Reshoring and Restoring:

CHIPS Implementation for a Competitive Semiconductor Industry

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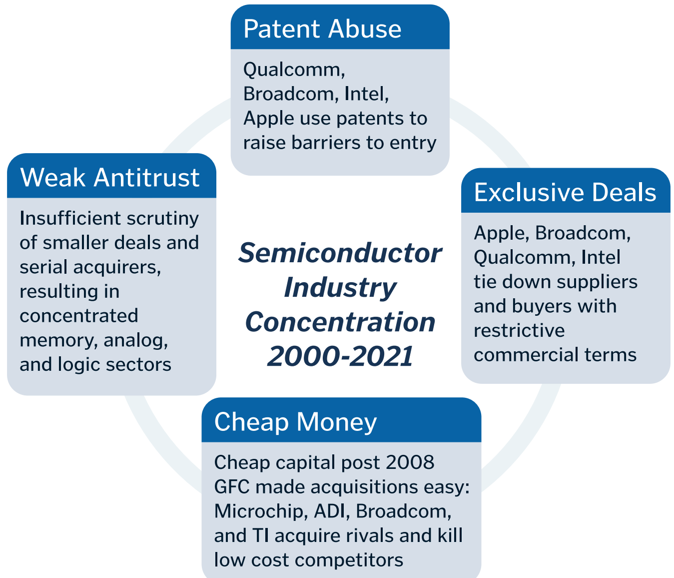


Passed in August 2022, the bipartisan Creating Helpful Incentives to Produce Semiconductors Act ("CHIPS Act") appropriated over $50 billion to support the domestic American semiconductor industry. It's passage is a critical step to rebuild our national security and economic resilience.

The CHIPS Program Office (CPO), a new Department of Commerce team charged with implementing the Act's industrial policy, is doing the right things to reshore semiconductor fabrication ("fab") capacity and rebuild supply chain resilience. Already, there is substantial investment in building domestic fabs to produce high-end semiconductors, and policymakers have undertaken key steps to ensure some level of domestic production by using public investment.

MONOPOLY OF LEADING-EDGE LOGIC CHIPS

However, the CHIPS Act faces two simultaneous problems of two different but related natures. First, at the leading edge of the industry, the direct fabrication of the most advanced logic chips has become monopolized by a single firm, Taiwan Semiconductor Manufacturing Company (TSMC), the bulk of whose operations are concentrated in geopolitically contested regions. This follows from decades of policy, in response to which American logic chip companies have turned to a "fabless" model of outsourcing all direct fabrication in response to financial pressures to avoid large capital expenditures. In this segment, the market power of TSMC and of American fabless chip companies could undermine the CHIPS Act's effectiveness.

The U.S. semiconductor industry used to be competitive and vibrant, but today it is too concentrated and is plagued by many of the dangers one would expect from a consolidated sector, notably shortages, weak innovation, high prices, and the pooling of risk by a monopolist. According to TrendForce's third-quarter 2023 financial analysis of foundry revenues, TSMC had 58% market share, nearly five times more than second-place Samsung at 12% share. Only two American firms were in the top 10: GlobalFoundries at third place with 6% share and Intel's new Foundry Services business at ninth place with 1% share. Based on these share estimates, the global foundry industry's Herfindahl–Hirschman

Index, a commonly accepted measure of concentration, is 3,621, which is considered highly concentrated.[1] While TSMC controls 58% of foundry revenue share, its profit pool share likely exceeds 80%.

Two decades of patent abuse, exclusive deals, cheap money, and weak antitrust enforcement have gutted what used to be a crown jewel of the American economy. While there is a need for significant capital investment to sustain the semiconductor business, this consolidation is the result of business practices, not economies of scale.

Since 2010, *intra-sector acquisitions have shrunk the number of independent U.S. semiconductor firms by over 40%*. Concentration and profits rose while innovation and resilience fell. The result is a handful of firms that exercise market power over the modern economy's most critical input.

Top U.S. Chip Makers declined by 44% since 2010

- AMD
- ~~Altera~~ (Intel, 2015)
- Analog Devices, Inc.
- ~~Atmel~~ (Microchip Technology, 2016)
- ~~Broadcom Inc.~~ (Avago merger, 2016)
- ~~Cypress Semiconductor~~ (Infineon, 2020)
- ~~Fairchild~~ (ON Semiconductor, 2016)
- Intel Corporation
- Lattice Semiconductor
- ~~Linear Technology~~ (Analog Devices, 2017)
- Marvell Technology Group
- ~~Maxim Integrated~~ (Analog Device, 2021)
- Microchip Technology
- Micron Technology
- ~~Microsemi~~ (Microchip, 2018)
- ~~National Semiconductor~~ (TI, 2011)
- NVIDIA Corporation
- ON Semiconductor
- ~~PMC Sierra~~ (Microsemi, 2016)
- Qualcomm Inc.
- Qorvo (MicroDevices + TriQuint, 2
- ~~Sandisk~~ (Western Digital, 2015)
- Semtech
- Silicon Laboratories
- Skyworks Solutions
- Texas Instruments
- ~~Xilinx~~ (AMD, 2022)

This monopoly problem is not natural, but is rather the result of policy. For comparison's sake, high-end memory chips require similar levels of manufacturing complexity and capital investments as logic chips; however, the memory market is intensely competitive. Micron, a U.S.-based, vertically integrated producer, has domestic fabs making the highest-end products. And in response to the CHIPS Act, Micron has committed to significant domestic investment, because if it did not, its competitors would seize market share.

1 TrendForce, "Latest Financial Reports of the Global Seven Foundries," November 22, 2023, https://www.trendforce.com/news/2023/11/22/news-latest-financial-reports-of-the-global-seven-foundries-how-will-the-next-stage-develop/. Author estimates.

MATURE-NODE RESILIENCE

The second problem — separate from leading-edge logic chip monopolization — is in the less-advanced portions of the industry, where shortages of low-cost, high-volume mature-node and lagging-edge chips led to a range of price increases and manufacturing shutdowns in the wake of the pandemic. Whereas monopoly and massive profits characterize the industry's leading edge, lagging-edge chips are often commoditized such that thin margins, price wars, and overcapacity destabilize the market. In response to these competitive pressures, chip makers sought low-cost locations to build their fabs, with China at the top of the list. In turn, China seeks to control this category as a first step toward total semiconductor industry dominance. This category of chips is under the greatest threat of foreign subsidies and dumping, particularly from state-supported Chinese chip makers. This presents a real challenge for the CHIPS Act to maintain a domestic manufacturing base given the high costs and low margins that any private-sector American producer could expect. It is a demand problem driven by the component sourcing strategies of the largest original equipment manufacturers (OEMs) like Apple, HP, Dell, Samsung, Google, and others. If buyers of these mature-node chips continue their globalized sourcing to chase the lowest-cost producer, then U.S. fabs supported with CHIPS funds will struggle.

The lesson from these different parts of the semiconductor industry — leading-edge logic, memory, and mature node/lagging edge — is that anti-monopoly policy and trade policy are both industrial policy. The goal of the CHIPS Act is to make sure that there is a robust base of fabs that give buyers multiple sources to supply chips. This report describes some of the key elements involved in constructing an anti-monopoly policy for the semiconductor industry, to ensure that the CHIPS Act is successful in fostering resilience in this critical sector. It explains how the semiconductor industry works, why the semiconductor industry got into trouble, and some of the key policy problems to address. We also offer solutions to restore the vitality of the industry.

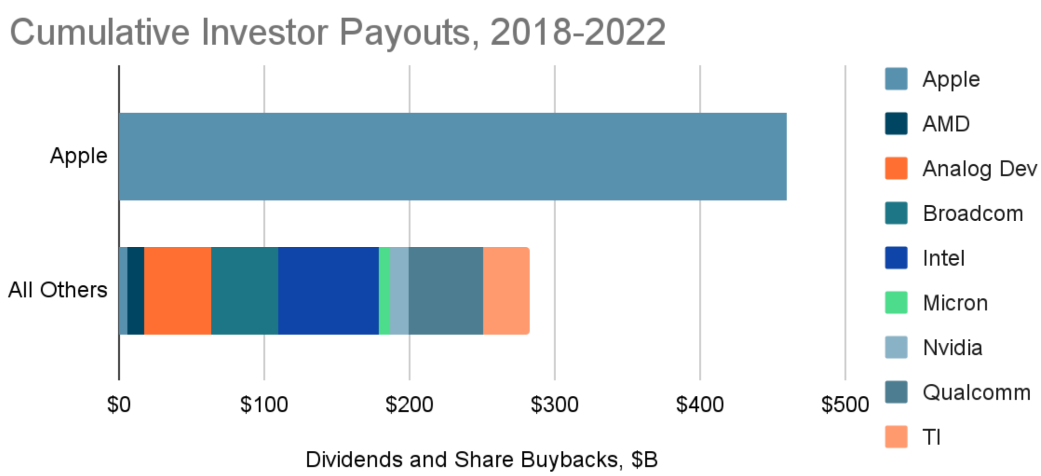
POLICY GUIDES MARKET STRUCTURE

The CHIPS Act addresses the symptoms of both problems — leading-edge monopolies and mature-node resilience — but not the root causes. Over the last five years, nine of the 10 largest U.S. semiconductor firms spent $239 billion in earnings on investor payouts[2] rather than building fabs, investing in R&D, and hiring workers (see graph below). When including Apple, the world's largest buyer of chips, *this capital misallocation leaps to a staggering $698 billion* — an amount 14 times the total CHIPS Act funding, or enough to *build 70 leading-edge fabs.*

2 "Investor payouts" refers to the combination of dividends and share buybacks. Data gathered from financial filings.

