Slowdown in Semis? Why the Long-Term Growth Story Remains Compelling for the Nasdaq Global Semiconductor Index™

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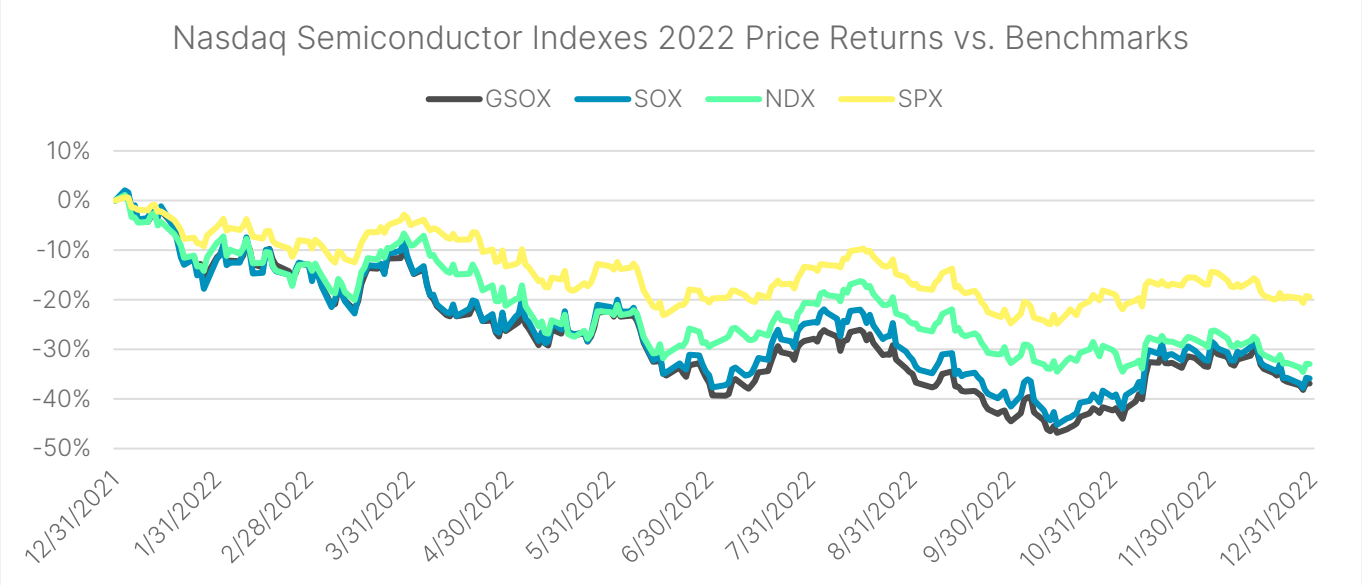
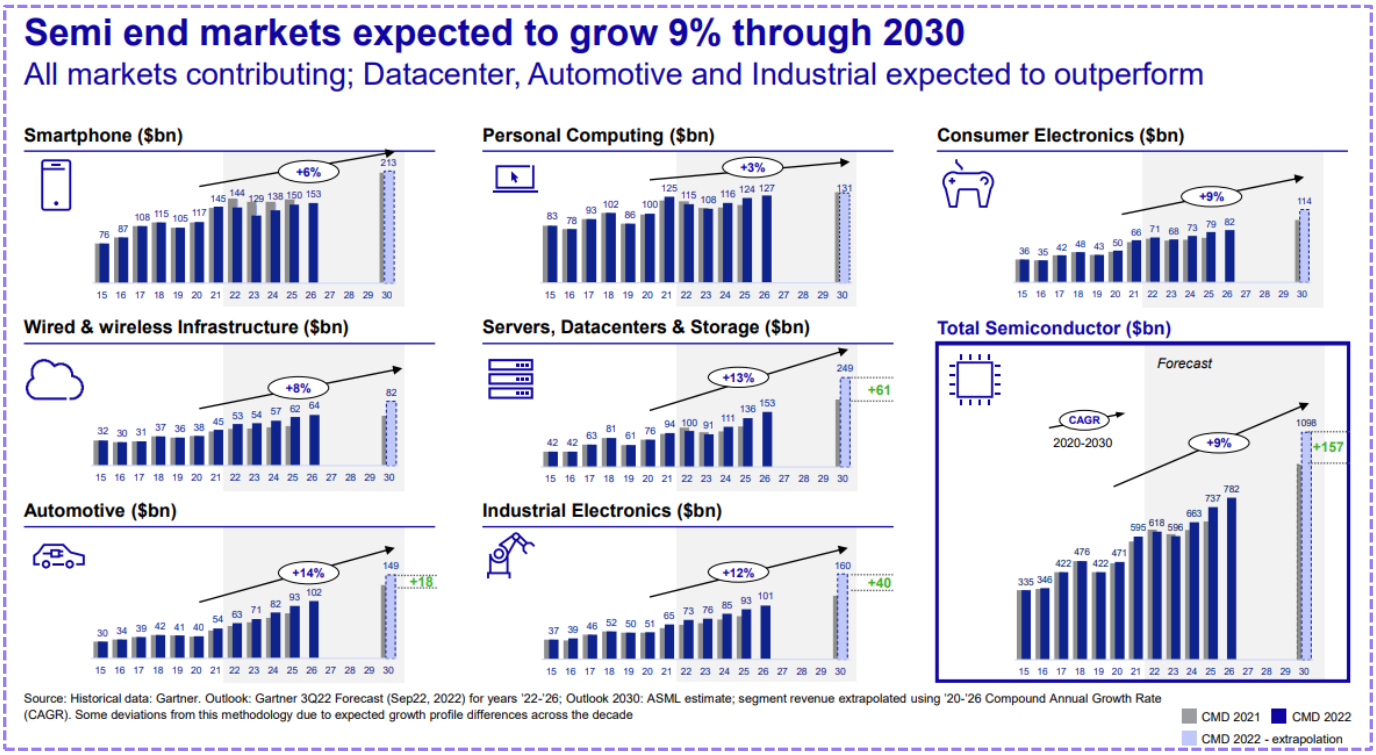
With 2022's broadly disappointing performance in the rearview mirror, it is worth reassessing what drove investment returns over the past year and how investor consensus has evolved for different areas of the market. The global semiconductor industry is perhaps one of the most multifaceted and dynamically evolving industries of all time, straddling a number of key disruptive technologies that are still very much in the early stages, as well as massive, well-established consumer and enterprise end markets that are incredibly sensitive to macroeconomic developments. The Covid-19 pandemic turbocharged much of the industry thanks to widespread stay-at-home policies, prompting historic increases in demand for traditional semiconductor-laden products such as computers, smart phones, and gaming systems. At the same time, unprecedented supply chain interruptions led to painful shortages in many types of semiconductors that had varying degrees of impact on different end-users. With the last vestiges of pandemic mitigation policy recently abandoned in China, it now appears the global semiconductor supply chain has more or less returned to normal. In terms of demand, the "reverse-bullwhip" effect has firmly taken hold with undeniable declines in consumer purchases of electronics, and some deceleration in enterprise-driven demand as companies around the world have been gripped by fears of recession, especially within the broader Technology sector. The question now beckons: is the semiconductor industry entering a painful, multiyear leg in a cycle that sees widespread demand destruction and outright contraction in industry revenues?

