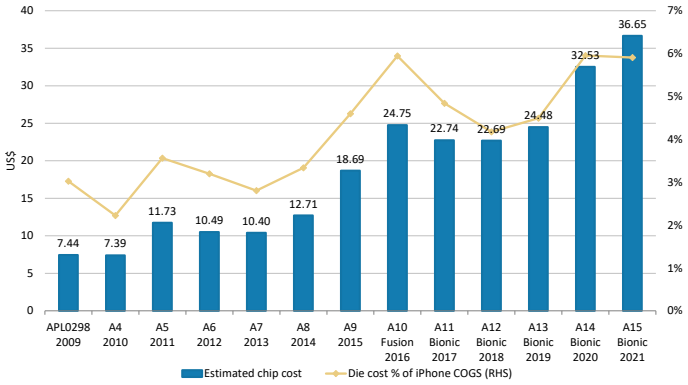
Source: Company data, Morgan Stanley Research estimates. Note: Y+0 means the first year of a certain node is being mass produced.

Apple is the most loyal user of TSMC's leading-edge technology, and is now surveying 2nm

Apple looks likely to be the anchor user for future nodes – it has been the first user of TSMC's latest process technology. Apple's pioneering of new nodes is also key reason why TSMC can form its technology leadership.

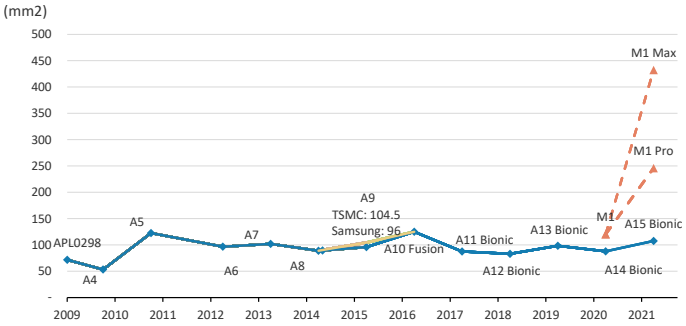
Considering the increasing number of transistors in Apple's silicon, for either an iPhone or Mac, coupled with the limited transistor cost reduction, we think that cost per die for Apple could increase. We estimate that the cost of every generation of Apple A series processors is growing 10-20%, given more transistors per chip. According to our foundry supply chain checks, Apple has shown interest in TSMC's 2nm.

Exhibit 69: Apple iPhone: Estimated AP cost versus percentage of iPhone COGS



Source: Company data, Morgan Stanley Research estimates

Exhibit 70: Apple silicon die size trend



Source: Company data, Morgan Stanley Research estimates for 2021

Intel is outsourcing more CPU production to TSMC 3nm to stay in the game

Intel has decided to start CPU outsourcing with the more expensive N3b process later in 2022. Our most recent industry checks suggest that Intel might agree to share some additional costs, and prepay for 3nm capacity to secure priority at TSMC. In the long term, whether Intel will return to its internal fab remains the key risk to TSMC, and that's why TSMC asked Intel to prepay for the future N3 capacity expansion.

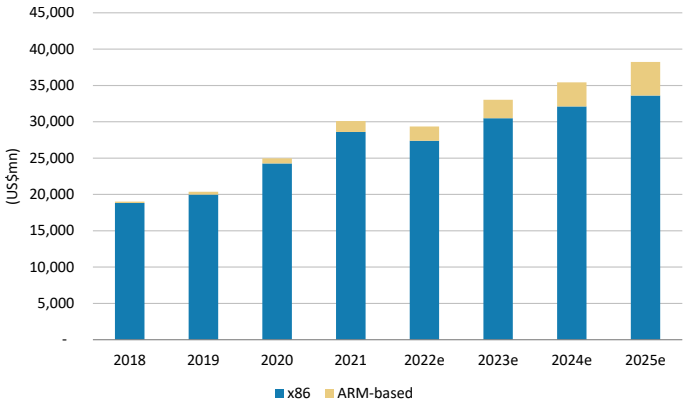
Given TSMC's strong technology, we think Intel's CPU outsourcing may reach 20-25% in 2024. We assume Intel's demand normalizes at 30-40kwpm in 2024, so the annualized CPU outsourcing to TSMC would be US$9bn, or around 9% of TSMC's 2024 revenue. By adding GPU, FPGA, and AI chip outsourcing, Intel could account for over 10% of revenue in 2024, making it the second-largest customer after Apple.

AI, 5G, and EV remain the main growth drivers and help TSMC outgrow foundry peers

We are still in the middle of a 5G penetration increase. We think there are another 2-3 years to go in the 5G smartphone replacement cycle. In general, 5G smartphones carry 30-40% higher semi content than 4G, and TSMC accounts for almost 80% of global 5G System-on-Chip (SoC) production.

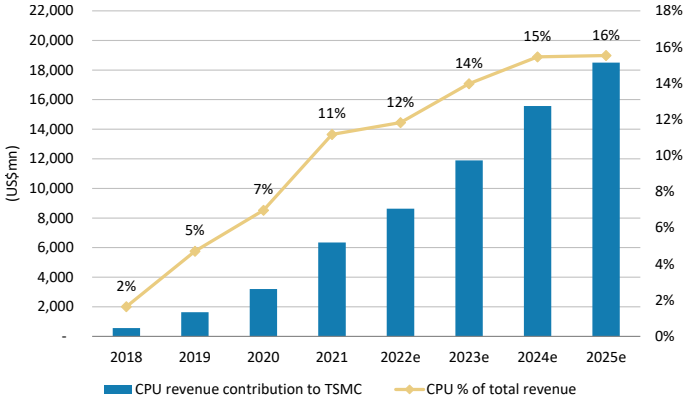
AI data center demand continues to grow at a rapid pace, judging by NVIDIA's quarterly AI GPU revenue. That bodes well for more AI inference chip designs to come. We also believe auto semis will be a new growth driver for TSMC in coming years, given autonomous driving requires TSMC's leading-edge process. TSMC is well positioned in these segments, which will help it outgrow the foundry industry in coming years.

Exhibit 71: CPU foundry TAM: 12% CAGR in 2018-25 by including ARM-based CPU



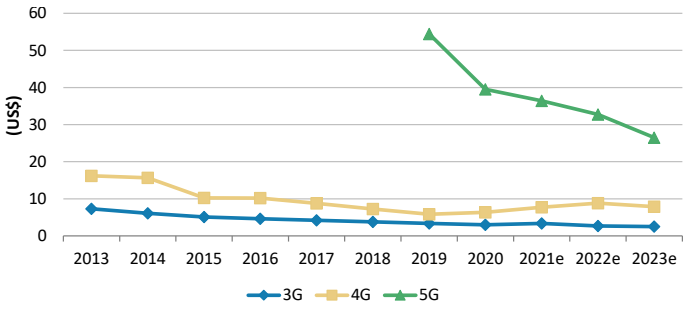
Source: Company data, Morgan Stanley Research estimates

Exhibit 72: CPU outsourcing to account for 16% of TSMC's total revenue in 2025, up from 7% in 2020



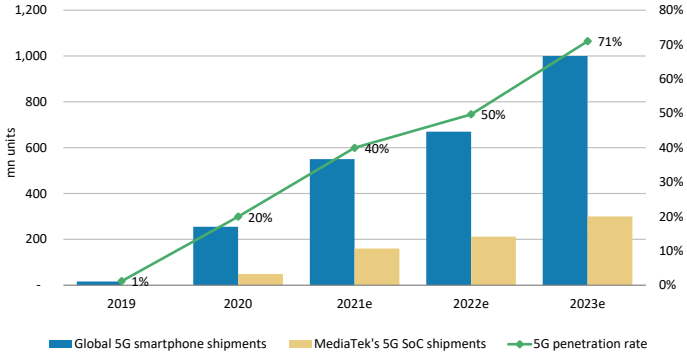
Source: Company data, Morgan Stanley Research estimates

Exhibit 73: Smartphone chipset pricing comparison – 5G semi content is 30-40% higher than 4G



Source: Company data, Morgan Stanley Research estimates

Exhibit 74: Global 5G smartphone shipments and penetration – still on the rise in the coming two years



Source: Company data, IDC, Morgan Stanley Research estimates

TSMC's global fab footprint

US – Arizona fab Phase 2 is in planning amid expensive infrastructure cost

TSMC budgeted US$12bn to build the first fab in Arizona, which will utilize its 5nm technology for semiconductor wafer fabrication with 20k wpm capacity. Construction started in 2021 with production targeted to begin in 2024.

TSMC's founder, Dr. Morris Chang, recently cited that US manufacturing cost is 50% higher than in Asia. That said, we think a US operation should benefit TSMC as well. Today, 95% of TSMC's production sits in Taiwan, but Taiwan sometimes encounters issues with shortages of electricity and wafers. In the long term, it makes sense for TSMC to diversify its operational risk for a number of reasons. However, TSMC may protect its key foundry know-how carefully and keep its key R&D team within Taiwan – as foundry know-how forms a "silicon shield"' for Taiwan and TSMC.

Japan – a JV fab with Sony has been confirmed

In its 4Q21 analyst meeting, TSMC added that the fab in Japan will be a JV with Sony, saying "*we can also leverage their [Sony's] operating and manufacturing experience in Japan, which helps us ramp in the learning curve. So that made us make the decision of a joint venture fab with Sony.*" However, TSMC management highlighted that "*Typically, [for] every TSMC fab, no matter where it's located, [it] will serve all the customers from around the world. And this Japan joint venture will also be the same.*"

Below we lay out the key summary of this upcoming fab in Japan:

- It will utilize 22/28nm and 12/16nm FinFET technologies for semiconductor wafer fabrication
- Planned capacity is 55k wpm, with capex budget of US$8.6bn for the project

China – TSMC to expand 28nm capacity in China

TSMC has announced a 28nm capacity expansion plan at its fab in Nanjing to address China's domestic demand. However, it would be difficult for TSMC to build EUV capacity in China (6nm or 5nm) because exports of EUV tools to China are currently restricted. Our industry checks with equipment vendors suggest that a total 40kwpm of 28nm will be expanded in 2022 and 2023.