Defense-industry leader BAE runs a secure fab in New Hampshire that makes chips for fighter planes and other national security purposes. In December 2023, BAE was the first chip maker to receive a grant under the CHIPS Act — $35 million — to upgrade and expand capacity of this critical fab.[3] However, BAE not only spent $3.3 billion on investor payouts between 2021 and 2022 but its board approved another $1.9 billion share buyback in mid-2023.

If economies of scale were driving the needs of this industry, semiconductor firms would be building fabs to compete — as they used to do and as certain parts of the industry still do — instead of paying out shareholders.



Industrial policy in semiconductors is not new; indeed all semiconductor firm behavior is responsive to government rule-writing. Consider recent examples, both positive and negative:

- In 2015, antitrust enforcers allowed Intel to buy FPGA[4] leader Altera, providing the biggest logic chip company with a dominant position in the adjacent FPGA market.
- In 2017, the FTC sued Qualcomm over patents. The Pentagon, the Department of Energy, and the Antitrust Division opposed the FTC, and the Ninth Circuit ruled for Qualcomm.
- Antitrust enforcers allowed Microchip to build an anticompetitive moat by acquiring low-cost competitors Micrel (2015), Atmel (2016), and Microsemi (2018).

3 Department of Commerce, "Biden-Harris Administration and BAE Systems, Inc., Announce CHIPS Preliminary Terms to Support Critical U.S. National Security Project in Nashua, New Hampshire," December 11, 2023, https://www.commerce.gov/news/press-releases/2023/12/biden-harris-administration-and-bae-systems-inc-announce-chips.
4 See Key Terms section for a definition of FPGA.

- In 2011, antitrust enforcers allowed Texas Instruments to acquire National Semiconductor.
- Policymakers allowed Apple to monopolize smartphones and TSMC to exclude rivals in high-end fabs.
- Policymakers blocked the mergers of Nvidia-ARM, Broadcom-Qualcomm, and Tsinghua Unigroup-Micron.
- Policymakers granted permanent normal trade relations status to China in 2001 as part of its entry into the World Trade Organization, which allowed the offshoring of swaths of industrial production to that country, including the fabrication of mature-node chips.

In other words, the consolidated nature of the market, as well as the sectors where there is more competition, is a function of policy choices. Fortunately, there is ample policy space to address the private deployment of capital in this sector. The CHIPS Act provides the Secretary of Commerce broad discretion to "establish such rules, regulations and procedures that [she] considers appropriate."[5] This policy latitude should be applied to meet Congress' intent that "the Secretary [of Commerce] should allocate [CHIPS] funds in a manner that … strengthens the leadership of the United States in the semiconductor industry."[6]

We recommend a set of measured, targeted policies to restore semiconductor competition and innovation, ensuring American leadership for another generation:

1. **Incubate entrants with a goal of four independent, leading-edge logic foundries:** The CPO must fund fabs with the intent to increase competition and resilience. Research shows that four market participants is ideal to restore the benefits of competition. TSMC's dominance in the foundry market creates too brittle of a supply chain and opens the door for monopsonists, or buying monopolies, to manipulate tight fab capacity to exclude other fabless chip makers and new competitive entrants.
2. **Include Federal Trade Commission review and consultation in CHIPS program:** Given the role of anticompetitive behavior in creating today's concentrated market, the CPO should work in consultation with antitrust enforcers at the FTC to allocate CHIPS funding and setting criteria for funding recipients.

5 15 U.S. Code § 4659(a)7, https://www.law.cornell.edu/uscode/text/15/4659.
6 15 U.S. Code § 4652(d), https://www.law.cornell.edu/uscode/text/15/4652.

3. **Develop thicker markets:** New fabs need long-term demand contracts from U.S. government and private-sector buyers, foundries should operate under quasi-common carrier principles, and the industry should work toward standardized designs to lower switching costs.

4. **Pass legislation to require dual-sourcing:** To prevent another single foundry gaining market dominance, fabless firms should be required to dual-source their manufacturing among at least two foundries. This will help to "thicken" the market and balance supply.

5. **Address long-term incentives that underlie the fabless business model:** As noted above, a number of predatory practices have enabled the fabless model. The CPO and NIST must require more open patent and IP licensing, while disincentivizing extractive business practices like dividends and buybacks, which divert retained earnings away from workers, fabs, and R&D.

6. **Shore up domestic resilience for mature-node semiconductor production:** The CPO should work closely with the International Trade Administration (ITA) to monitor markets and promote the adoption of antidumping and countervailing duties (AD/CVD) against foreign dumping or subsidies for commoditized mature-node chips. The reality, however, is that AD/CVD tools will have limited effectiveness because final product assembly tends to happen in East and Southeast Asia, close to Chinese chip makers.

7. **Increase most-favored nation (MFN) rates on end-use chip products:** Tariffs can play a role to diversify final assembly. An increase in MFN rates on final electronic products like smartphones and computers will encourage some shift of electronics assembly away from Asia, giving domestic chip makers an incremental advantage.

8. **Pass legislation to create an American Semiconductor Supply Chain Resiliency Fee:** Protect mature-node chip manufacturers from predatory supply chain practices by assessing a fee on select consumer electronics that are not built with available American semiconductors. This new law would require original equipment manufacturers (Apple, Samsung, Dell, HP, Lenovo, Amazon, Google, Sony, LG, etc.) to source 30% of their products' aggregate semiconductors from U.S.-based fabs or pay a $10-$20 per device fee on all products sold in the U.S. with a retail price of $300 or higher. This new fee — the American Semiconductor Supply Chain Resiliency (ASSCR) Fee — would be managed by the CPO with the intent to protect domestic semiconductor makers from both unfair foreign competition and unethical OEM supply chain practices. Alternatively, many of the same objectives could be accomplished through a tax subsidy for chip buyers

(OEMs) that source their chips from domestic fabs, following the policy and funding structure of the Inflation Reduction Act.

9. **Pass legislation to establish demand-side subsidies for consumer electronics made with domestic chips:** As an alternative to the ASSCR, Congress could establish chip content subsidies on products sourced with a significant share of domestically made semiconductors. This demand-side subsidy structure is analogous to the Inflation Reduction Act's electric vehicle and heat pump subsidies. Electronics OEMs in price-sensitive consumer categories would risk margin and market share losses by sourcing non-U.S. chips.

Last, *Apple's role must be addressed*. It is the world's largest buyer of semiconductors and among the largest fabless chip makers. Apple dominates both ends of the semiconductor value chain, maintains tight control over product distribution, and chases away category competitors. Apple can either catalyze the CHIPS Act or continue to free ride on the U.S. taxpayer.

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INTRODUCTION

In mid-August, *The Information* reported that Apple and Taiwan Semiconductor Manufacturing Company (TSMC) struck a deal whereby Apple will get special pricing from TSMC for producing the most advanced logic chips, saving the iPhone maker billions of dollars, and giving it a competitive advantage over rivals. The deal also allows Apple to buy TSMC's supply of the most advanced 3 nanometer (nm) chips, so that Apple will have them a year or more before any of their competitors.[7] In fact, after Intel cancelled its TSMC orders, Apple bought TSMC's entire 3nm production capacity for 2023.[8] Other chip buyers will have to work around Apple's preferential position and TSMC's fab availability. In return, TSMC will get a multiyear commitment on their leading-edge fabs from Apple, which is by far TSMC's largest customer. This kind of deal is designed to fortify the market power of both a giant buyer and a giant seller. The consequence is a key national security vulnerability for the U.S., since TSMC has pledged to retain its key fabs in the hot zone of Taiwan. Without Apple's help, it is unlikely it would be able to do so. The Apple-TSMC deal excludes competitors from acquiring advanced semiconductors and from building competitive fabs elsewhere, and in doing so, Apple and TSMC are undercutting key parts of the Creating Helpful Incentives to Produce Semiconductors Act ("CHIPS Act").