The industry's performance in 2022, as tracked by the Nasdaq Global Semiconductor Index (GSOX™), certainly seems to indicate that likelihood: down 37% for the year, slightly underperforming the Nasdaq-100® and almost



doubling the loss within the S&P 500. Yet the GSOX Index established a rather clear low point in mid-October and staged a meaningful rally in Q4, finding strength yet again at the beginning of 2023 in the context of improving macroeconomic conditions. Most notably, the pronounced slowdown in US inflation over the past several months augurs well for a potential recovery in Technology, and Growth stocks more broadly. With inflation cooling, the Federal Reserve can potentially pause its rate hikes after February's projected 25 bps increase, likely averting a true recession in the US as employment and other economic fundamentals remain fairly strong. In Europe, the lack of a catastrophic energy crisis in the current winter season has also prompted a reconsideration among economic forecasters of the depth of a potential recession. And in China, with the economy on its way to fully reopening, an additional global economic tailwind waits in the wings. With inflation, interest rates and growth all stabilizing, 2023 could very well be a year of recovery for the global economy, and for the semiconductor industry in particular.

Long-Term Semiconductor Growth Drivers Remain Compelling



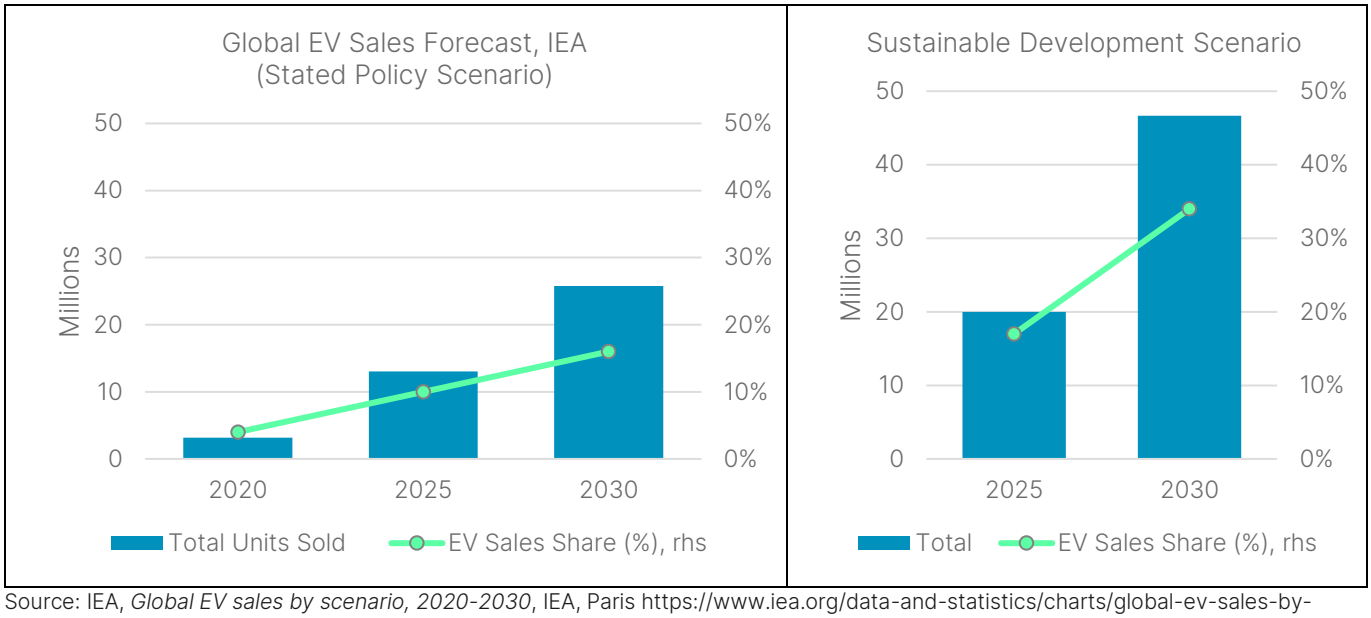
Source: ASML 2022 Investor Day Presentation. As of 11/11/2022.

Since the last true global recession, semiconductor revenues have increased at a compound annual growth rate (CAGR) of approximately 8%, more than doubling from $230 billion in 2009 to nearly $600 billion in 2021. Final expectations are for slower growth of approximately 4% in 2022, and a possible contraction of as much as 4% in 2023.[1] Yet the long-term forecast for the remainder of the decade is very much on track as an extension of the previous decade, with industry bellwether ASML forecasting a CAGR of approximately 9% through 2030, and global revenue surpassing $1 trillion. Notably, this accounts for slow growth in the Personal Computing market, historically the largest destination for chips. Thus the current weakness in PCs (global shipments down 16% YoY)[2] must be placed into the context of their declining importance for the semiconductor industry overall. Thanks to much faster growth in Automotive (14% CAGR), Servers/Datacenters/Storage (13%), Industrial Electronics (12%), Consumer Electronics (9%), Wired/Wireless Infrastructure (8%), and Smartphones (6%), PCs (3%) will be the 5th-biggest end market for semis by the end of the decade.

[1] https://www.semiconductors.org/global-semiconductor-sales-decrease-2-9-month-to-month-in-november/
[2] https://www.gartner.com/en/newsroom/press-releases/2023-01-11-gartner-says-worldwide-pc-shipments-declined-28-percent-in-fourth-quarter-of-2022-and-16-percent-for-the-year

Let's dig a little deeper into what's driving the acceleration of growth in some of these other end-markets, starting with Automotive – historically, a light user of more advanced semiconductors that was disproportionately impacted by Covid-19-related supply chain disruptions. For much of the past two years, auto manufacturers were left waiting behind larger, more established customers like computer and smartphone manufacturers to get their orders filled. In 2022, light vehicle sales in the US dropped 8.1% YoY, "impacted significantly by supply chain disruptions, and sales were still down 19% from the 2019 level. This suggests vehicle sales might increase in 2023 even with higher rates and a soft economy."[3] In other words, there is now a likely backlog of buyers that will take some time to normalize, potentially offsetting some of the weakness in consumer electronics demand should it persist into this year.