Europe – TSMC still evaluating

During its earnings call in January, TSMC suggested that the fab expansion plan "*is still in a very early stage*" and that TSMC "*is still assessing*." However, TSMC does not rule out the possibility of building fabs in overseas areas, which includes Europe. Infineon suggested in the report that it thinks Europe should focus on bringing modern, but not state-of-the art technology to meet local demand. STMicro also indicated that it wasn't inclined to participate in the initiative.

Samsung – Foundry Overview

Samsung is already a leading player in global semiconductors but not a pure play foundry – and has "the best of both worlds" between memory and logic.

- Samsung already has a significant presence in foundries: It has committed US$111bn investment to lead the industry by 2030 and increased that amount to US$151bn in 2021.
- **Samsung is positioning itself for the transition to an acceleration in innovation and digitization of everything:** It is already leading as a cutting-edge provider of multiple product categories centered on 5G (network, smartphones) and high-performance computing (HPC). It has previously stated that these will become the backbone of future growth and facilities.
- **Samsung already has a well-developed and advanced global manufacturing platform:** It has a strong presence in the US (although this has not been well communicated), focused on communications, HPC, image sensing, memory controller and automotive chips offering.
- **Where Samsung is different:** It has the key building blocks (device, memory, and logic) and maintains a No. 1 position globally in all categories, with the exception of logic/foundry.
- **We do not think it is at any natural disadvantage:** It is fair to say that Samsung's overall market position in foundry may not be as large (in absolute terms) as TSMC's. Yet we note its ability to leverage its longstanding semiconductor fabrication expertise, leading R&D with next-generation 3nm GAA process, and its own AP chip and ecosystem.
- **We expect the gap between Samsung Foundry and TSMC to narrow:** Currently, TSMC has a more than 50% share of global foundry market sales, while Samsung's market share is 17%. Samsung has its own competence as a chip producer and has been increasingly securing new customer wins such as IBM (Power 10 CPU), NVIDIA (Ampere-based RTX and GeForceX GPU chips) and Tesla (full self-driving chip).

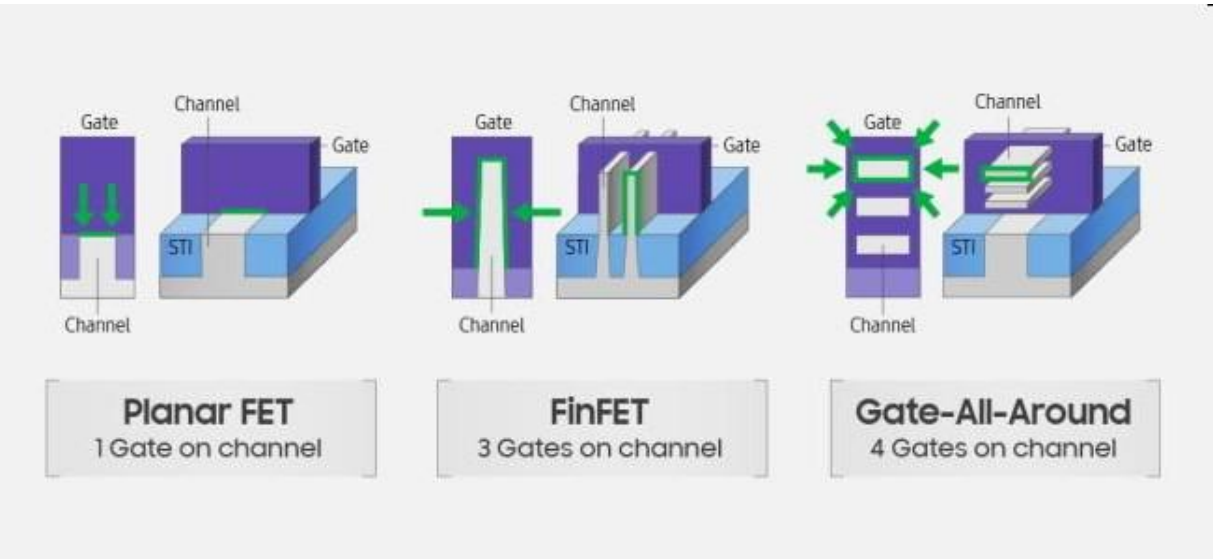
Racing to close the gap

Samsung foundry compares favorably with best-in-class TSMC: Samsung started offering foundry services in the mid-2000s, as it realized that only the largest chipmakers will survive in the long term. Its former LSI division split into an independent pure foundry provider and a separate IC design business in 2017 to enhance its foundry business independence and remove a potential conflict of interest with Samsung's own logic business.

In terms of size, Samsung's 380k wafers per month (wpm) compares with TSMC's 1,070k wpm, with a higher proportion of leading-edge for Samsung, at 27% of 5-10nm wafers versus TSMC's 16%, including a larger trailing edge and some 8/6-inch wafers. The size in revenues was almost three times higher for TSMC in 2020, at US$50bn versus Samsung at US$17bn, with similar revenues per wafer, at ~US$40mn.

A highly competitive two-way race for technology superiority: TSMC continues to drive Moore's Law, but Samsung is a close competitor, and both are about the same in introducing extreme ultraviolet lithography (EUV), leading-edge production. For 5nm and 5G chips in 2020, Qualcomm favors Samsung, while Apple depends on TSMC, showing that there is real competition here. TSMC has been leading the industry since the 14nm process, and is, in our view, likely to maintain its technology leadership via R&D and strong execution in production ramp-up. However, Samsung has an aggressive timeline to catch up on 3nm nodes – it plans to start to ramp up in 2H22 with a new technology evolution (Gate-All-Around) allowing a performance leap. It is also devoting significant resources in the development of its 2nm node manufacturing capacity. At present, it is hard to say which manufacturing will emerge as next year's top 3nm contract chipmaker.

Exhibit 75: Samsung 3nm first to transition to GAA in 2022, TSMC 2nm in 2023



Source: Samsung Electronics, Morgan Stanley Research.

Comparing growth and returns – foundry growing at ~2x and with operating margins >5-6ppts higher than memory. Over the past 10 years, the foundry market, in terms of sales, has grown at 10% per annum (on average) and sustained an average operating margin of 35-36%. In contrast, DRAM has grown at 5% per annum, while its average operating margins have been ~30%. In simplistic terms, the foundry market is growing at ~2x the rate and carrying margins >5-6ppts higher than that seen in memory.

As long as Samsung manages to stay reasonably close to TSMC, it should be able to continue to operate at the leading edge. If it falls too far behind in process technology and manufacturing capacity, competitors in end markets would gain too much of a competitive edge.

Product and customer mix

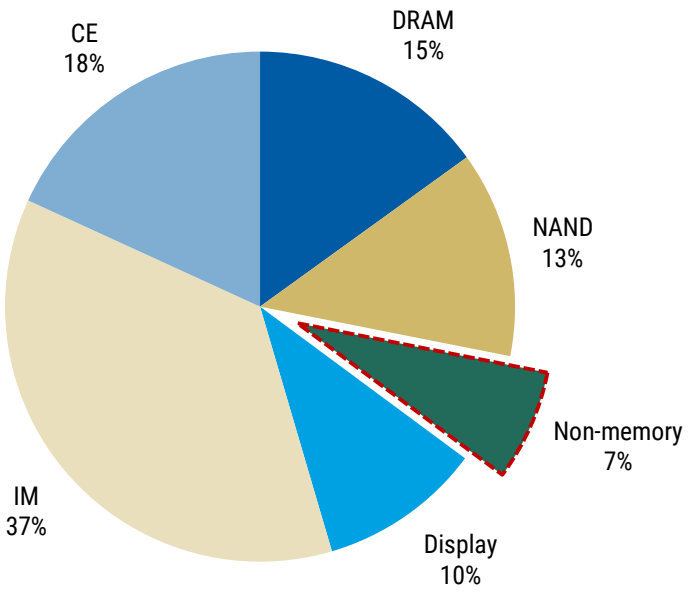
We estimate that Samsung's logic business will account for 8% of total sales in 2022, which still is a small part of its operations. We estimate 50-60% of Samsung logic division's revenue is generated by its captive customer, while the rest is fragmented and consists of multiple global customers, including Qualcomm at mid- to high-10% and NVIDIA at a mid- to high-single-digit percentage. To support its captive customer, application processor and CMOS image sensors account for 70%+ of its product portfolio, while the rest is from a series of IC chips including display driver ICs and power management ICs.

Samsung accounts for about 40% of the global market in the advanced 10nm or lower process segment: But its share is much smaller in the mature process segment. Samsung wafer foundry currently serves over 100 customers; it plans to secure up to 300 foundry customers by 2026 and triple production from the 2017 level. The journey has been more challenging recently: Qualcomm's Snapdragon 8 Gen 1 orders have moved back to TSMC following 4nm issues with yield from Samsung. Foundry capacity expansion will also include legacy nodes (which refer to 16nm or above chip-making processes) starting this year to secure new customers and boost profitability.

Samsung has achieved major milestones in the past by leveraging its global presence in the semiconductor industry and more competitive pricing strategy against TSMC.