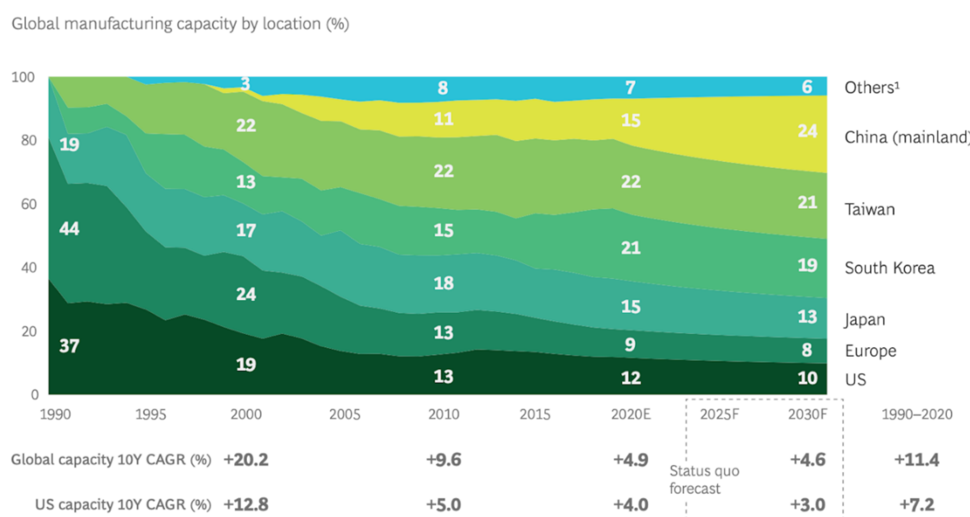

Figure 1: Boston Consulting Group analysis for Semiconductor Industry Assoc. 2020

7 Wayne Ma, "How Apple Will Save Billions of Dollars on Chips for New iPhone," *The Information*, August 7, 2023, https://www.theinformation.com/articles/how-apple-will-save-billions-of-dollars-on-chips-for-new-iphone.
8 Josh Norem, "Apple Reportedly Buying All of TSMC 3nm Wafers for 2023 Thanks to Intel Dropping Out," *ExtremeTech*, August 29, 2023, https://www.extremetech.com/computing/apple-reportedly-buying-all-of-tsmc-3nm-wafers-for-2023-thanks-to-intel.

The CHIPS Act passed in August 2022, appropriating over $50 billion to support the domestic American semiconductor industry. From 1990 to 2020, the share of global semiconductors manufactured in the U.S. declined from 37% to 12% (see chart). With chip shortages during the pandemic leading to price increases and shortages of other products, it was time to act. The CHIPS Act specifically addresses the offshoring of chip manufacturing, the fragility of chip supply chains, and the national security threat stemming from China's goal to gain semiconductor supremacy.[9]

The American economy is as dependent on these tiny, complex devices as previous generations were on oil. Semiconductor chips are pervasive across the U.S. economy, in agriculture, construction, health care, retail, warehousing, manufacturing, and much more. A typical car today uses more than 1,000 chips, while an electric vehicle needs over 2,000. Accordingly, just as the OPEC oil embargo coincided with inflation and economic stagnation in the 1970s, not only did chip shortages worsen the pandemic recession, but they were also a significant contributor to price increases in affected industries.[10] As a nation, we invest massive sums to protect the reliable supply of oil with policies like the strategic petroleum reserve, fuel economy standards, pipeline regulation, and drilling leases on public land. The strategic importance of semiconductors demands an analogous set of policy tools.

But why are we in a situation where key inputs are made in geopolitical hot spots? Two decades of mergers, acquisitions, exclusive deals, and patent abuse have resulted in a handful of firms that exercise market power over the modern economy's most critical input, pushing production offshore as they retained the profitable monopoly segments of the industry. Policymakers did nothing when AMD was forced to divest its direct chip manufacturing for lack of funding in 2009, nor when logic chip leader Intel was allowed to buy FPGA leader Altera in 2015, nor when American-developed EUV lithography technology was monopolized by Dutch firm ASML, nor when Broadcom monopolized network switches and broadband chips, nor when Apple monopolized smartphones. For the CHIPS Act to succeed, this trend must change. If the CHIPS Act included strong antimonopoly rules, we could break this kind of collusive arrangement between Apple and TSMC and ensure that private investment complemented public investment to produce a competitive and resilient market.

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9 Ann Cao, "China gave 190 chip firms $1.75B in subsidies in 2022 as it seeks semiconductor self-sufficiency," *South China Morning Post*, May 7, 2023, https://www.scmp.com/tech/tech-war/article/3219697/china-gave-190-chip-firms-us175-billion-subsidies-2022-it-seeks-semiconductor-self-sufficiency.

10 Federal Reserve Bank of St. Louis, "Did the Computer Chip Shortage Affect Inflation?," *On the Economy Blog*, May 10, 2022, https://www.stlouisfed.org/en/on-the-economy/2022/may/did-computer-chip-shortage-affect-inflation.

LEADING-EDGE LOGIC MONOPOLY

However, different sides of the industry are characterized by different problems. First, the most advanced segments, which make the leading-edge logic chips that run smartphones and data centers, are monopolized by a few firms. TSMC dominates the fabrication of these chips, with buyers like Apple and Nvidia controlling their own chip subcategories, despite themselves being wholly reliant on TSMC. The result has been high prices for logic chips, a brittle supply chain full of bottlenecks, and stifled industry innovation.

With a few exceptions, like trusted defense chips, policymakers have facilitated consolidation, offshoring, and a “capital-light” structure, an approach eagerly supported by Wall Street investors. The “fabless” model — in which a chip maker designs and markets the chips but outsources their actual fabrication — has led to the ability of semiconductor firms like Broadcom, Qualcomm, Nvidia, Apple, Amazon, Google, and others to avoid the expense of physical production and offload risk to the operators of fabs. Because of the market power embedded in patent laws and weak antitrust, such fabless firms were profitable enough to pay high prices to contract foundries to produce semiconductors while retaining high margins themselves.

But in shifting to a capital-light, offshore, fabless model, the U.S. chip industry’s scaling and innovation muscles have atrophied. More importantly, much of the industry developed deep dependencies on an oligopoly with physical plants located in East Asia. Two-thirds of the leading-edge fabs that build ultrafast, efficient sub-10nm chips are in Taiwan. The other third is in South Korea. TSMC and United Microelectronics Corporation (UMC) account for 47% of advanced 10nm node chips, and Samsung accounts for the rest. In 2022, Samsung was the first to launch 3nm chips, with TSMC close behind.

Intel, the last American leading-edge manufacturer and only fully integrated logic chip maker, originally said their 10nm chips would arrive in 2016, but they failed to ship until 2021. As of January 2023, there was no fab in the U.S. that could build sub-10nm node chips at commercial volume. In part supported with CHIPS funding, new U.S.-based fabs from TSMC and Intel will restart domestic leading-edge chip making by 2024.

There is a direct conflict between the current leading-edge logic semiconductor market structure and the CHIPS Act’s paired goals of (1) reshoring production and (2) building a resilient domestic supply chain. That is, the leading-edge chip makers will protect their market power and high product margins by raising barriers to entry and undermining efforts to increase foundry capacity and supply chain resilience. For these firms, more leading-edge fab capacity undermines their market power.

Fabless firms monopolize specific categories of logic chips: Qualcomm for wireless modems; Nvidia for GPUs; AMD and Intel for CPUs; and Broadcom for network and broadband chips. Broadcom freely applied surcharges to their leading-edge chips during the height of the pandemic because buyers had no substitutes. In fact, FY22 was

Broadcom's best year ever. Revenues jumped 21% to hit a record $35 billion. Net income was a record $11.5 billion on 35% profit margins (also a record). Broadcom achieved these exceptional financial results while cutting capital expenditures, as it continued to depend on the concentrated foundry market for fabrication. The truth is that a brittle supply chain may be bad for the U.S. economy, but it is great for fabless profits. More domestic leading-edge foundries means more chip competition and downward pressure on fabless margins. More domestic leading-edge foundries also means more chip-making capacity, which new entrants can use to bring much-needed competition. The CHIPS Act will be for naught if the leading-edge fabless firms' market power is left unchecked. This is why restoring leading-edge logic competition is critical to achieving CHIPS Act objectives and protecting long-term American leadership.

Historically, the concentrated state of the market is unusual. But even today, there are positive examples of what a competitive chip market looks like. The market for memory chips, even at the leading edge, is intensely competitive, and success in the memory segment demands both leading-edge technology and operational efficiency. With fierce competition and thin margins, memory firms find that the cost efficiency gained from vertical integration is the only path to profitability. Where the semiconductor industry is highly competitive, the fabless model is incompatible. The biggest U.S. memory maker, Micron Technology, has survived by holding onto its fabs and employees. Texas Instruments has had similar success in the competitive analog chip market, and it is similarly vertically integrated.

THE APPLE EFFECT

Apple, the world's most valuable company, which operates on a scale unlike any other, is by far the biggest buyer of semiconductors. It represents a particularly concerning and extreme example of this market power problem. The company has accelerated U.S. semiconductor offshoring by relentlessly chasing the cheapest suppliers and, as noted above, is working to build a market-power fortifying alliance with TSMC, with no regard for U.S. workers, geostrategic interests, or supply chain resilience. Apple's abnormally high profits reflect the unhealthy nature of the high-end logic chip market. To give a sense of scale, Apple has spent $458 billion since 2018 on dividends and share buybacks, an amount equal to nearly ten CHIPS Acts.[11]

Apple's willingness to accept supply bottlenecks reflects its monopsony power. As the world's biggest chip buyer, with supplier agreements that mirror the TSMC deal, Apple is always at the front of the line for foundry supply, ahead of other OEM competitors. Apple's ability to capture TSMC's entire 2023 manufacturing output for the world's most cutting-

11 From 2018 to 2022, Apple's financial data shows a total of $367 billion spent on share buybacks and $71 billion on dividends.

edge 3nm chip process is without compare in U.S. industry. It would be as if one plane manufacturer bought the entire supply of aluminum for a year. A brittle supply chain and chip scarcity increase Apple's market power by putting smaller, second-tier competitors under greater business continuity risk.