More importantly and looking beyond the short term, however, is the transformation of high-end autos into "one of the most complex pieces of software you can have in the world at the moment," per privately-owned semiconductor company Arm's Vice-President of Automotive Go-to-Market Dennis Laudick, who also described it as: "basically a data centre on wheels." Between advanced driver assistance systems, "infotainment" systems, and the rise of electric vehicles, "the average value of semiconductors per car is forecast to rise from $700 in 2020 to $1,138 by 2028" with "full electrification [adding] around $1,000 in the value of semiconductors to each vehicle and could require up to five times more chips." [4] (Notably, this excludes charging infrastructure.) Given that the trend electric vehicles (EVs) is still in its infancy, an incredibly long runway exists for automotive-related semiconductor growth. The International Energy Agency (IEA) forecasts the share of global sales represented by EVs to grow from 4% (3.16 million units) in 2020 to 16% (25.76 million units) in 2030 understated government policies, with an increase to 34% (46.64 million units) under a more aggressive "sustainable development" scenario; the respective CAGRs this decade are 23.3% and 30.9%. With more ambitious goals set for 2035 by governments and individual automakers, double-digit annualized growth in automotive semiconductor demand can persist for many years to come.

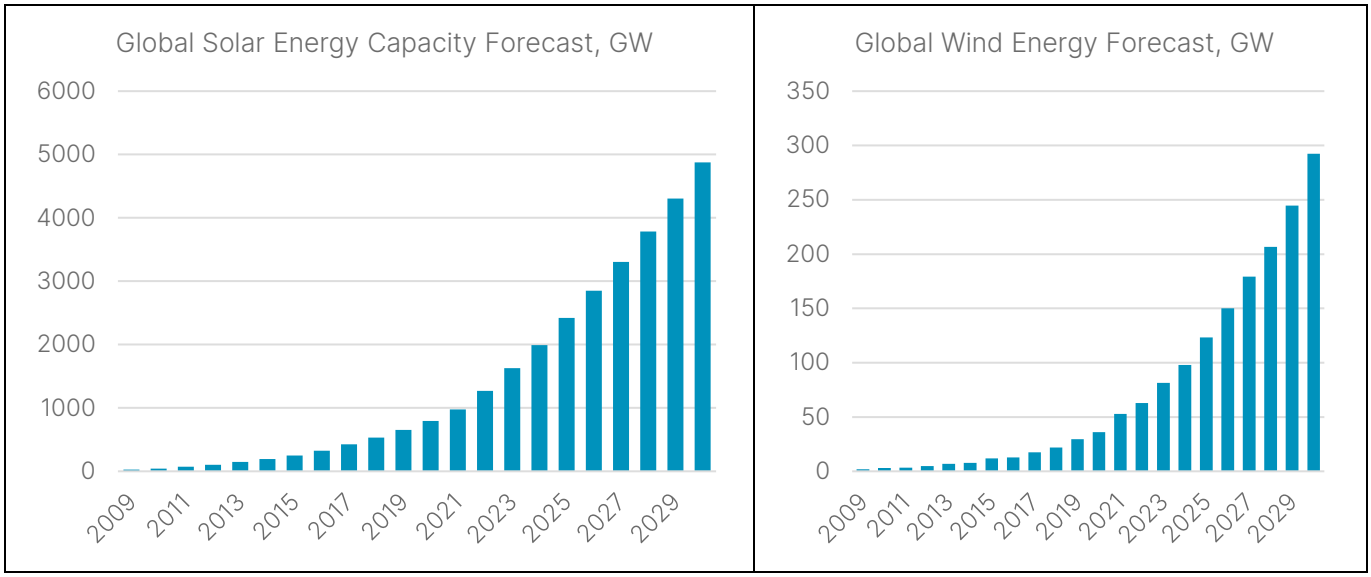


Source: IEA, *Global EV sales by scenario, 2020-2030*, IEA, Paris https://www.iea.org/data-and-statistics/charts/global-ev-sales-by-scenario-2020-2030, IEA. Licence: CC BY 4.0

Fully autonomous vehicles are even further away, and would require the greatest amount of processing firepower – enough to support half a billion lines of code by 2030. Renault CEO Luca de Meo envisions a future of "software-defined cars" that "will become intelligent, they will learn from the driver, so your car after three years will be better than when you buy it, because it knows you." The upshot? "Today, software represents 10 per cent