- December 2019: Baidu AI chip 'Kunlun' (14nm)
- August 2020: IBM Server CPU 'Power 10' (7nm EUV)
- August 2020: NVIDIA GPU 'GeForce RTX 30' Series (8nm EUV)
- September 2020: Qualcomm 5G smartphone AP Snapdragon 4 Series and next generation AP Snapdragon 875 chips
- January 2021: Samsung to manufacture Qualcomm's 5G modem chips Snapdragon X65 & Snapdragon X62
- Chips to be supplied to IBM will be used in next-generation servers, which require the most advanced fabrication technology.
- STMicroelectronics is also a new customer for 16nm MCU.
- NVIDIA is upgrading its GPUs from Samsung's 8-nm process to TSMC's 5-nm node.
- Samsung for the first time is making 4-nm GPUs for AMD.

Exhibit 76: Samsung's revenue mix in 2022E



Source: Company data, Morgan Stanley Research estimates.

Why Samsung is behind on foundry

We think Samsung has been less successful than TSMC in the foundry business for various reasons, including:

1. Lack of a complete IP portfolio, which leans towards mobile;
2. Imbalance of customer base and high dependency on its captive customer;
3. Execution risks for clients – it struggled on production yields in early ramp-up; and
4. Potential conflicts of interests and risks that could lead customers to consider Samsung as an alternative rather than as a primary option for System LSI (fabless) and foundry business.

Samsung started mass production of 4nm using EUV in 2H21, while 3nm is under development, and it is expected to start mass production in 2Q22. Samsung is ramping up its 5nm EUV production in 2022, as well, with plans to add capacity totaling 35k wpm in Hwaseong and Pyeongtaek in 2022. It is also eyeing the start of mass production of the advanced 3nm (and lower) fabrication process from 2H22 while considering expansion of mature node capacity in the medium to long term to meet rising demand.

When Samsung started its foundry business

Samsung established its foundry in 2005 and made it an independent business unit in 2017 to better serve its customers. Samsung offers full-service solutions, encompassing design kits and proven IP to fully turnkey manufacturing, to achieve market success with advanced IC designs by foundry, ASIC and COT engagements.

Samsung Foundry's extensive portfolio features advanced logic technologies, including:

- 28nm and 18nm fully depleted-silicon on insulator (FD-SOI);
- 14nm, 11nm, 10nm, 8nm, 7nm, 5nm, and 4nm fin field-effect transistor (FinFET);
- 7nm, 5nm, and 4nm extreme ultraviolet (EUV); and
- 3nm gate-all-around (GAA).

Its 2-nm process based on third-generation GAA technology will start volume production in 2025.

The company also delivers specialty technologies, including radio frequency (RF), embedded non-volatile memory (eNVM), high voltage, bipolar-CMOS-DMOS (BCD), CMOS image sensor (CIS) and fingerprint sensors.

It also has world-class packaging and test services, together with its SAFE™ (Samsung Advanced Foundry Ecosystem) partners.

Capacity outlook

Samsung has five fabs dedicated to foundry (four in Korea and one in Austin, Texas). The Pyeongtaek fab is being expanded to increase production capacity and another campus will be built in the US. The 3 production fabs in Korea are all located close to Seoul (Hwaseong and Giheung are just 2 miles apart and Pyeongtaek 12 miles away). They work almost like a single fab with capacity control according to demand.

- The Giheung fab is focused on producing specialty and legacy products, as well as 8" wafers.
- The Hwaseong fab specializes in CMOS Image Sensor (CIS) and advanced chips with 5nm technology.
- The Pyeongtaek site is also a production facility for products at or below 5nm.
- The Austin plant is currently producing legacy nodes (Samsung has been operating the Austin site for 25 years since 1996).
- Taylor, Texas will be Samsung's newest ($17bn) fab expansion in the US

As Exhibit 77 shows, we estimate Samsung's total wafer capacity as of end-2022 to be 350k wpm for 12-inch wafers and 250k wpm for 8-inch wafers. Samsung utilizes its 12-inch wafers for advanced node products, while 8-inch capacities are used for ICs, including eFlash, power ICs, DDI, CIS, mixed-signal RF, and power discrete chips.

Samsung added wafer capacities for CIS and EUV production lines in 2021, which were at 40k and 20k, respectively, and is likely to add more in 2022. Samsung plans to run two EUV lines at Hwaseong and Pyeongtaek and is likely to target 3nm mass production in 2Q22, according to the company. We estimate Samsung's 5-7nm should continue to rise from 5% of the mix in 2019 to 23% in 2022, led by the EUV production lines. Its number of pieces of EUV equipment should also rise, and Samsung management expects ~51 units by end-2022, up from 35 units in 2021.

Expansion in Taylor, Texas: Samsung has announced US$17bn to build an advanced logic fab in the US (Taylor, northeast of Austin, Texas). The plant construction is already started while mass production is set to begin in late 2024, according to the news.

Samsung's current Austin S2 fab and implications:

- Samsung's Austin fab is currently running 100k/wpm, with 50% of capacity based on 14nm process for controllers, ADAS chips, AP, and RF modules. The rest is 28nm and 65nm legacy products, including DDI.
- Based on 5nm, we estimate every 10k/wpm requires W2.5-3.0tr investment for equipment, alone, and W1.0tr for infrastructure.
- Samsung bought more land in Austin near its existing foundry plant in October 2020.
- We estimate an equivalent of 20-50k new foundry capacity (based on 5nm US$10-17bn capex), which addresses a tight supply environment and future potential outsourcing wins. We expect foundry to become a key driver of Samsung's long-term growth, reducing memory volatility with steady returns, and hence providing re-rating potential.
- Details are not disclosed, but we estimate Samsung produces chips for its US customers, including Tesla, Qualcomm, and NVIDIA, at S2.

Exhibit 77: Samsung – foundry wafer capacity

Fab	Location	2016	2017	2018	2019	2020	2021	2022e	2023e
12-inch wafer capacity									
S1	Giheung	70	90	90	100	100	100	100	100
S2	Austin, Texas	60	90	90	90	100	110	110	110
S3 (Line-17)	Hwaseong			20	10	15	40	50	60
S4 (Line-11 for CIS)	Hwaseong			10	20	30	45	50	55
P2 (5nm EUV)	Pyeongtaek						20	40	45
P3 (4-5nm EUV)	Pyeongtaek								30
Total		**130**	**180**	**210**	**220**	**245**	**315**	**350**	**400**
8-inch wafer capacity									
Line 5, 6, 7, 8	Giheung	180	180	200	250	250	250	250	260
Technology mix									
4nm								5%	
5-7nm					5%	12%	15%	23%	
8-10nm					10%	15%	15%	20%	
11-14nm					22%	18%	15%	12%	
Legacy nodes					63%	55%	55%	40%	
Total					100%	100%	100%	100%	

Source: Company data, Morgan Stanley Research. e=Morgan Stanley Research estimates.

Intel – Foundry Overview

Intel is restarting its foundry initiative after exiting the business several years back. The company has laid out an ambitious catch up plan, and aims to provide a competitive, leading-edge and specialty foundry with a foot print across the North America and EMEA.

- Intel plans to commit nearly $30bn a year in capex – in order to catch up to leading-edge fab competitors across the Asian market.
- **Production starts this year at the mature Intel 16 node:** The roadmap places Intel 3 production (the first of the competitive leading-edge nodes) in the 2H23 time frame and Intel 18A in the 2H24 time frame for prospective customers.
- **Intel has noted early customer interest from several fabless peers, but we believe customer acquisition in leading-edge nodes will be a challenge:** The company's history in foundry should still be fresh in the minds of potential customers, and there is a significant learning curve in running successful foundry operations.
- **Intel gets several things from the acquisition of Tower:** We cite specialty fab capabilities, an existing base of customers at mature nodes, and a more well-rounded offering that utilizes a range of nodes in end-user devices (i.e. smartphone, automotive, networking equipment) as well as packaging, assembly, and test capabilities.
- **Intel sees the foundry market TAM growing to $180bn by 2030:** It is targeting the automotive, computing, and mobile segments of this TAM, which it believes makes up roughly 85% of the market – or $153bn of total Intel-specific opportunity.

Reaffirmed commitment to a large and growing market

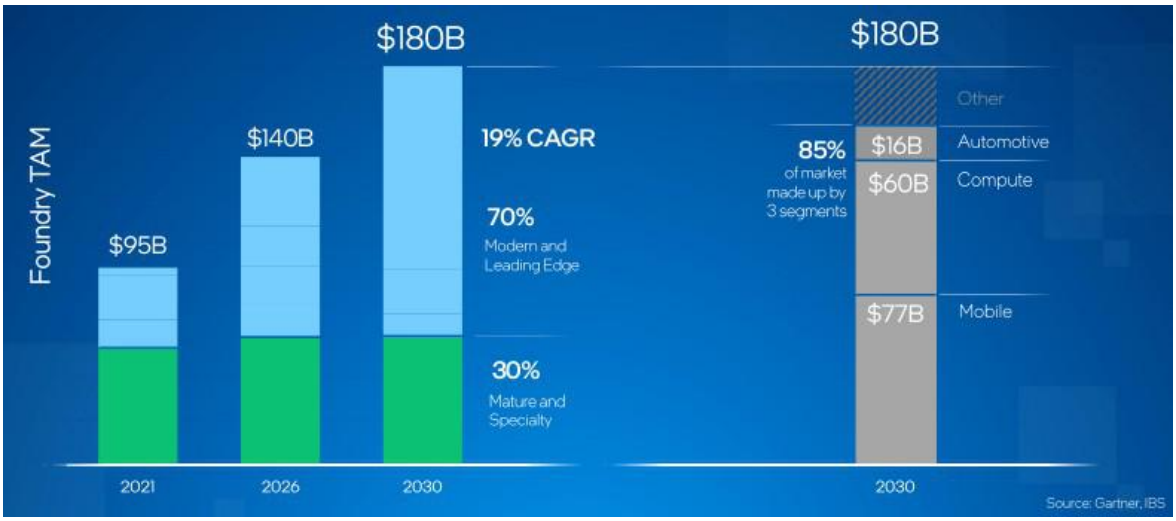
Intel expects global foundry to be a $140bn TAM by 2026 and a $180bn TAM by 2030, composed approximately of 70% leading edge and 30% trailing edge and specialty demand. With the recent acquisition of Tower Semiconductor, Intel has now positioned itself to have greater exposure to three key pillars of foundry demand at both the leading and trailing edges, which it believes make up 85% of the TAM. The company's primary market, computing, is estimated to make up approximately a third of total foundry demand.