Apple's monopolization of smartphones means that TSMC has effectively one customer for the world's most important chip category. In the first half of 2023, the iPhone accounted for 55% of all smartphones sold in the U.S., but Apple captured over 85% of category profits. When embedded services like Apple support, Apple wallet, and others are included, some mobile-industry analysts believe that Apple captures over 100% of category profits. In turn, TSMC's leading-edge foundry dominance gives Apple the ability to obstruct new entrants attempting to build non-Apple chips on TSMC's most advanced process. The result is that iPhone prices rise and smartphone competition falls.

MATURE-NODE RESILIENCE

Separately from the monopoly of leading-edge chips, the lagging edge of the semiconductor industry, which produces "mature-node" semiconductors, is characterized by overcapacity, boom-and-bust cycles, and trade dumping. These dynamics contributed strongly to the COVID chip shortages, which were experienced almost exclusively in the mature-node segment. The most obvious problems for both leading-edge logic and mature-node chips may be similar — the offshoring of production and brittle supply chains — but the causes are fundamentally different. The costs of a fab for mature-node chips outstrip the anticipated returns that an American producer could expect, particularly when foreign nations subsidize local chip makers with cheap land, low-cost labor, and other incentives. Furthermore, with the time required to build a new mature-node fab, manufacturers are unlikely to expand capacity in response to short-term demand. The end result is a poor outlook for reshoring and manufacturing resilience, without the public support offered by the CHIPS Act, in conjunction with more comprehensive market governance.

KEY POINTS FOR IMPLEMENTATION

At the leading edge, successful CHIPS Act implementation will require both deconcentrating the foundry market and altering the incentives that have pushed American firms toward the fabless model in the first place. This means eliminating anticompetitive and exclusive practices, incubating new entrants (particularly into direct-chip fabrication), and creating more durable, "thicker" markets with more buyers and sellers. These goals can be accomplished through clear requirements for contracting practices, patent reforms, some legislative changes, and coordination with other federal agencies, particularly antitrust enforcers. Within operational guardrails — intentional policies to restructure these markets and generate real competition — many of these companies would favor reshoring production, dispersing their sources of supply, or even opting to invest in constructing and operating their own fabs. Without the ability to outsource created by restrictive IP rights, without the financial pressures from Wall Street to avoid capital expenditures, and without the market power to simply add their own markups on top of those of an external foundry, chip companies' business models would shift.

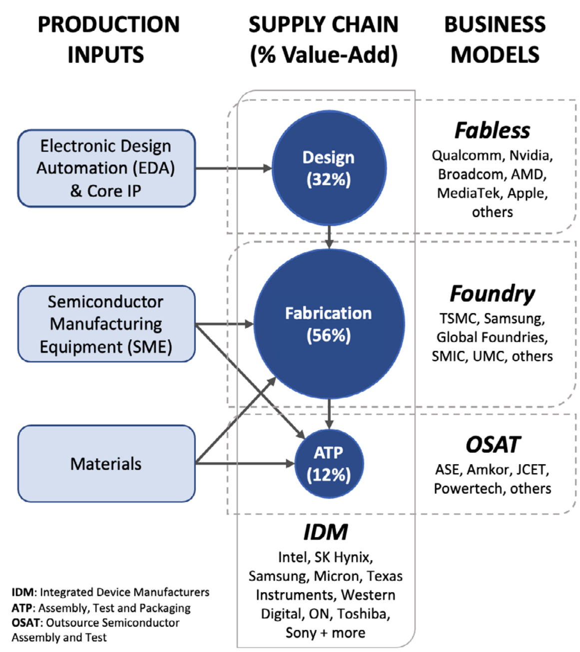
Semiconductor buyers also have a critical role to play, perhaps the most important in this ecosystem, and particularly with respect to mature-node chips. Without consistent, committed, long-term demand from chip buyers, the future of domestic, taxpayer-funded mature-node fabs will be under constant threat from low-cost overseas fabs. The introduction of a component sourcing fee — such as the American Semiconductor Supply Chain Resiliency Fee this report proposes — would nudge chip buyers (i.e., Apple, Dell, Samsung, HP, Amazon, Google, Sony, LG, etc.) to preference U.S.-built chips and penalize them if they continue the bad practice of chasing the world's cheapest chips at the expense of American resilience. For the industry's mature segments, successful implementation will require the subsidies and funding to reshore lagging-node fabs, which the CHIPS Act foresees, but also close coordination with the Congress and the U.S. trade agencies to implement targeted customs duties to ensure the survival of a domestic manufacturing base. This would include increased tariff rates for electronic products and antidumping and countervailing duties when subsidized foreign producers unfairly dump excess production of lagging-node chips onto world markets.

The report is outlined as follows: First, because the semiconductor industry and supply chain are complex and diverse, we explain the key segments of the semiconductor supply chain and the different business models that companies have adopted within those segments. Second, given industry complexity, we detail the chip categories — logic, memory, and analog — highlighting the particular problems of concentration in the logic market despite its technical similarities to the more competitive market for memory chips. Third, we provide a brief history of the semiconductor industry, the technology policies that inculcated its early growth, and how policy changes brought us to the current situation. We close by outlining the main provisions of the CHIPS Act and providing detailed recommendations for its implementation through interagency coordination.

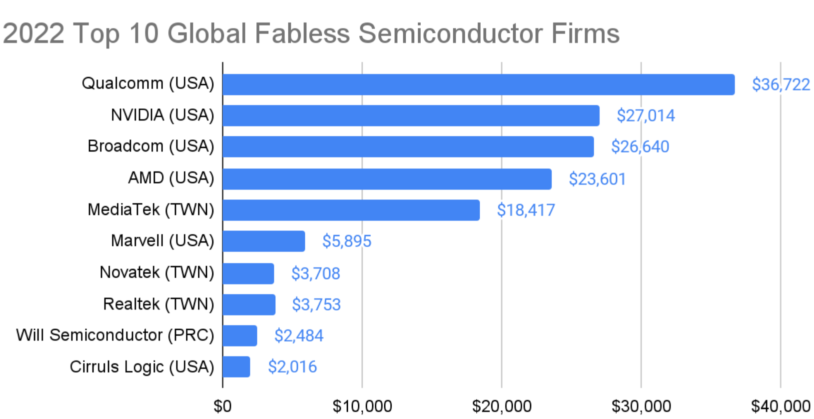
THE SEMICONDUCTOR SUPPLY CHAIN

The semiconductor supply chain is most easily understood divided into three parts:[12]

- **Design:** At this stage, the layout and topography of chips are designed using specialized software. These designs are patented.
- **Fabrication:** Fabrication is the physical manufacturing of silicon wafers and chips. Fabrication is expensive and capital-intensive, but it accounts for roughly 56% of the industry's total value added.[13]
- **Assembly, Test, and Packaging (ATP):** ATP is the final stage in manufacturing, in which chips are placed in casing for protection and interfacing with other components. Resembling consumer electronics assembly, ATP is relatively low margin, providing only 12% of the value added to chips.



There are several business models that chip companies adopt to fit into this supply chain, but the following three are most relevant to current policy problems:



12 Saif M. Khan, "The Semiconductor Supply Chain: Assessing National Competitiveness," *Center for Security and Emerging Technologies*, January 2021, https://cset.georgetown.edu/publication/the-semiconductor-supply-chain/.
13 Ibid., Appendix A.

Integrated Design and Manufacturing (IDM): In a traditional model of vertical integration, the company owns and integrates all stages of production: design, fabrication, and ATP. In the industry's early days of rapid growth and innovation, most firms adhered to this model, as do most memory and analog chip manufacturers today. For leading-edge logic chips, however, Intel and Samsung are the only remaining IDMs.

Fabless: Avoiding the expensive capital expenditures needed to build chip fabs, these companies specialize in designing, selling, and supporting chips. However, they rely on independent contract foundries to build their product. Qualcomm, Broadcom, Nvidia, Apple, and many others are considered fabless semiconductor firms, but the business model effectively did not exist prior to the 1990s.

Foundry: These companies specialize in the fabrication of chips, leaving other companies to design them and conduct final assembly. This business model has grown since the 1990s in conjunction with the fabless model. Today, the global leaders are TSMC (Taiwan), Samsung (South Korea), UMC (Taiwan), and GlobalFoundries (U.S.), with TSMC taking a wide lead over the rest.

Outsourced Semiconductor Assembly and Testing (OSAT): Firms that specialize in the final stage of assembly, test, and packaging (ATP) are predominantly low-margin firms in low-wage Asian countries. According to Accenture, 84% of OSAT revenues came from the Asia-Pacific region and just 16% from the U.S. The only U.S. firm among the top ATP providers is Amkor.