[3] https://www.calculatedriskblog.com/2023/01/annual-vehicle-sales-decrease-8-in-2022.html
[4] https://www.ft.com/content/a09c4500-27ae-42d7-8b3f-e6d13f1b3f3b

of the value of the car. In 2030 it will be 40%," per de Meo.[5] In other words, the next automotive evolution will not only incorporate autonomous driving technology, but could more or less transform the car into a large robot. Automotive innovation serves as a useful launching point to talk about two overarching disruptive innovations that will provide years of runway for continued semiconductor demand growth: the green energy transition, and the rise of artificial intelligence. With the energy transition, there exist numerous long-term drivers for semiconductor growth even outside of the ongoing adoption of EVs. Per Infineon – a leader in the power semiconductor space – the range of semiconductor expenditures for a typical wind energy installation is 2,000-3,500 EUR per megawatt (MW)-hour; 2,000-5,000 EUR per MW for a typical solar energy installation; and an incremental 2,500-3,500 EUR per MW for storage of that energy.[6] Legacy forms of energy generation like fossil fuel-based, nuclear, or hydroelectric are estimated at close to zero, although they too will add incremental demand on the storage side of the equation with the buildout of smart grids that are necessary to manage a much more complex and variable array of energy sources. The bottom line: the energy transition is still in its infancy, but the requirements to generate, transport, store, measure, and regulate the clean energy of the future will serve as a massive tailwind for semiconductor demand for the foreseeable future. Below are estimated growth trajectories of solar and wind energy capacity for this decade, exceeding 5,000 gigawatts by 2030 (~20-25% CAGR, each).



Source: BloombergNEF as of January 18, 2023.

Artificial intelligence (AI) is potentially even more compelling in terms of a long-term semiconductor investment thesis, but also more challenging to quantify. The recent release and popularity of new generative AI platforms like ChatGPT, DALL-E 2, and Stable Diffusion herald the arrival of AI as an everyday technology with almost limitless applications. From analyzing and automating a litany of rote tasks that human beings still manually perform, to assisting all kinds of economic activities in the modern knowledge-based economy – managerial, creative, academic, healthcare, and even coding itself – the new wave of AI systems, trained and operated on the most sophisticated chips from the likes of NVIDIA, are truly transformative leaps in software and computing. Google, which holds the single largest portfolio of AI patents in the world, recently announced a new AI tool from its Google Cloud division that is "designed to help big box retailers better track the inventory on their shelves, aiming to improve a technology that has struggled to work well in the past" by leveraging a combination of a "retailer's own ceiling-mounted cameras, camera-equipped self-driving robots or store associates."[7] Separately, Google demonstrated the ability of one of its AI chatbots to answer common medical questions, with an accuracy rate of ~93%, which matched the average rate of real-life doctors.[8] On the other hand, Microsoft recently announced a

[5] https://itwire.com/business-it-sp-511/business-it/qualcomm-and-renault-see-potential-in-software-connected-vehicles.html
[6] https://www.infineon.com/dgdl?fileId=8ac78c8b821f36170182604d725d000e
[7] https://www.wsj.com/articles/google-cloud-introduces-shelf-inventory-ai-tool-for-retailers-11673549442
[8] https://arxiv.org/pdf/2212.13138.pdf

$10 billion investment into OpenAI, a leader in the generative AI space, with intentions to integrate the technology into its Azure cloud platform as well as its Microsoft Office software suite, Bing search engine, and GitHub.[9]
With all the excitement around the energy transition and AI, it can be easy to overlook another major secular trend that has already been underway for several years, but is still in the relatively early innings: cloud computing (i.e., the Servers, Datacenters & Storage segment). While widespread cloud adoption among enterprises has already taken place, there are still many legacy IT environments and infrastructure investments in use. In 2021, Gartner estimates that less than 17% of enterprise IT spending was related to public cloud services, but by 2026, it will exceed 45%.[10] As more data is stored in the cloud, and as more computational processes take place in the cloud, the industry leaders such as Amazon Web Services, Microsoft Azure, and Google Cloud will continue devouring chips from the likes of NVIDIA to meet the demand.

Despite a pronounced slowdown in certain segments of its business – Gaming is down 51% YoY in its most recent quarterly financial results, which helped drive a 50% drop in its share price in 2022 – NVIDIA continues to show strength in its Data Center unit, up 31% YoY. JPMorgan's lead semiconductor analyst, Harlan Sur, recently noted the importance of Data Center to NVIDIA, one of the largest and most important constituents in GSOX: "It's more than 60% of your overall revenues. The business is tracking toward 40% year-over-year growth in fiscal '23, which is more than 1.5x the cloud CapEx growth last year. And the team has driven roughly about a 70% CAGR over the past 3 years, which is about 2x the annualized growth rate relative to cloud CapEx spending growth."[11]

As NVIDIA and others benefit from the continued demand for higher-margin, specialized Data Center processing chips, memory providers like Micron and Samsung (the latter not part of the index) may experience an inventory correction and weaker short-term performance as a result.[12] Both companies have recently noted a deceleration in server chip demand, on top of the consumer slowdown that got underway early in 2022. Regardless, cloud computing remains at or near the top of most enterprise IT budgets in terms of prioritization and overall spending, earning itself a unique standing as a "digital utility" type of expense akin to paying for electricity.[13]