Further, in mobile, which it expects to be 43% of the market, the company maintains exposure to RF front end and smartphone power management on mature nodes, and computing on Intel's leading edge nodes.

Last, the company expects to be competitive in the small, but growing, automotive foundry sub-segment, with EV battery management and AV/ADAS computing products.

Through IFS standalone, the company plans to make its Intel 16 process node available to customers this year, Intel 3 in 2H23, and Intel 18A in 2H24. Through Tower, customers will have full availability to .5um to 45nm once the deal has closed.

Intel IFS segment market breakdown



Intel Investor Day slides

We expect Intel to execute to the ambitious process technology roadmap, but foundry success is not automatic from there

We were quite negative on Intel's foundry ambitions the first time, during a period that the company had unequivocal process technology leadership, which informs our current viewpoint. That's consensus now, but it was not consensus at the time. There were several reasons for this view:

- Intel's current revenue per wafer is demonstrably 10x TSMC's revenue per wafer on equivalent wafers. That's not definitive, because there are back-end wafer costs that TSMC does not incur, but TSMC has a business optimized around selling wafers at a low enough price that it makes sense for customers to divest their fabs, while Intel has a business optimized around maximizing revenue per wafer.
- TSMC has thousands of people dedicated to demand fulfillment, doing foundry-specific things that are very important to the smooth operations of a foundry business. It has systems to protect the anonymity of customers, systems to allow expedited orders and different time frames of different customers, and has processes and business flexibility to work with different customers.
- Most of the potential users of Intel's foundry business are companies that on some level compete with Intel.

As the situation panned out, we felt validated with that viewpoint. But we would go further. As we presented these concerns to the management team at the time – particularly the fact that its revenue per wafer was so much higher than TSMC's, which might indicate that it was not cost-competitive – management responded that Intel would be much more competitive on 10nm. When we presented concerns that the company's process technology was too microprocessor-centric to be successful in a broader foundry context, management said that Intel' process would be much more flexible at 10nm.

And then, its 10nm process was a catastrophic failure because in their words, it tried to scale the transistors too aggressively at 2.7x. While it's overly reductive to say that this is purely because of foundry, and multiple management teams have told us that it's a mistake to blame 10nm on foundry, we do know that the company was extremely ambitious about 10nm because of the foundry efforts, and that ultimately that ambition was problematic.

As we moved past that, the foundry concerns became even clearer. It moved the Apple 4G baseband in-house, mostly because using TSMC for such a prominent product undermined foundry efforts, and it caused a multi-year wafer shortage. The baseband chip was 4x the size of the competing Qualcomm chip and had a die size that was close to that of a client CPU, despite being a small fraction of the revenue.

So as we now fast-forward several years, the company doesn't currently have process leadership, but does have a reasonable plan to get there.

But the world has changed in a very significant way: The risks of dependency on non-US suppliers, particularly in Taiwan, have become clearer. There is appetite to diversify those exposures, starting with the US government, but also from foundry customers who could be vulnerable to any geopolitical dislocation.

Our issue is that as we have presented our concerns about the foundry business to the management team, the answer has almost always been "this is a geopolitical inevitability." It is not. Yes, the customers are not going to be dependent upon one region, which is why NVIDIA and Qualcomm have made the very significant investment to bring up a second foundry at the cutting edge (Samsung). Yes, customers are open to working with Intel as the process technology improves.

But having just gone through those migrations to Samsung makes it clear that bringing on another foundry at the cutting edge is expensive both in terms of dollars spent and in terms of engineering resources. It requires a high degree of confidence that Intel will remain committed to the business, which it was not in the past. And it requires the investment of tens of billions of dollars to put scale manufacturing in place before the customer commitments can come. We have seen Qualcomm announced as an IFS customer, and NVIDIA has described that it is open to working with Intel – of interest, these are the two companies in our US coverage that have made the biggest investment in diversifying from TSMC already – but both appear to be holding back on committing resources to a transition until they see proof points.

Government support could help, but it remains unclear what the government objectives are. We are seeing potential subsidization of TSMC fabs in Arizona and Samsung fabs in Texas. We still see material opportunity that could come out of legislation, mostly the potential for public/private partnerships, but as of now we see this as mostly a capex subsidy that reduces the costs.

The potential acquisition of Tower, announced earlier this year, could also be a shot in the arm, if it plays a prominent role in IFS. It doesn't feel that way so far – the description of Tower's business is that it is tangential to the main effort of building a cutting-edge foundry business, and Tower allows it to serve the rest of the business. But this could be an important element.

So overall, we believe in Intel's process technology efforts, but it still needs to build a foundry business around those capabilities. In the meantime, capital investment is very heavy – the company has guided to multiple years of no free cash flow, and though we expect it to outperform those targets, free cash flow will be low. It appears that we need to see another 2-3 process node migrations before it can start the process of getting customers to commit to a material wafer ramp.

Quantech – Look for Sector-Neutral Alpha amid Macro Complexities

Navigating macro complexities

Global equity market performance has been dominated by top-down macro risk in 2022 YTD. Inflation shock and rate shock have been holding back investor sentiment, while growth fear has started to take place as supply chain disruptions are worsening amid China's lockdowns and heightened geopolitical tensions. In 2Q, bearishness is still on the rise, while financial conditions are tightening.

We believe the Growth-oriented investment theme still faces macro headwinds via valuation compression.

Defensiveness is essential exposure, while we also suggest looking for stocks with strong free cash flows, and leadership in consensus earnings estimate revisions.

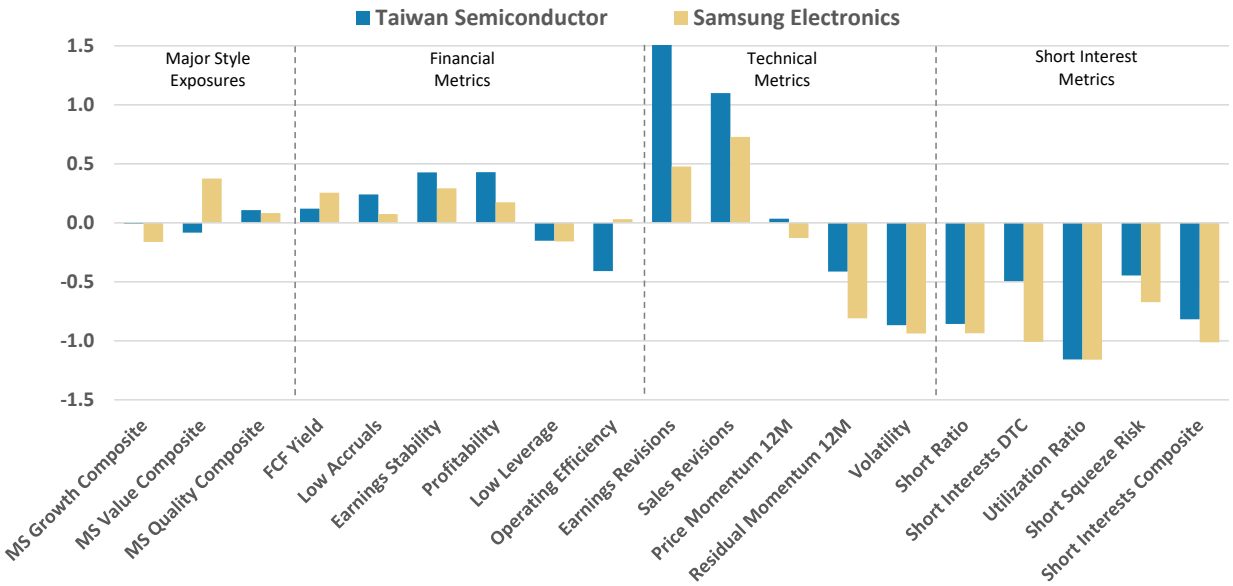
In view of the aforementioned macro complexities, we prefer large-cap stocks – i.e., industry leaders, which possess pricing power to strengthen their financial stability.

Quantifying exposures of Samsung vs. TSMC

Here we dig into the financial and technical factors of Samsung Electronics (005930.KS) and TSMC (2330.TW), and conduct a cross-sectional comparison versus other stocks in Asia/EM. We rely on Morgan Stanley's Global Quant Research Database and normalize the different metrics into Z-scores for evaluation.

Overall, Samsung and TSMC share many similar characteristics, but Samsung has more of a Value tilt, while TSMC has more of a Long-term Growth tilt.

Exhibit 78: Comparing factor exposures of TSMC and Samsung Electronics



Source: FactSet, IBES, Morgan Stanley Research; data as of April 30, 2022. Notes: factor definition could be referred to Asia Quant Biweekly Perspectives.

Highlights and Quant takes

Value exposures: Samsung is clearly a Value stock, with higher FCF yield and cheaper valuation on all metrics, comparing to TSMC. Even if we take PEG ratio into account, Samsung is also priced relatively cheaper per each unit of growth.

- With rising market expectations of prolonged inflation and a more hawkish Fed ahead, both US nominal yield and real yield would tend to rise, which would induce investors to look for stocks with higher earnings yield. We expect valuation correction to continue (Exhibit 79), and Value stocks' performance would be relatively resilient. On this front, Samsung Electronics is preferred over TSMC.