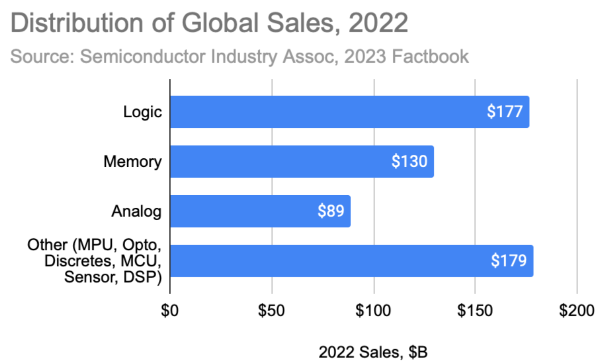
In addition to these core business models, there are other firms in the semiconductor industry that support various stages of the supply chain.

Electronic Design and Automation (EDA): The critical software needed to design chips is called electronic design and automation, and it comes from the United States. Cadence, Synopsis, and Mentor Graphics (now owned by Siemens) are the three leaders and are all located in the U.S. Without EDA software, fabless firms could not design semiconductors.

Semiconductor Manufacturing Equipment (SME): These are the firms that make the capital equipment needed to manufacture chips, and this segment is dominated by U.S. firms, with one exception. Lam Research, Applied Materials, and KLA are U.S. firms that sell to semiconductor makers globally. However, one critical manufacturing step, lithography, is dominated by non-U.S. firms: ASML (Netherlands), Nikon (Japan), and Canon (Japan). Nikon and Canon both produce deep ultraviolet (DUV) machines capable of etching down to 10nm. ASML also builds DUV machines, but critically it is the only manufacturer of next-gen extreme ultraviolet (EUV) machines that can design 3nm chips. While this problem is outside the scope of this report, as a result, for the very leading-edge logic chips, there is a single company capable of making the necessary capital equipment.

SEMICONDUCTOR DEVICES AND FIRMS

While the modern economy depends on semiconductor chips as a critical input, they are not a homogenous product. Chips represent a diverse product category ranging from simple commoditized devices that cost pennies to sophisticated processors that power supercomputers.



There are three primary categories of semiconductors: logic, memory, and analog.[14] Roughly 40% of semiconductor value-add is attributed to logic and about 25% to memory (see chart).

LOGIC CHIPS

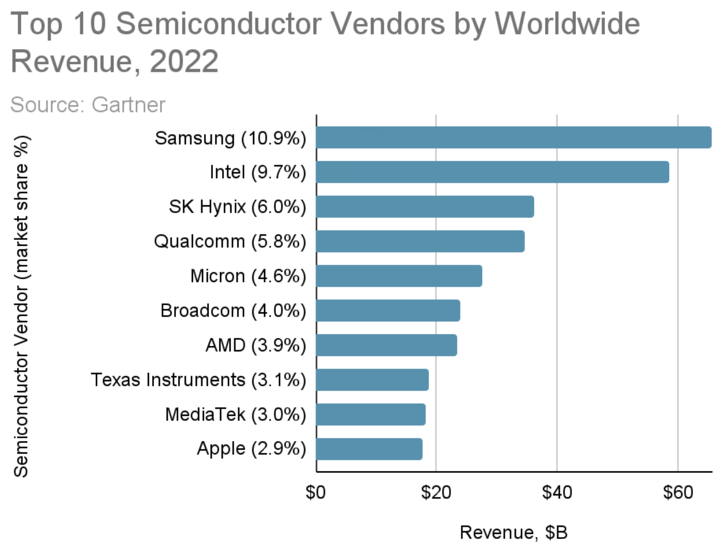
Logic chips are the "brains" of computers that process information to complete computing tasks. Logic chips are the essential component of computers, smartphones, and data centers, for both civilian and military uses, and they are currently the most specialized and expensive category of chips.

Much of our analysis focuses on logic chips — which account for most of the industry's revenue — because the market for leading-edge logic is highly concentrated, with competition weak across most of the category. Despite there being many logic chip firms, any given logic market niche is highly concentrated and often dominated by a single firm, such as Broadcom for broadband chips. The table below provides a summary.

Logic Chip Use[15]	Market Leaders
PCs, servers, data centers	Intel, AMD, Apple
Smartphones, IoT	Qualcomm, MediaTek, Apple, Samsung
Networking, broadband	Broadcom, Marvell
Graphics, data centers, AI	Nvidia, AMD, Intel
Utility processors (FPGA)	Xilinx/AMD, Altera/Intel, Microchip, Lattice

14 For the purposes of this paper, we will not focus on important but second-tier semiconductor categories like optoelectronics, discretes, MCUs, sensors, and DSPs. These are included in the "Other" category in the chart above.
15 Includes specialty logic chips, also known as ASICs.

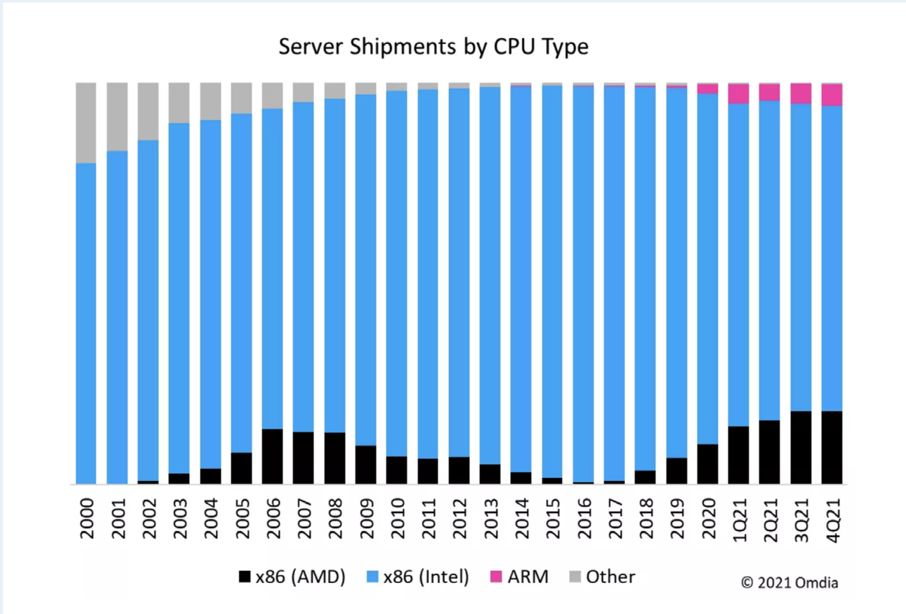
There are also several types of logic chips. The most well known are central processing units (CPUs). For 40 years, PC and server CPUs have centered on Intel's x86 architecture. Smartphones and other mobile devices rely on the ARM architecture, which is less powerful but more battery efficient and flexible than x86. Thanks to iPhone sales volume, Apple's ARM-based mobile processor chip is one of the world's largest in this category.



Graphics processing units (GPUs) are a different type of logic chip. Originally a niche category that helped gaming consoles and Wintel PCs better render images, the parallel processing abilities of GPUs have made them a mainstay of data centers and AI processing. Nvidia has been the leading GPU company for over a decade, with AMD close on its heels. Intel is a new entrant. GPUs are not based on x86 or ARM; instead, each GPU maker has its own proprietary ISA. This lack of interoperability among GPU chip makers raises barriers to entry and makes it easier for Nvidia to cement its price-maker position.

The AI Meteor Causes Server CPU Mass Extinction

When Nvidia announced its quarterly results on May 24, 2023, a generational seismic event tore through the semiconductor industry. The explosion of generative AI services has resulted in massive demand for GPUs, and everyone wants Nvidia's chips. The impact of this compute architecture shift will manifest in data centers. There is $1 trillion invested in the world's data centers, and the architecture is nearly all x86 CPUs, with Intel holding roughly an 80% share (see chart). Data center investments have a four-year lifespan, which means $250 billion is spent annually. Industry analysts agree that these data centers will shift to support AI — rather than web-based — services, which means x86 CPUs will be replaced with GPUs. This is an existential threat to Intel, which makes 30% of its revenue from data center CPUs and only recently joined the GPU category. Compounding Intel's problems are the moves by Big



Tech — Amazon, Google, Microsoft, Facebook — to design and build their own CPUs and GPUs. AMD is in a better position than Intel because it holds the No. 2 share position in server CPUs and No. 2 share in GPUs. Intel's slow move into GPUs, because this category threatened its highly profitable server CPU business, is an *Innovator's Dilemma* case study. This server CPU mass extinction event will make Intel's turnaround much harder.

As of September 2023, financial markets valued fabless AMD, which generated $24 billion in revenues in 2022, at $177 billion, and fabless Nvidia, with 2022 revenues of $27 billion, at $975 billion. Vertically integrated Intel, with 15 fabs around the world and generating $63 billion in 2022 revenues, was valued at $153 billion, less than the asset value of its strategically important fabs. This example reflects Wall Street's current understanding that industrial policy, despite the CHIPS Act, will remain oriented around fabless "capital-light" firms with market power.

	2022 Revenue	Total Assets (as of 12/31/22)	Market Valuation (as of 9/1/23)
Nvidia (fabless)	$27B	$41B	$1,192B
AMD (fabless)	$24B	$67B	$177B
Intel (IDM)	$63B	$182B	$153B

The final logic category is field-programmable gate arrays (FPGAs), which are utility processors used in a variety of applications. They are unique for their versatility and flexibility, and are favored in telecommunications, defense, industrial automation, medical devices, and other low-volume, compute-intensive applications. Xilinx is a leader but was recently acquired by AMD. After acquiring Altera in 2015, Intel became the second-biggest FPGA chip maker. Two other U.S. firms, Microchip and Lattice Semiconductor, are a distant third and fourth.