Recent Legislative & Regulatory Actions Impacting the Semiconductor Industry

Similar to how short-term uncertainties on the demand side need to be balanced against long-term convictions around growth prospects, recent legislative and regulatory actions impacting semiconductors have introduced volatility to the industry, but have been broadly targeted toward strengthening its resiliency with respect to both supply-chain interruptions and geopolitical risks. On October 7, 2022, the Biden administration (via the Commerce Department) announced a new set of restrictions on semiconductor exports to China – a set of policies that were not fully priced in by the market. The impact on returns to GSOX was swift and severe, down 5.1% on the day of the announcement and 11.9% over the entire span of a weeklong drawdown. The index's lowest closing level of the year was in fact on October 14, with names like NVIDIA losing 14.5% of their share price. Per Factset, 25.8% of NVIDIA's trailing-12-month revenues came from Mainland China, a bit above the 20% average across all GSOX constituents.

Investors greeted the news with some shock given the severity of prohibitions, which are aimed at handicapping China's tech sector from facilitating the country's advancements in military and surveillance technology, AI, and other areas of such significance that "the country spends more per year importing chips than oil." The restrictions cover not only the export of physical chips, but also "chip design software, chip manufacturing equipment, and US-built components of manufacturing equipment"; they "also apply to any company worldwide that uses US

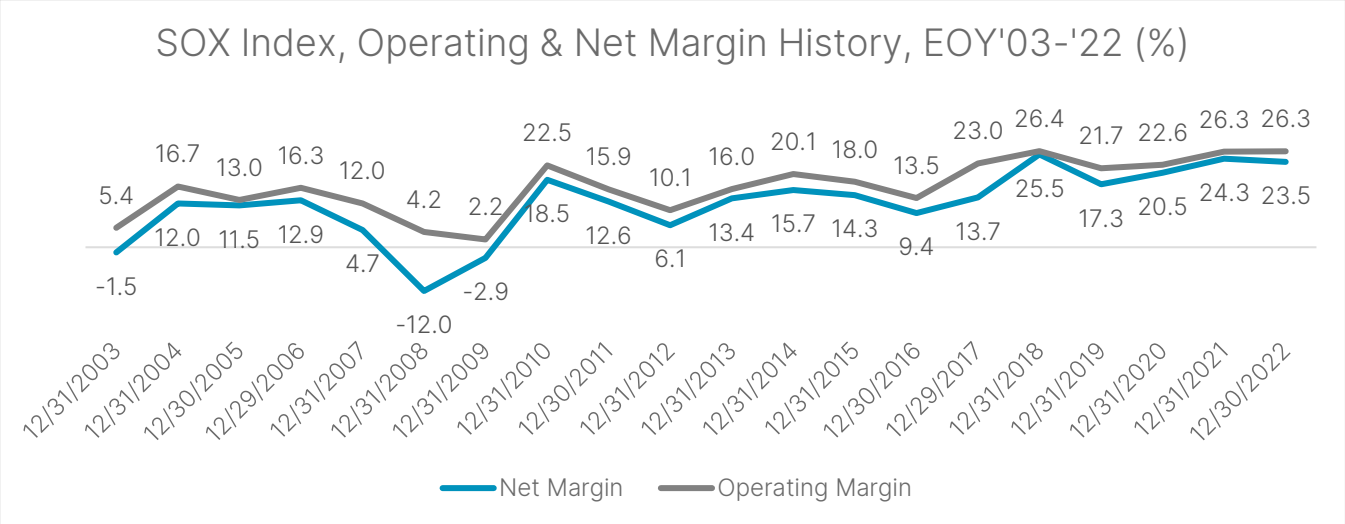
[9] https://www.wsj.com/articles/microsoft-plans-to-build-openai-capabilities-into-all-products-11673947774
[10] https://www.gartner.com/en/newsroom/press-releases/2021-08-02-gartner-says-four-trends-are-shaping-the-future-of-public-cloud
[11] https://twitter.com/TheTranscript_/status/1612225259502977025
[12] https://www.bnnbloomberg.ca/samsung-profit-plunges-69-on-sharp-memory-price-declines
[13] https://www.techtarget.com/searchcloudcomputing/feature/Public-cloud-spending-competition-to-rise-in-2023

semiconductor technology" which ends up encompassing "all the world's leading chipmakers" that are based in US-allied countries including Japan, South Korea, and the Netherlands. Severe restrictions on the ability of US residents to continue working at Chinese chip firms have led to an immediate exodus of highly-valued employees from the country's semiconductor industry, leading some exports to label the Biden administration's approach as "strangling with an intent to kill." [14]