Growth exposures: Our Growth composite is taking a balanced approach between cyclical growth and long-term growth metrics. Both Samsung and TSMC stand out from long-term growth perspectives vs. the rest of Asia/EM, but lag on cyclical growth – which their leadership in long-term growth can't outweigh, resulting in a slightly negative exposure to Growth composite for now.

- We think their negative exposures to Growth are only tactical, because the current environment of high inflation is driven by commodity prices. Energy and Materials stocks have been leading in the cyclical growth with 50-100% YoY EPS changes.

Quality exposures: Both Samsung and TSMC are Quality stocks per our factor analysis. TSMC is helped by its outstanding profitability the most, while Samsung is more all-around – its balance sheet liquidity (i.e., accruals), earnings stability, and profitability are ranked higher than the other Asia/EM stocks.

- Balance Sheet Quality exposures are crucial to take up in a volatile market regime. It is more than a defensive factor; it is also a characteristic to strengthen outperformance consistency beyond market cycle. The market is now pricing toward late-cycle with flattened US yield curves, and Asia/EM Quality stocks usually outperform against such a macro backdrop.

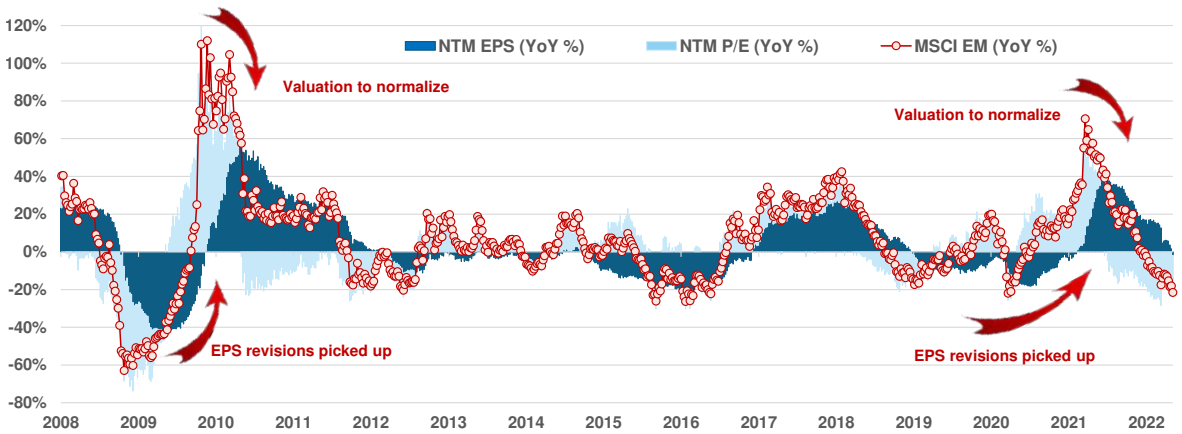
Technical exposures: There are three major factors to look at from technical perspectives – consensus revisions, price momentum, and price volatility. Samsung and TSMC share similar characteristics on these fronts: they have low price volatility, market in-line price momentum, but have leadership in consensus revisions in both EPS and sales estimates.

- Earnings estimate reductions in Asia/EM have been accelerating in the current results season (dark blue bars in Exhibit 79). Both our macro quant model (QuantASIA) and sector specific model (QuanTECH) are favoring stocks that are leading in revisions by consensus. The stock price performance of both Samsung and TSMC is currently supported by that.

Short interest exposures: This is a differentiated factor category that many quant models are missing. It assesses the sentiment among long/short managers on a high frequency basis. Both Samsung and TSMC have low absolute levels of short interest, implying that investor sentiment favors them relatively.

- Investors are looking for businesses with pricing power nowadays. For semiconductor players, industry leaders are particularly favored because of various fundamental reasons, like sizable market shares and edges in productivity. Our quant model also prefers large-cap stocks, which makes both Samsung and TSMC stand out on a sector-neutral basis.

Exhibit 79: Market return breakdown by valuation multiple changes (YoY %) and EPS estimate changes (YoY %) - MSCI EM



Source: MSCI, IBES, Morgan Stanley Research; data as of May 6, 2022.

Quant model recommendations

From a top-down perspective, the market is standing at late stage bear market but with Fed tightening ahead, which would favor Value stocks to prolong outperformance. Our QuantASIA model suggests selecting Value stocks with high FCF yield and consensus earnings estimate revisions leadership. From this perspective, TSMC is relatively disadvantaged vs. Samsung.

- We expect the rotation from TSMC to Samsung to continue in 2Q and 3Q.

From a sector-neutral perspective, we view both Samsung and TSMC as preferred stocks, given their industry-leading positions and relatively resilient financials vs. other industry peers. Exhibit 80 shows all the stocks favored by our Quantech model. Over the long term, we expect their performance to continue lead other industry players.

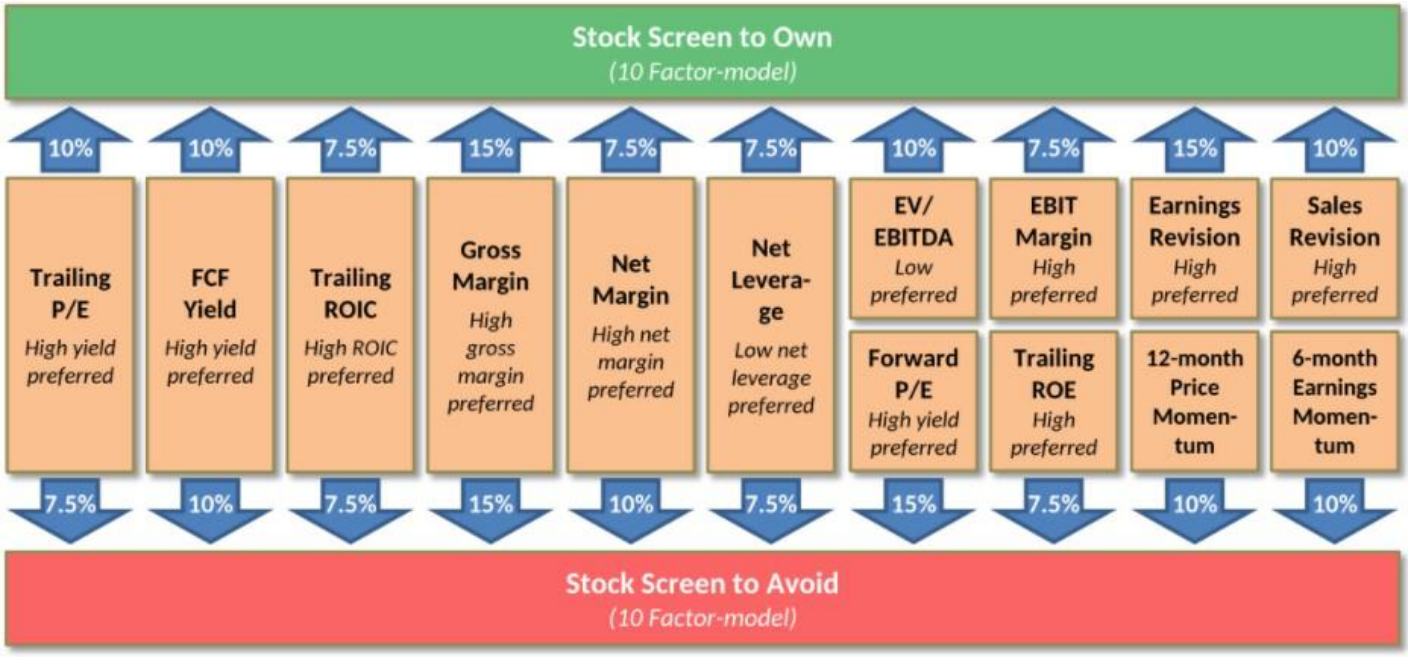
- We also suggest revisiting TSMC when economic slowdown risk evolves further into a recession that decelerates or pauses the pace of Fed's tightening: It is premature to trade on that yet, but it deserves a close watch into 4Q of this year.

Exhibit 80: Quantech Model Screening – favored stocks in Global Semiconductor & Tech Hardware