MEMORY AND ANALOG CHIPS

As the name implies, memory chips are used to store data on which computations are made. Leading-edge memory chips have similar design precision to leading-edge logic chips, forcing memory firms to make massive capital investments in new fabs. In this market, vertical integration and operational efficiency via the IDM model are critical to success.[16]

There are two major memory categories: DRAM and flash (aka NAND). DRAM is a larger market than flash and is dominated by the Big Three: SK Hynix, Samsung, and Micron. The Big Three also compete in the flash category, along with Japanese firm Kioxia and U.S.-based Western Digital.

Analog is a vast category of devices that generally function as the interface between the physical and digital worlds. They tend to be simpler devices than logic and memory chips, and include temperature sensors, motion detectors, backup cameras, radio frequency chips, power management integrated circuits, amplifiers, and much more. For analog chips, the category leader, Texas Instruments, makes over 80,000 products with a focus on the automotive, industrial, and consumer electronics sectors.[17] Of the top 10 analog firms, six are U.S.-based, three are European, and one is Japanese. Analog firms generally operate their own fabs and are under less market pressure to stay on the cutting edge like logic and memory.

Memory and analog chips represent the competitive side of the semiconductor industry. In the memory segment, chips are standardized in a way that is not true for logic chips, so the switching costs for buyers are substantially lower. As a result, margins are thin and competition is intense. These distinctions, however, are the result of how each market segment has developed over time.

16 Kioxia and Western Digital have formed a joint venture to make flash memory, further concentrating the market. Recent rumors suggest they are considering a merger.

17 Major semiconductor providers to the automotive industry are NXP (Netherlands), onsemi (U.S.), Infineon (Germany), and ST Micro (Switzerland/France/Italy).

SHORT HISTORY OF AMERICAN SEMICONDUCTOR INNOVATION AND COMPETITION

For the first several decades of the industry, American semiconductor companies relentlessly innovated and competed to secure their place in the market. Under conditions of relatively weak intellectual property (IP) rights, a very powerful buyer in the U.S. government, and strong antitrust enforcement, chip companies needed to constantly develop better chips at lower cost to survive. However, in the 1980s and 1990s, policymakers strengthened IP protections, relaxed antitrust policy to facilitate consolidation, tolerated what were previously unlawful exclusive business practices, and altered trade policy to enable the outsourcing of direct manufacturing. These choices led to the "capital-light" model valued by Wall Street.

THE EARLY SEMICONDUCTOR MARKET

The semiconductor industry was born at Bell Labs in 1947 with the invention of the first transistor. The U.S. government's industrial strategy in response to this innovation was markedly different from that of recent decades. Across this early period, the federal government used a mix of supply incentives, demand supports, antitrust policy, and regulatory coordination to create a robust and innovation-focused competitive ecosystem.[18]

Aggressive antitrust action by the Department of Justice (DOJ) compelled AT&T to broadly license their patents to competitors. In 1952, $25,000 gave anyone access to Bell Labs' entire semiconductor patent portfolio, and 40 firms wrote a check that year.[19]

Even as early pioneers like Texas Instruments (TI) jumped into the lead, developing the first silicon-based semiconductors in 1954, an ecosystem of successful competitors entered the business: Fairchild, IBM, Motorola, RCA, Raytheon, National Semiconductor, and dozens more launched chips in the late 1950s.

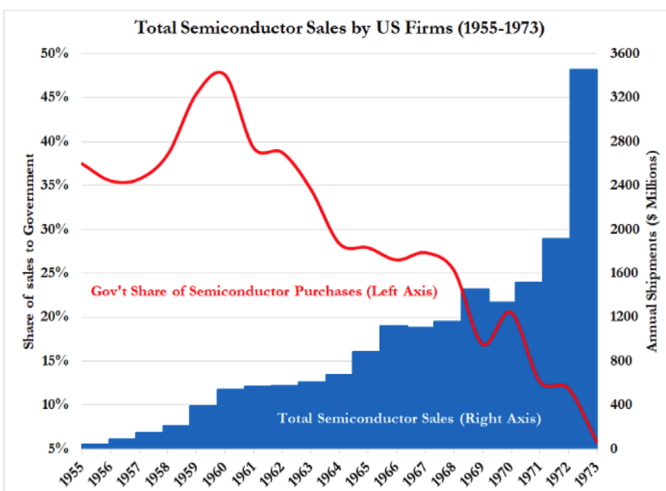


Figure 2 - Williams and Khan, A Brief History of Semiconductors, March 20, 2021

18 Alex Williams and Hassan Khan, "A Brief History of Semiconductors: How the US cut costs and Lost the Leading Edge," Medium, March 20, 2021, https://employamerica.medium.com/a-brief-history-of-semiconductors-how-the-us-cut-costs-and-lost-the-leading-edge-c21b96707cd2.

19 David C. Mowery, "Federal Policy and the Development of Semiconductors, Computer Hardware and Computer Software: A Policy Model for Climate Change R&D?," NBER Working Paper, May 2011, https://www.nber.org/system/files/chapters/c11753/revisions/c11753.rev0.pdf.

The Department of Defense (DoD), with a budget equal to roughly 9% of GDP in the early 1960s, provided reliable demand against which early innovators could source capital to build vertically integrated semiconductor manufacturing facilities. The pull of strong demand for chips proved invaluable to early innovators. TI's breakthrough integrated circuit was largely funded in-house, but the military immediately committed to large-scale purchases.[20] Further, the DoD required dual-sourcing, which meant other firms retained market share, and also meant that Bell Labs and other large-scale R&D departments were required to publish their technical details and widely license their technology to ensure that the building blocks of innovation were available to all firms with which the DoD contracted.[21]

FOREIGN COMPETITION

Just as growing private-sector demand for chips exceeded DoD's spending by the late 1960s, the government's share of semiconductor purchases declined from a high of 47% in 1960 to just 5% in 1973. The 1970s also saw the rise of Japanese semiconductor firms. Backed by industrial policy, trade protections, and cheap capital, NEC, Hitachi, Toshiba, and others captured market share and overwhelmed the U.S. leaders, particularly in the market for memory chips. Intel, founded in 1968 to make DRAM (memory), abandoned the memory market in 1971 and shifted to logic chips. By the end of the 1970s, Japanese memory chips were higher quality and lower cost than those from U.S. firms.

The 1980s were a dark period for the American chip industry. Fairchild sold its DRAM business to Schlumberger. National Semiconductor sold to Hitachi. IBM spent $250 million to bail out Intel. By 1986, seven out of nine U.S. DRAM firms had quit the category.[22] The Defense Science board believed that Japan was on its way to dominating the world's information market.[23] The market share of U.S. semiconductor firms dropped to 38% in 1988. The U.S. responded with antidumping rules, trade protections, and the SEMATECH consortium.

Founded in 1987, SEMATECH was a public-private partnership funded by the U.S. government and 14 U.S. semiconductor firms, including IBM, Intel, AMD, Motorola, and TI. The goal was to share the burden to accelerate leading-edge manufacturing technology so that the U.S. industry could collectively respond to the Japanese. By the 1990s, SEMATECH had developed processes to improve yields and reduce costs. The consortium's most

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20 Ibid., p. 165.
21 Alex Williams and Hassan Khan, "A Brief History of Semiconductors: How the US cut costs and Lost the Leading Edge," Medium, March 20, 2021, https://employamerica.medium.com/a-brief-history-of-semiconductors-how-the-us-cut-costs-and-lost-the-leading-edge-c21b96707cd2.
22 Leslie Helm, "In the Chips: America's semiconductor industry again leads the world. But new Asian competitors are gaining strength. And you can never count Japan out," *Los Angeles Times*, March 5, 1995, https://www.latimes.com/archives/la-xpm-1995-03-05-fi-39145-story.html.
23 Ibid.

important project was advanced lithography. Using fundamental research from the U.S. national labs with support to commercialize the technology from the big U.S. firms, extreme ultraviolet (EUV) lithography technology emerged from SEMATECH in the 1990s. Still concerned about Japanese firms, SEMATECH invited a Dutch firm, ASML, to join in 1999. ASML spent two decades perfecting EUV and is today the one and only firm that makes this equipment, which has become essential for high-end logic chips.

U.S. memory chip manufacturers recaptured their global leadership in the 1990s with the success of memory firms like Micron and Western Digital. These companies formed and expanded in a competitive market, and it shows in their business model to this day.

Micron Leads the Way

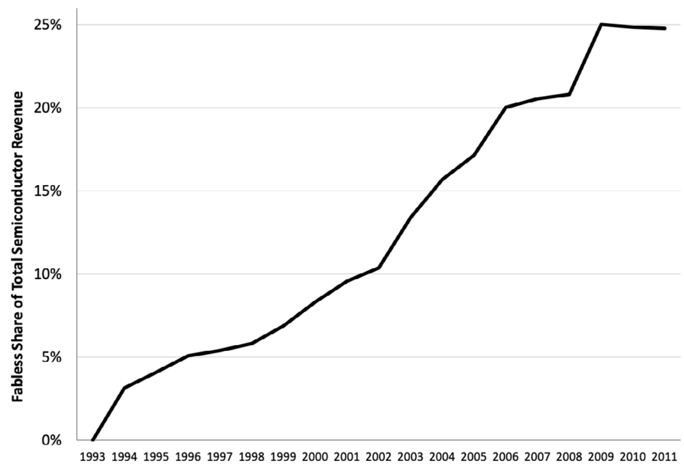
With an investment from Idaho's potato king, J.R. Simplot, four engineers launched a memory chip business in Boise in 1978, when leading American firms were running away from memory because of intense Japanese competition. But Simplot understood cyclical commodity businesses and leaned in.