On the other hand, 2022 brought the passage of the US CHIPS and Science Act (Act), a major piece of industrial policy rivaling anything passed within the last half-century. With approximately $53 billion of spending to expand domestic manufacturing of semiconductors, the Act leverages a combination of investment tax credits, loan guarantees, and direct grants for R&D in crucial areas including defense and wireless infrastructure. Beyond the immediate impacts on the US semiconductor industry, the Act includes an additional $200 billion in authorizations for spending on STEM, R&D, and workforce and economic development programs at the National Science Foundation, US Department of Energy, and US Department of Commerce, with a total price tag of approximately $280 billion over the next 10 years. Officially signed into law on August 9, 2022, the Act did not have a meaningfully positive impact on markets, with the GSOX Index dropping 4% on day one and recovering to post a one-week gain of 1.9%. Yet the implications for the industry's capacity to meet future demand, and do so in a way that reduces the risks of supply chain disruptions, is profound. Those tax credits for the buildout of domestic manufacturing capacity in the US amount to 25%, enough to spur the biggest semiconductor foundry players like Intel, Taiwan Semi, Samsung, and Micron to collectively announce at least $200 billion of new investments over the coming years. Similar governmental policies afoot in the European Union, Japan, and South Korea have catalyzed a global rebalancing of future semiconductor manufacturing capacity away from overconcentration in East Asia (especially Taiwan, given its ongoing geopolitical risks vis-à-vis China). The future of semiconductor manufacturing appears to be realigning, with geographical diversification among multiple Western democratic nations that will collectively subsidize the costs of the necessary capital expenditures, while continuing to lead in software and design innovation.

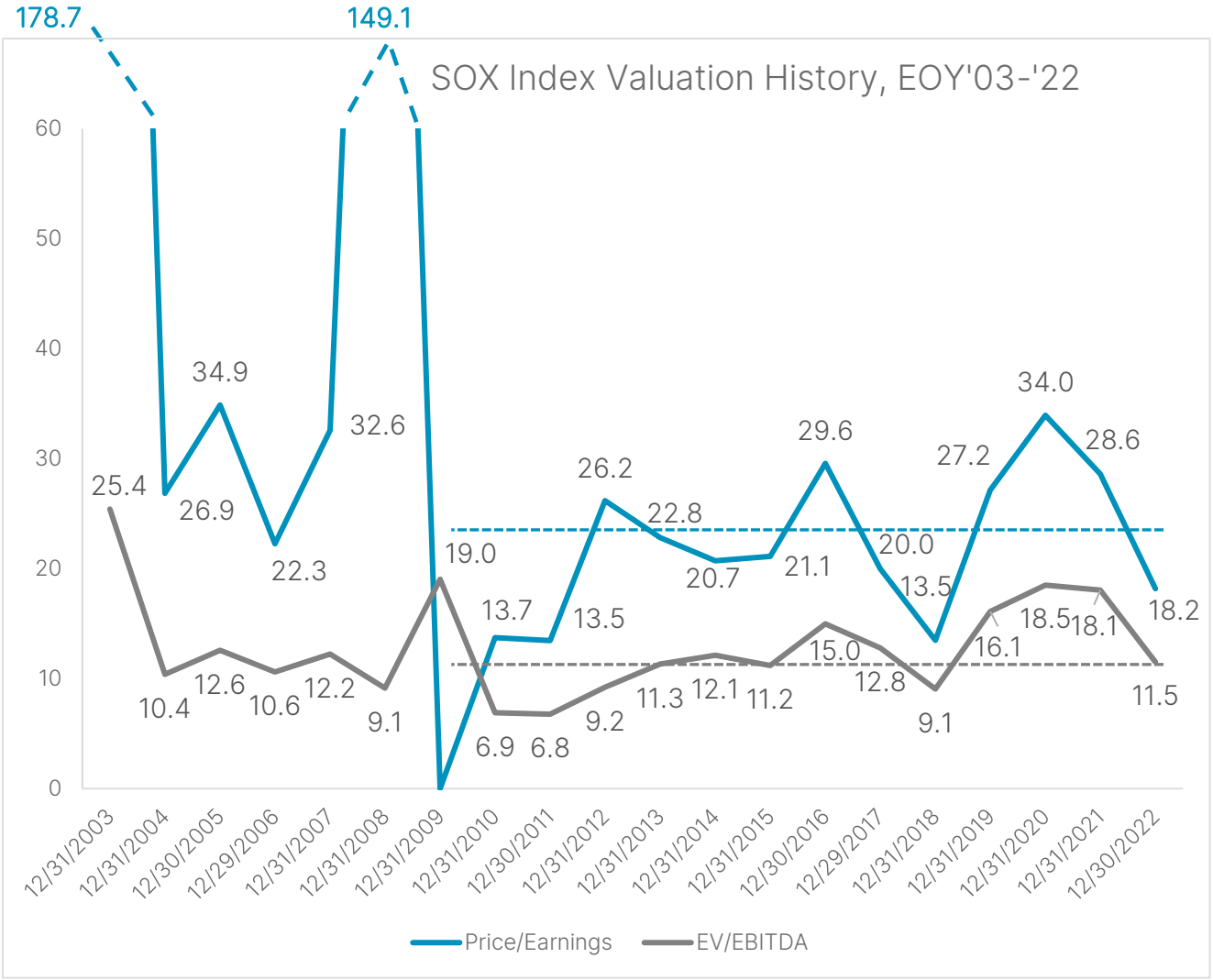
Current Fundamentals Remain Encouraging for Investors