Ticker	Company	Country	MS Rating	Target Price Upside	Mkt Cap Mn US$	Price Last	Rank of Percentile in Quant Model
AAPL.O	Apple, Inc.	United States of America	OW	22%	2,455,915	172.39	25th pctl
2330.TW	TSMC	Taiwan	OW	12%	471,143	636	5th pctl
005930.KS	Samsung Electronics	S. Korea	OW	22%	321,751	74000	31th pctl
CSCO.O	Cisco Systems Inc	United States of America	EW	11%	212,163	55.15	16th pctl
8035.T	Tokyo Electron	Japan	OW	12%	71,849	56040	27th pctl
000660.KS	SK Hynix	S. Korea	EW	9%	65,241	124500	7th pctl
7974.T	Nintendo	Japan	OW	20%	54,568	58180	9th pctl
KLAC.O	KLA Corp	United States of America	EW	6%	53,143	377.38	27th pctl
6981.T	Murata Manufacturing	Japan	EW	15%	41,581	8462	20th pctl
7741.T	HOYA	Japan	OW	21%	36,244	15345	11th pctl
ANET.N	Arista Networks	United States of America	EW	13%	34,175	122.32	14th pctl
7751.T	Canon	Japan	OW	8%	33,233	2782	20th pctl
HPE.N	Hewlett Packard Enterprise	United States of America	EW	1%	22,126	16.84	22th pctl
TER.O	Teradyne Inc	United States of America	OW	16%	20,630	114.01	17th pctl
NTAP.O	NetApp Inc	United States of America	OW	24%	16,521	87.63	23th pctl
066570.KS	LG Electronics	S. Korea	OW	41%	13,826	128000	25th pctl
SEDG.O	Solaredge Technologies Inc	United States of America	EW	29%	13,733	238.26	31th pctl
6857.T	Advanteset	Japan	EW	16%	13,123	9480	8th pctl
FFIV.O	F5 Networks Inc	United States of America	OW	38%	10,382	203.16	15th pctl
HLMA.L	Halma PLC	United Kingdom	EW	10%	10,190	2432	33th pctl
6146.T	DISCO	Japan	EW	5%	9,433	32400	3th pctl
CGNX.O	Cognex Corp	United States of America	EW	27%	8,658	65.18	10th pctl
LITE.O	Lumentum Holdings Inc	United States of America	EW	7%	6,744	90.4	16th pctl
011070.KS	LG Innotek	S. Korea	EW	6%	6,578	348500	19th pctl
SLAB.O	Silicon Laboratories Inc.	United States of America	EW	30%	5,842	160.06	26th pctl
2409.TW	AU Optronics	Taiwan	EW	14%	5,791	20.15	2th pctl
6967.T	Shinko Electric Industries	Japan	OW	19%	5,272	5060	6th pctl
3481.TW	Innolux	Taiwan	EW	15%	4,775	16.95	3th pctl
6806.T	Hirose Electric	Japan	EW	21%	4,737	17400	29th pctl
7731.T	Nikon	Japan	EW	6%	4,227	1322	1th pctl
0522.HK	ASM Pacific	Hong Kong	EW	11%	3,867	79	30th pctl
SIMO.O	Silicon Motion	Taiwan	EW	13%	3,175	78.12	18th pctl
5274.TWO	Aspeed Technology	Taiwan	OW	12%	3,032	3030	10th pctl
7729.T	Tokyo Seimitsu	Japan	EW	23%	1,562	4725	13th pctl
6271.TW	Tong Hsing	Taiwan	EW	1%	1,510	264.5	5th pctl
240810.KQ	Wonik IPS	S. Korea	OW	43%	1,468	38450	29th pctl
6807.T	Japan Aviation Electronics Industry	Japan	EW	12%	1,357	1867	24th pctl

For important disclosures regarding companies that are the subject of this screen, please see the Morgan Stanley Research Disclosure Website at www.morganstanley.com/researchdisclosures. Source: MSCI, IBES, Worldscope, RIMES, Morgan Stanley Research. Data as of May 17, 2022.

Exhibit 81: QUANTECH model factors summary: factors' weight based on optimal back-tested results



Source: Morgan Stanley Research

Disclosure Section

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Global Stock Ratings Distribution

(as of April 30, 2022)

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	Coverage Universe		Investment Banking Clients (IBC)			Other Material Investment Services Clients (MISC)	
Stock Rating Category	Count	% of Total	Count	% of Total IBC	% of Rating Category	Count	% of Total Other MISC
Overweight/Buy	1424	40%	374	44%	26%	626	40%
Equal-weight/Hold	1564	44%	373	44%	24%	705	45%
Not-Rated/Hold	0	0%	0	0%	0%	0	0%
Underweight/Sell	564	16%	95	11%	17%	219	14%
Total	3,552		842			1550	

Data include common stock and ADRs currently assigned ratings. Investment Banking Clients are companies from whom Morgan Stanley received investment banking compensation in the last 12 months. Due to rounding off of decimals, the percentages provided in the "% of total" column may not add up to exactly 100 percent.

Analyst Stock Ratings

Overweight (O or Over) - The stock's total return is expected to exceed the total return of the relevant country MSCI Index or the average total return of the analyst's industry (or industry team's) coverage universe, on a risk-adjusted basis over the next 12-18 months.

Equal-weight (E or Equal) - The stock's total return is expected to be in line with the total return of the relevant country MSCI Index or the average total return of the analyst's industry (or industry team's) coverage universe, on a risk-adjusted basis over the next 12-18 months.

Not-Rated (NR) - Currently the analyst does not have adequate conviction about the stock's total return relative to the relevant country MSCI Index or the average total return of the analyst's industry (or industry team's) coverage universe, on a risk-adjusted basis, over the next 12-18 months.

Underweight (U or Under) - The stock's total return is expected to be below the total return of the relevant country MSCI Index or the average total return of the analyst's industry (or industry team's) coverage universe, on a risk-adjusted basis, over the next 12-18 months.

Unless otherwise specified, the time frame for price targets included in Morgan Stanley Research is 12 to 18 months.

Analyst Industry Views

Attractive (A): The analyst expects the performance of his or her industry coverage universe over the next 12-18 months to be attractive vs. the relevant broad market benchmark, as indicated below.

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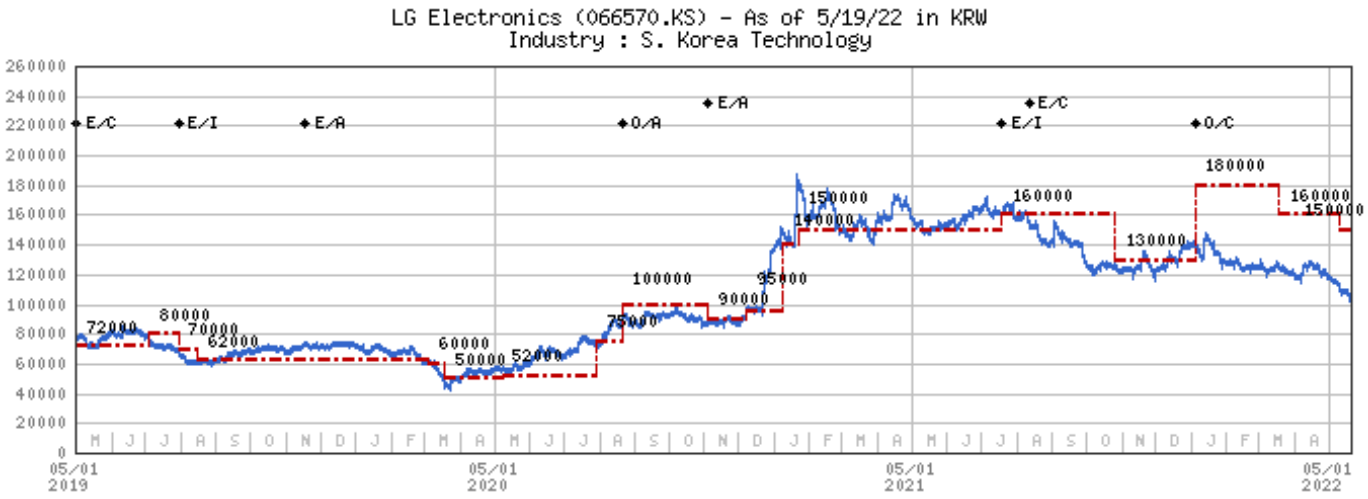
Cautious (C): The analyst views the performance of his or her industry coverage universe over the next 12-18 months with caution vs. the relevant broad market benchmark, as indicated below.

Benchmarks for each region are as follows: North America - S&P 500; Latin America - relevant MSCI country index or MSCI Latin America Index; Europe - MSCI Europe; Japan - TOPIX; Asia - relevant MSCI country index or MSCI sub-regional index or MSCI AC Asia Pacific ex Japan Index.

Stock Price, Price Target and Rating History (See Rating Definitions)



Stock Rating History: 5/1/17 : E/I; 7/10/17 : U/I; 11/26/17 : U/C; 1/22/18 : E/C; 7/30/19 : E/I; 11/18/19 : E/A; 8/21/20 : O/A; 11/4/20 : E/A; 7/19/21 : E/I; 8/12/21 : E/C; 1/4/22 : O/C

Price Target History: 3/14/17 : 65000; 5/30/17 : 85000; 7/10/17 : 62000; 9/6/17 : 70000; 10/24/17 : 74000; 1/22/18 : 106000; 7/23/18 : 92000; 9/10/18 : 85000; 12/18/18 : 68000; 4/1/19 : 72000; 7/4/19 : 80000; 7/30/19 : 70000; 8/16/19 : 62000; 3/4/20 : 60000; 3/19/20 : 50000; 5/8/20 : 52000; 7/30/20 : 75000; 8/21/20 : 100000; 11/4/20 : 90000; 12/8/20 : 95000; 1/8/21 : 140000; 1/22/21 : 150000; 7/19/21 : 160000; 10/26/21 : 130000; 1/4/22 : 180000; 3/18/22 : 160000; 5/10/22 : 150000

Source: Morgan Stanley Research Date Format : MM/DD/YY Price Target No Price Target Assigned (NA)
Stock Price (Not Covered by Current Analyst) Stock Price (Covered by Current Analyst)
Stock and Industry Ratings (abbreviations below) appear as ◆ Stock Rating/Industry View
Stock Ratings: Overweight (O) Equal-weight (E) Underweight (U) Not-Rated (NR) No Rating Available (NA)
Industry View: Attractive (A) In-line (I) Cautious (C) No Rating (NR)