Fast forward to 2023, and Micron is going strong despite the worst industry slump since 2001. In fact, the question to ask is how Micron survived. Micron's South Korean competitors, Samsung and SK Hynix, receive significant government support and benefit from vertical integration. The Chinese government steals Micron's trade secrets to jump-start their national champion, YMTC. Apple, the world's largest memory buyer, struck a massive deal with YMTC to undercut Micron and Samsung. The Department of Commerce smartly added YMTC to the Entity List to put a stop to Apple's toxic sourcing strategy.

Memory is the most competitive corner of the semiconductor business because these chips are commoditized and switching costs are low. Unlike Qualcomm, Broadcom, and others, Micron remains vertically integrated. The IDM model yields the lowest cost structure. There is no large memory firm that relies on outsourced foundries. Micron reinvests most of its earnings in people, R&D, and fabs. Dividends and share buybacks are relatively small. With CHIPS Act support, Micron will spend $100 billion to build a megafab in Syracuse and $15 billion to expand its Boise R&D center. These new facilities will be the first new U.S. memory fabs in 20 years. If there is a model for the future of U.S. semiconductors, then Micron is it.

GLOBALIZATION AND LOGIC MONOPOLY

Figure 3: Growth of the Fabless Business Model



Authors' calculations based on data from the Global Semiconductor Alliance (GSA) and Semiconductor Industry Association (SIA)

Figure 3 - Williams and Khan, A Brief History of Semiconductors, March 20, 2021

Despite their success, Japanese memory firms missed the transition to logic chips driven by the 1990s demand for consumer PCs. With the shift to logic chips came greater concentration and more anticompetitive practices. This happened along several dimensions, facilitated by changes to global trade rules, financial markets, and intellectual property rights. In this environment, chip companies could divest from fabrication and rely on external, foreign foundries. Many found ways to dominate particular chip market segments through exclusive dealings or IP restrictions. Most now face financial pressures to make significant investor payouts in the form of buybacks and dividends.

The 1990s also saw the rise of the foundry and fabless business models. Silicon Valley startups without the capital to build fabs would design and sell their niche chips but leave the manufacturing to others. The high cost of leading-edge fabs priced out all but a few of the biggest vertically integrated semiconductor makers like Intel, TI, AMD, and Micron.

There was also a series of changes to intellectual property rules, formed in parallel with a massive expansion of industry IP licensing practices, which helped create the fabless model.[24] Previously, antitrust rules in the United States placed strong restrictions on how companies could license their technologies, largely requiring fair terms that would allow easy entry and competition among licensees.[25] IP protections for the topography and design of silicon chips ("mask work rights") were largely created in 1984 by the Semiconductor Chip Protection Act, bolstered by the 1994 launch of the World Trade Organization and

24 See, for example, "Understanding the Semiconductor Intellectual Property (SIP) Business Process," Fabless Semiconductor Association (now Global Semiconductor Alliance), https://www.design-reuse.com/news_img/Handbook_Understanding_SemiIP_BusinessProcess.pdf; Sumita Sarma and Sunny Li Sun, "The genesis of fabless business model: Institutional entrepreneurs in an adaptive ecosystem," *Asia Pacific Journal of Management* 34 (2017): 587–617, https://link.springer.com/article/10.1007/s10490-016-9488-6.

25 Erik Peinert, "Intellectual Property and the Fissured Economy," *American Affairs*, 7(2): 3–22, https://americanaffairsjournal.org/2023/05/intellectual-property-and-the-fissured-economy/.

its Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS), which internationalized new and stronger IP protections.

Altogether, these shifts facilitated the fabless business model and the outsourcing of the labor- and capital-intensive segments of the industry, and contributed to a broader pattern in the industry of restricting entry through unfair IP licensing terms. The first foundry was TSMC, founded in Taiwan in 1987. By outsourcing the actual manufacturing of chips, fabless American firms found a capital-light approach to growth. This model rapidly expanded from nothing in 1993 to a 25% share of chip output by 2009.[26] The fabless model does allow many firms to specialize in the expensive, complex, and time-consuming task of chip design, and it makes sense for certain areas of the chip industry, like bespoke chips in niche sectors, startups with innovative designs, or lines of business where there isn't yet demand for high production volumes.

But fabless production eliminates many of the operational efficiencies that come from vertical integration with the traditional IDM model, and it shrinks the know-how of fabless firms. There are efficiencies from integrated design and fabrication — standardization, control, guaranteed interoperability — that the fabless model has not entirely eliminated. Likewise, two sets of firms — the fabless firms and the foundries — each add their own markups to the final price of the chips. In the market for logic chips, as outlined below, both foundries and fabless firms have substantial market power, so this is a real cost concern even beyond the threat to resilience from outsourcing fabrication. In short, the shift to the fabless model depended on both the acquisition of market power and the lack of competitive pressure, supported by the fact that the more competitive market for memory chips still abides by the cost-competitive IDM model. Fabless designers compete based on the strength of patents and exclusivity of their commercial agreements, instead of the institutional capacity of their productive facilities, their ability to deliver predictably to customers, and the excellence of their engineers.

MARKET POWER AND RENTS

The semiconductor industry, and the leading-edge logic segment in particular, is rife with monopolists, monopsonists, and anticompetitive practices. Broadcom behaves more like a private equity firm than a semiconductor maker, using its monopoly in networking switches to leverage into new categories, disregarding its FTC (and EU) consent agreements to the contrary.[27] Qualcomm exploits aggressive patent licensing terms. Apple uses its market

26 David Byrne, Brian K. Kovak, and Ryan Michaels, "Price and Quality Dispersion in an Offshoring Market: Evidence from Semiconductor Production Services," National Bureau of Economic Research, November 2013.
27 Federal Trade Commission, In the Matter of Broadcom, Inc., Docket No. C-4750, Decision and Order (November 4, 2021), https://www.ftc.gov/system/files/documents/cases/1810205c4750broadcomfinalorder.pdf.

power to exclusively control cutting-edge components and secure preferential pricing. Industry analysts estimate that in 2022, Apple captured 85% of the global mobile-phone profit pool on 18% of unit share.[28] Only Samsung smartphones compete with Apple, because only Samsung has protected access to internal supplies of processors, displays, cameras, and memory. The mobile-phone industry, the world's most important compute category, retains little of its former competitiveness.

However, the chip market does not need to be structured in this way. By comparing the memory and logic sectors, we have a useful reference by which to understand how logic firms block new entrants and flex their market power.

Memory chips have similar levels of manufacturing complexity as logic chips, and they also require huge capital investments. In anticipation of CHIPS Act grants and credits, memory chip maker Micron committed $115 billion through the end of the decade to build leading-edge memory fabs in the U.S. As discussed above, memory chips have low switching costs and are highly commoditized. However, all memory makers follow a vertically integrated IDM business model. The sector's competitiveness results in thin margins, and the value chain for a profitable memory chip cannot support an independent foundry's high margins.

By contrast, in leading-edge logic, fabless firms must contend with margin-stacking along their supply chain, a problem that IDMs — whether analog, memory, or logic — avoid. The only way to compensate for these additional expenses in the supply chain is for fabless firms to charge more. If Apple, Qualcomm, or Broadcom operated in a competitive market, then margin pressures would compel them to vertically integrate like a memory or logic chip maker.

AMD and Intel provide another comparison in the x86 logic chip subsector. AMD is now fabless, while Intel remains the largest IDM. In general, AMD chips are more expensive than comparable Intel ones. Because of Intel's execution challenges and leading-edge CPU delays, AMD has some of the best CPUs and can maintain margins while absorbing TSMC's costs. If Intel can get back to delivering leading-edge chips on time, AMD is likely to come under severe margin pressure.

Current policy, which facilitates consolidation, turns semiconductor production into a winner-take-all market. Some claim that it takes over $500 million to design a 5nm chip.[29] Only a few firms can afford this investment, and only two foundries can build it. A 5nm

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28 Counterpoint Research, "2022 Global Smartphone Shipments Lowest Since 2013; Apple Regained No. 1 Rank with Highest-Ever Operating Profit Share of 85%," February 3, 2023, https://www.counterpointresearch.com/insights/2022-global-smartphone-shipments-lowest-since-2013-apple-regained-no-1-rank-highest-ever-operating-profit-share-85/.
29 Joel Hruska, "As Chip Design Costs Skyrocket, 3nm Process Node Is in Jeopardy," Extremetech, June 22, 2018, https://www.extremetech.com/computing/272096-3nm-process-node.

chip is demonstrably better than a 7nm one in terms of both compute power and energy efficiency. If Qualcomm's competitor MediaTek is unable to design and build a 5nm mobile-phone chip, then Qualcomm has no competition and can increase the margins on its leading-edge chips. In turn, these higher margins give Qualcomm the resources to pay TSMC's premium and repeat the cycle at the 3nm process, and again at the 2nm process. Competition is needed to reduce fabless economic rents and break the cycle.