Using the PHLX Semiconductor Index™ (SOX™) of US-listed semiconductor companies as a proxy for the global industry (given its nearly three decades of live history), one can clearly observe two trends that suggest fundamentals for the sector have changed for the better. Both operating and net margins are at or near record highs, and have been on a fairly steady uptrend since 2012 – much longer than previous cycles.



[14] https://www.vox.com/world/2022/11/5/23440525/biden-administration-semiconductor-export-ban-china

Looking at valuations over the same time frame, one can see the sector currently trading notably below its index-weighted average trailing P/E of 22.2 since year-end 2010, with a year-end 2022 P/E of 18.2. EV/EBITDA multiples are also very reasonable, at 11.5 vs. a long-run average of 12.2 since 2010. Yet today, the fundamental long-term growth drivers are arguably much more obvious for the industry than they were 10 or 15 years ago. In terms of overall earnings power, the massive spikes of P/E in the early years of the 21st century seem to be a thing of the past, when large chunks of the industry were subject to brutal cycles of inventory buildup, demand destruction, and heavy losses. With valuations almost 50% lower than their recent peak levels around year-end 2020, investors may have an unusually attractive opportunity to consider as an entry point.



As far as a real-time check on short-term fundamental trends before the next earnings season gets underway, we can look at perhaps the most important industry bellwether in Taiwan Semi – the leading foundry provider in both cutting-edge technology and overall volumes – which reported its latest quarterly results on January 12: "2022 was quarter after quarter of record-breaking numbers and ended up being a record-breaking year, with full-year revenue up 33.5% to $75.88 billion," despite "a tremendous slowdown on 7 [nanometer] orders due to weakness in PC and smartphones."[15] Margins "greatly improved due to price increases," reinforcing the viewpoint that the sector commands greater pricing power than ever before. And even with a forecasted slowdown in the first half of 2023, TSMC expects a recovery in the second half and growth on a full-year basis, despite forecasting the rest of the industry to contract slightly. In 2022, TSMC's US-listed shares dropped 38% in price.

[15]https://www.semianalysis.com/p/tsmc-says-they-will-sidestep-the

Summary

Certain segments of semiconductor demand have undeniably cooled off in the past year or so, just as supply chain disruptions are normalizing and boosting output. While the sector has gotten caught up in the broad-based correction impacting growth equities and especially Technology, numerous reasons exist for preserving long-term optimism. Several highly impactful secular trends, including the transformation of the automotive market with software and EV technology; the clean energy transition; the rise of artificial intelligence and its seemingly limitless applications; and the widespread adoption of cloud computing augur well for semiconductor companies of all stripes, from the major foundry players and cutting-edge design shops, to the various equipment providers and legacy analog chip suppliers. Other exciting trends outside of the scope of this paper, such as the cybersecurity industry's adoption of AI and the expansion of the gaming industry onto new platforms – including, eventually, the metaverse – are predicted to grow strongly in the current decade and beyond. With solid margins and pricing power, a normalization of supply chains, and historic support from multiple countries to subsidize future capex needs, the semiconductor industry is positioned for an extended period of exciting innovation and growth, easily earning its moniker as the "new oil of the 21st century."[16]

ETFs currently tracking GSOX include the HSBC Nasdaq Global Semiconductor UCITS ETF (London: HNSC).

Sources: Nasdaq Global Indexes, FactSet, Bloomberg.

[16] https://www.wsj.com/articles/chips-semiconductors-manufacturing-china-taiwan-11673650917