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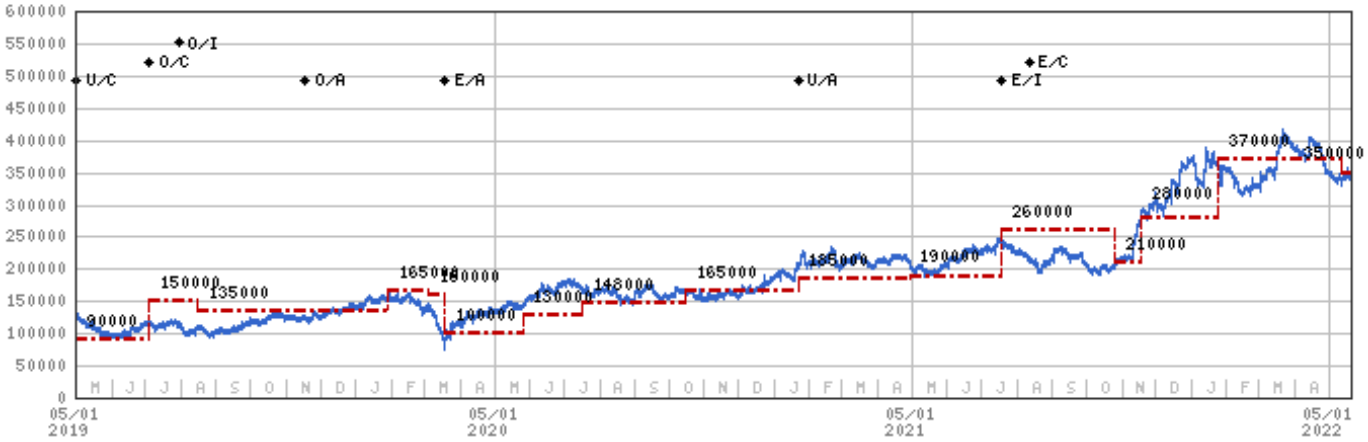
LG Innotek (011070.KS) - As of 5/19/22 in KRW
Industry : S. Korea Technology



Stock Rating History: 5/1/17 : O/I; 5/30/17 : E/I; 11/26/17 : E/C; 11/21/18 : U/C; 7/4/19 : O/C; 7/30/19 : O/I; 11/18/19 : O/A; 3/19/20 : E/A; 1/22/21 : U/A; 7/19/21 : E/I; 8/12/21 : E/C

Price Target History: 2/22/17 : 150000; 5/30/17 : 130000; 7/7/17 : 148000; 8/9/17 : 160000; 1/22/18 : 140000; 1/30/18 : 130000; 3/26/18 : 125000; 6/19/18 : 150000; 11/21/18 : 95000; 1/22/19 : 92000; 4/1/19 : 90000; 7/4/19 : 150000; 8/16/19 : 135000; 1/29/20 : 165000; 3/4/20 : 160000; 3/19/20 : 100000; 5/26/20 : 130000; 7/17/20 : 148000; 10/16/20 : 165000; 1/22/21 : 185000; 4/29/21 : 190000; 7/19/21 : 260000; 10/26/21 : 210000; 11/18/21 : 280000; 1/24/22 : 370000; 5/12/22 : 350000

Source: Morgan Stanley Research Date Format : MM/DD/YY Price Target No Price Target Assigned (NA)
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Industry View: Attractive (A) In-line (I) Cautious (C) No Rating (NR)

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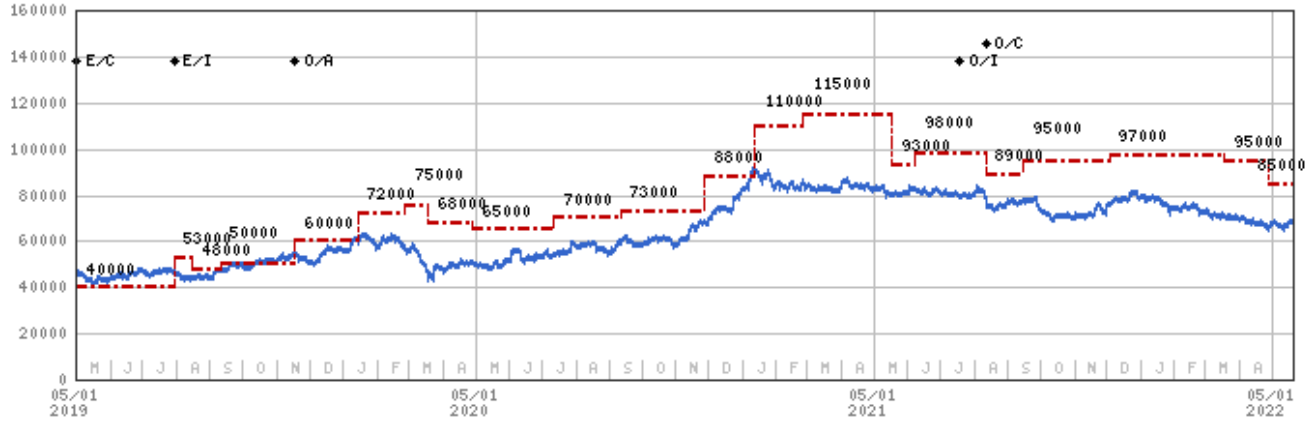
Samsung Electronics (005930.KS) - As of 5/19/22 in KRW
Industry : S. Korea Technology



Stock Rating History: 5/1/17 : O/I; 11/26/17 : E/C; 7/30/19 : E/I; 11/18/19 : O/A; 7/19/21 : O/I; 8/12/21 : O/C

Price Target History: 4/28/17 : 52000; 8/15/17 : 54000; 9/7/17 : 56000; 9/22/17 : 58000; 11/26/17 : 56000; 6/28/18 : 54000; 11/1/18 : 50000; 11/21/18 : 47000; 12/14/18 : 42000; 1/15/19 : 40000; 7/30/19 : 53000; 8/16/19 : 48000; 9/10/19 : 50000; 11/18/19 : 60000; 1/14/20 : 72000; 2/26/20 : 75000; 3/19/20 : 68000; 4/29/20 : 65000; 7/12/20 : 70000; 9/11/20 : 73000; 11/27/20 : 88000; 1/12/21 : 110000; 2/25/21 : 115000; 5/18/21 : 93000; 6/8/21 : 98000; 8/12/21 : 89000; 9/15/21 : 95000; 12/3/21 : 97000; 3/18/22 : 95000; 4/28/22 : 85000

Source: Morgan Stanley Research Date Format : MM/DD/YY Price Target No Price Target Assigned (NA)
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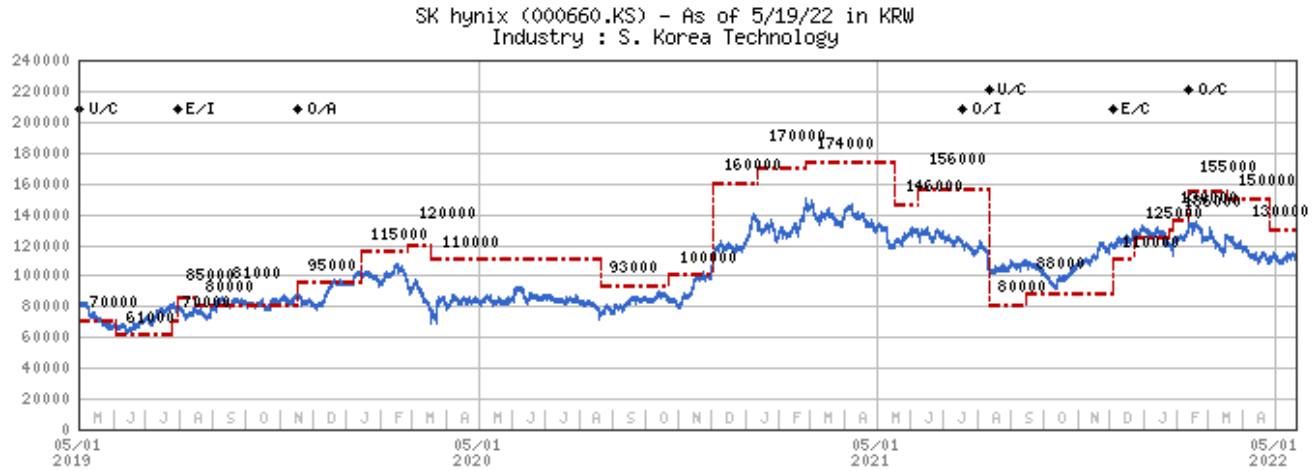

Stock Rating History: 5/1/17 : NA/I; 6/27/17 : O/I; 9/20/17 : NA/I; 11/26/17 : NA/C; 8/5/18 : U/C; 7/30/19 : E/I; 11/18/19 : O/A; 7/19/21 : O/I; 8/12/21 : U/C; 12/3/21 : E/C; 2/11/22 : O/C

Price Target History: 2/8/17 : NA; 6/27/17 : 80000; 8/15/17 : 82000; 9/20/17 : NA; 8/5/18 : 71000; 9/6/18 : 70000; 11/13/18 : 69000; 12/14/18 : 63000; 1/15/19 : 61000; 1/25/19 : 63000; 3/3/19 : 60000; 4/25/19 : 70000; 6/4/19 : 61000; 7/25/19 : 70000; 7/30/19 : 85000; 8/16/19 : 80000; 9/10/19 : 81000; 11/18/19 : 95000; 1/14/20 : 115000; 2/26/20 : 120000; 3/19/20 : 110000; 8/21/20 : 93000; 10/23/20 : 100000; 12/2/20 : 160000; 1/12/21 : 170000; 2/25/21 : 174000; 5/18/21 : 146000; 6/8/21 : 156000; 8/12/21 : 80000; 9/15/21 : 88000; 12/3/21 : 110000; 12/23/21 : 125000; 1/24/22 : 130000; 1/28/22 : 136000; 2/11/22 : 155000; 3/18/22 : 150000; 4/27/22 : 130000

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Industry View: Attractive (A) In-line (I) Cautious (C) No Rating (NR)

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Effective January 13, 2014, the industry view benchmarks for Morgan Stanley Asia Pacific are as follows: relevant MSCI country index or MSCI sub-regional index or MSCI AC Asia Pacific ex Japan Index.

Stock Rating History: 5/1/17 : NA/I; 11/26/17 : NA/C; 7/30/19 : NA/I; 11/18/19 : NA/A; 4/9/20 : E/A; 9/7/20 : O/A; 7/19/21 : O/I; 8/12/21 : O/C

Price Target History: 4/9/20 : 31000; 8/6/20 : 33000; 9/7/20 : 45000; 11/27/20 : 48000; 1/27/21 : 65000; 10/26/21 : 55000; 3/18/22 : 50000

Source: Morgan Stanley Research Date Format : MM/DD/YY Price Target No Price Target Assigned (NA)
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INDUSTRY COVERAGE: S. Korea Technology

COMPANY (TICKER)	RATING (AS OF)	PRICE* (05/20/2022)
Ryan Kim		
Advanced Process Systems Corp (265520.KQ)	E (03/18/2022)	W21,850
Duk San Neolux Co Ltd (213420.KQ)	O (04/09/2020)	W43,700
Ecopro BM (247540.KQ)	O (08/03/2021)	W493,400
Iljin Materials (020150.KS)	O (02/21/2019)	W94,700
L&F Co Ltd (066970.KQ)	O (12/17/2020)	W273,400
Posco Chemical Co Ltd. (003670.KS)	U (04/27/2021)	W136,500
SK IE Technology (361610.KS)	O (04/19/2022)	W121,500
Solus Advanced Materials Co Ltd (336370.KS)	O (05/11/2021)	W67,600
Wonik IPS Co Ltd (240810.KQ)	O (09/07/2020)	W41,050
Shawn Kim		
LG Display (034220.KS)	U (04/27/2022)	W17,150
LG Electronics (066570.KS)	O (01/04/2022)	W104,500
LG Innotek (011070.KS)	E (07/19/2021)	W345,000
Samsung Electro-Mechanics (009150.KS)	E (05/12/2021)	W159,000
Samsung Electronics (005935.KS)	O (11/18/2019)	W60,700
Samsung Electronics (005930.KS)	O (11/18/2019)	W68,000
Samsung SDI (006400.KS)	E (10/26/2021)	W605,000
Samsung SDS (018260.KS)	U (01/06/2022)	W146,500
Seoul Semiconductor (046890.KQ)	U (04/04/2018)	W12,450
SK hynix (000660.KS)	O (02/11/2022)	W112,500

Stock Ratings are subject to change. Please see latest research for each company.

* Historical prices are not split adjusted.

INDUSTRY COVERAGE: Greater China Technology Semiconductors

COMPANY (TICKER)	RATING (AS OF)	PRICE* (05/20/2022)
Charlie Chan		
ACM Research Inc (ACMR.O)	O (01/22/2020)	US$13.66
Advanced Micro-Fabrication Equipment Inc (688012.SS)	O (01/25/2022)	Rmb113.58
Alchip Technologies Ltd (3661.TW)	O (05/14/2021)	NT$950.00
ASE Technology Holding Co. Ltd. (3711.TW)	E (10/12/2021)	NT$97.50
ASM Pacific (0522.HK)	E (10/12/2021)	HK$75.10
Global Unichip Corp (3443.TW)	U (02/12/2020)	NT$573.00
GlobalWafers Co Ltd (6488.TWO)	O (12/02/2020)	NT$574.00
Jiangsu Changjiang Electronics Tech (600584.SS)	U (10/12/2021)	Rmb24.75
Maxscend Microelectronics Co Ltd (300782.SZ)	U (01/11/2021)	Rmb200.01
MediaTek (2454.TW)	O (01/04/2021)	NT$846.00

Nanya Technology Corp. (2408.TW)	U (12/03/2021)	NT$66.80
Phison Electronics Corp (8299.TWO)	O (02/11/2022)	NT$391.00
Silergy Corp. (6415.TW)	U (05/20/2021)	NT$2,870.00
SMIC (0981.HK)	E (08/10/2021)	HK$16.28
TSMC (2330.TW)	O (02/07/2022)	NT$530.00
UMC (2303.TW)	O (09/14/2020)	NT$50.70
Universal Scientific Ind. (Shanghai) (601231.SS)	O (08/04/2015)	Rmb12.69
Vanguard International Semiconductor (5347.TWO)	E (02/12/2022)	NT$107.50
Will Semiconductor Co Ltd Shanghai (603501.SS)	O (02/22/2022)	Rmb163.67
WIN Semiconductors Corp (3105.TWO)	U (02/04/2021)	NT$200.00

Daisy Dai, CFA

Hangzhou Silan Microelectronics Co. Ltd. (600460.SS)	O (10/08/2021)	Rmb47.01
Shanghai Fudan Microelectronics (1385.HK)	E (07/19/2021)	HK$28.35
Yangjie Technology (300373.SZ)	E (10/08/2021)	Rmb76.35

Daniel Yen, CFA

3Peak (688536.SS)	E (01/17/2022)	Rmb539.00
ASMedia Technology Inc (5269.TW)	O (05/14/2021)	NT$1,405.00
Aspeed Technology (5274.TWO)	E (05/20/2022)	NT$2,380.00
Bestechnic Shanghai Co Ltd (688608.SS)	O (04/23/2021)	Rmb137.78
Chipsea Technologies Shenzhen Corp (688595.SS)	E (01/17/2022)	Rmb67.15
Egis Technology Inc (6462.TWO)	U (04/23/2020)	NT$108.00
Espressif Systems (688018.SS)	U (07/19/2021)	Rmb108.11
GigaDevice Semiconductor Beijing Inc (603986.SS)	O (12/03/2021)	Rmb142.25
Macronix International Co Ltd (2337.TW)	U (10/19/2021)	NT$39.30
Montage Technology Co Ltd (688008.SS)	U (05/20/2022)	Rmb64.48
Novatek (3034.TW)	U (05/20/2021)	NT$401.50
Nuvoton Technology Corporation (4919.TW)	O (07/19/2021)	NT$175.00
Parade Technologies Ltd (4966.TWO)	O (03/03/2019)	NT$1,530.00
Realtek Semiconductor (2379.TW)	E (02/24/2022)	NT$437.50
Shenzhen Goodix Technology Co Ltd (603160.SS)	U (06/16/2020)	Rmb58.70
Sino Wealth Electronic (300327.SZ)	O (07/19/2021)	Rmb60.31
Winbond Electronics Corp (2344.TW)	U (10/19/2021)	NT$28.95
WPG Holdings (3702.TW)	U (04/09/2021)	NT$56.00

Dylan Liu

Chipbond Technology Corp (6147.TWO)	E (05/20/2021)	NT$69.20
King Yuan Electronics Co Ltd (2449.TW)	E (10/12/2021)	NT$44.20

Ray Wu, CFA

Advanced Wireless Semiconductor Co (8086.TWO)	U (02/11/2022)	NT$87.80
China Resources Microelectronics Limited (688396.SS)	O (04/20/2021)	Rmb52.23
Hua Hong Semiconductor Ltd (1347.HK)	O (02/04/2022)	HK$29.50
Powerchip Semiconductor Manufacturing Co (6770.TW)	U (07/12/2021)	NT$58.80
RichWave Technology Corp. (4968.TW)	O (10/26/2021)	NT$206.50
Silicon Motion (SIMO.O)	E (08/12/2021)	US$90.85
StarPower Semiconductor Ltd (603290.SS)	O (03/01/2022)	Rmb392.30
UPI Semiconductor Corp. (6719.TW)	U (05/02/2022)	NT$515.00

Wafer Works Corp (6182.TWO)	O (04/20/2021)	NT$59.60

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* Historical prices are not split adjusted.

INDUSTRY COVERAGE: Semiconductors

COMPANY (TICKER)	RATING (AS OF)	PRICE* (05/19/2022)
Ethan Puritz		
Amphenol Corp. (APH.N)	E (08/23/2020)	US$67.59
Sensata Technologies Holding N.V. (ST.N)	O (12/13/2020)	US$44.46
Te Connectivity Ltd (TEL.N)	E (09/23/2019)	US$122.68
Joseph Moore		
Advanced Micro Devices (AMD.O)		US$96.67
Aeva Technologies Inc (AEVA.N)	E (07/19/2021)	US$3.19
Ambarella Inc (AMBA.O)	O (03/29/2016)	US$76.26
Analog Devices Inc. (ADI.O)	E (09/13/2021)	US$160.94
Broadcom Inc. (AVGO.O)	O (11/19/2019)	US$546.21
GlobalFoundries Inc (GFS.O)	O (03/03/2022)	US$54.23
Intel Corporation (INTC.O)	U (03/03/2022)	US$42.01
Marvell Technology Group Ltd (MRVL.O)	E (09/14/2015)	US$54.28
Microchip Technology Inc. (MCHP.O)	O (10/19/2020)	US$66.01
Micron Technology Inc. (MU.O)	E (08/12/2021)	US$69.40
NVIDIA Corp. (NVDA.O)	E (05/03/2022)	US$171.24
NXP Semiconductor NV (NXPI.O)	E (04/08/2021)	US$175.79
ON Semiconductor Corp. (ON.O)	E (08/03/2021)	US$56.07
Qorvo Inc (QRVO.O)	E (03/03/2022)	US$104.83
Qualcomm Inc. (QCOM.O)	O (06/16/2020)	US$130.57
Silicon Laboratories Inc. (SLAB.O)	E (01/19/2021)	US$139.33
Skyworks Solutions Inc (SWKS.O)	E (11/28/2018)	US$101.25
Teradyne Inc (TER.O)	E (03/03/2022)	US$102.18
Texas Instruments (TXN.O)	U (04/13/2020)	US$167.62
Western Digital (WDC.O)	O (01/23/2020)	US$58.01
Wolfspeed, INC (WOLF.N)	E (12/07/2020)	US$71.71

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