FOUNDRY CONCENTRATION

One of the other main consequences of the fabless model is that Taiwan-based TSMC absolutely dominates the foundry sector. No other contract foundry is close. In 2022, it captured roughly 55% of the sector's total revenues. Driving much of that volume is the business of American fabless firms like Apple, Qualcomm, AMD, and Nvidia. Sixty-four percent of TSMC's sales came from U.S. fabless firms, with Apple far ahead and representing about one-quarter of total revenues. TSMC is also highly profitable, capturing 60% gross margins in 2022, and its net revenue was more than all the other foundries combined (see table).

	TSMC	Intel	GlobalFoundries
2022			
Revenue (chg YoY)	$76B +33%	$63B -16%	$8B +23%
Gross Margins	60%	43%	27%
Operating Margin	50%	4%	14%
2021			
Revenue	$57B	$79B	$7B
Gross Margins	52%	55%	15%
Operating Margin	41%	25%	-1%

TSMC announced in March 2021 that they would invest a record $100 billion over the next three years to expand chip fabrication capacity and invest in R&D, including building their first fabs in the U.S., Japan, and Germany. With the exception of Samsung's modest foundry business, there is little competitive pressure on TSMC. GlobalFoundries, the only U.S. contract foundry firm, is far behind TSMC and not able to produce the most advanced logic chips. While capital equipment for fabrication has become more expensive, the industry has nonetheless consolidated at an alarming rate, and the number of firms able to produce the most advanced chips has dwindled (see table). Given these scale challenges, TSMC's investment is really an effort to increase its lead over other foundries and therein expand market share.

Foundry Concentration by Process Node, as of mid-2023[30]

Panasonic					
ST Micro					
IBM					
Infineon	**IBM**	**UMC**	**UMC**		
GlobalFoundries	**GlobalFoundries**	**GlobalFoundries**	**GlobalFoundries**		
Samsung	**Samsung**	**Samsung**	**Samsung**	**Samsung**	**Samsung**
TSMC	**TSMC**	**TSMC**	**TSMC**	**TSMC**	**TSMC**
Intel	**Intel**	**Intel**	**Intel**	**Intel**	**Intel**
32/28nm	**22/20nm**	**16/14nm**	**10nm**	**7nm**	**5/3nm**

Can Intel Recover?

Founded in 1968, Intel has been the backbone of the American semiconductor industry since the 1980s. Their x86 microprocessor architecture became the de facto standard that powered the global PC revolution. They rode PCs for three decades and were the undisputed leader. Intel made the fastest CPUs, had the most efficient fabs, built a powerful brand, could produce at massive volumes, and dictated the industry's direction. Even Apple switched to Intel CPUs in 2006. Their market dominance also resulted in a number of FTC and DOJ actions. However, they were late to smartphones. Despite billions of dollars in acquisitions and investments, Intel failed to gain a foothold. Mobile passed PCs in 2012 as the biggest semiconductor category.

Intel is not well. For the last decade, they have struggled to ship chips on time — sometimes as much as five years late. Their 10nm chips were a disaster. Intel CPUs are no longer the world's undisputed leader, and AMD is taking market share. Intel was kicked out of Apple's PCs in 2020. Financially, Intel had $9 billion in negative free cash flow in 2022 but still paid $6 billion in dividends. They have wasted tens of billions of retained earnings. Intel's first quarter 2023 results were the worst in company history.

More than any other U.S. semiconductor company, Intel's health matters. Their turnaround is progressing but slowly. To save cash, they finally slashed their dividend by 66% in February 2023. They returned to profitability in the second

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30 Process node is an imperfect measure of leading-edge chips. Intel claims, and most industry-watchers agree, that the "Intel 4" 7nm process outperforms TSMC's 5nm process and is on par with 3nm chips from both Samsung and TSMC. The next-gen "Intel 3" is a 5nm process that will compete with Samsung and TSMC 2nm chips. If Intel can execute on its 20A (2nm) and 18A (1.8nm) process technologies in 2025, then it has the potential to reclaim industry leadership.

quarter of 2023, but revenue was down 15% over the prior year. CHIPS Act funding is crucial. They have committed to a massive new $100 billion fab in Ohio and to spend $20 billion upgrading their Arizona and Oregon fabs. In early 2023, Intel's Oregon fab started to produce the latest 7nm chips ("Intel 4") using EUV for the first time. The chip design is unique, with separate "tiles" for key functions – aka, heterogeneous chiplet – integrated within a single package. In September 2023, Intel's Ireland fab came online with EUV to add more Intel 4 chip capacity and represents a glimmer of hope that Intel is returning to its old form. However, to build these chiplets, Intel relied on TSMC to build the graphics tile.

Intel also launched an independent foundry business, Intel Foundry Services (IFS), to compete with TSMC and Samsung. Rumors of early IFS customers include the Department of Defense, Amazon, MediaTek, and Qualcomm. Intel's chip designs tend to favor processing power over energy efficiency; however, most fabless firms prioritize energy efficiency over processing power. IFS may not ramp until Intel's next-generation "Intel 3" process in 2024. While second quarter 2023 IFS revenue was up 307%, this represents less than 2% of total corporate revenues and 1.5% of TSMC's second quarter revenue. IFS has a long way to go.

Industry-insider outlook is mixed. Some see a return to greatness, while others say it's too late. Intel does appear to be on track to launch their 5nm CPU ("Intel 3") in 2024 and 2nm in 2025. If they achieve these milestones, then Intel's technical recovery is complete. The question remains, however, how many x86 CPUs does the world need? And can Intel actually build a competitive foundry business?

Addressing the lack of domestic leading-edge fabrication drives the CHIPS Act, but this foundry-sector concentration should be a primary concern for those concerned about semiconductor competition. According to McKinsey, the foundry sector is extraordinarily concentrated, with an HHI over 4,000.[31] We need to not only reshore fabs but also ensure that we have viable foundry competition, which will erode fabless firm market power and provide an opening for innovative new chip makers.

31 For perspective, a Hirschman-Herfindahl Index (HHI) of 1,000 or lower is usually considered a competitive market, and 2,500 is considered highly concentrated.

In 2022, Intel announced that it would create an independent foundry business — Intel Foundry Services (IFS) — with the aim to become the second largest by 2030. Intel's failed acquisition of Tower Semiconductor (due to non-approval by Chinese competition authorities) will set back the IFS business. Even with the Tower deal, the combined company would have ranked seventh in the world, equal to about 3% of TSMC's business. Unfortunately, Intel's CEO is lobbying the U.S. government to loosen sanctions on China instead of focusing on restoring Intel's operational capacity.[32]

AMD's Turnaround: At What Cost?

"Real men have fabs" was a favorite line of tough, flamboyant AMD co-founder and longtime CEO Jerry Sanders. Founded in 1968, AMD was a typical Silicon Valley startup. Its big break came in 1976, when Intel needed a second source to keep up with x86 CPU demand. That led to a 1982 Intel licensing deal, creating an x86 duopoly. AMD survived the next 30 years as a lower-cost and more collaborative supplier than Intel. Intentional sourcing strategies from HP and others kept AMD afloat. However, as struggles mounted, AMD divested its fabs in 2009 (the spinoff became GlobalFoundries) and pursued a fabless model.

AMD narrowly avoided bankruptcy in 2017, but today, under the leadership of Lisa Su, it is one of the industry's best turnaround stories. In 2017, AMD's share of the x86 logic chip market was less than 10% to Intel's 90%. As of the first quarter of 2023, AMD had 34% share. Intel's years-long delays of key PC and server chips gave AMD an opening to seize category leadership. Unfortunately, this success has come at the cost of economic resilience, because fabless AMD is now entirely dependent on TSMC for fabrication. In fact, AMD has committed to using TSMC's troubled Arizona fab to build its chips, a project that is now delayed more than two years. If Intel can fix its production issues and execute on its roadmap, then AMD is certain to come under cost pressure from TSMC's high margins and take second-tier status at TSMC relative to Apple.

32 Jenny Leonard, "Chip Leaders Head to Washington to Lobby for China Rules Relief," Bloomberg, July 14, 2023, https://www.bloomberg.com/news/articles/2023-07-15/chip-leaders-head-to-washington-to-lobby-for-china-rules-relief; Tripp Mickle, David McCabe, and Ana Swanson, "How the Big Chip Makers Are Pushing Back on Biden's China Agenda," New York Times, October 5, 2023, https://www.nytimes.com/2023/10/05/technology/chip-makers-china-lobbying.html.

SEGMENTED MONOPOLIES

The flipside of this concentration in the foundry market is that the American fabless firms, many as there are, have all become near-monopolies in specific segments of the chip market. As one McKinsey report stated over 10 years ago, "One might conclude that fabless players create value because they require less capital investment. However, we find that these companies win by establishing dominance in specific applications rather than across applications."[33]

The rapid growth of the mobile industry in the early 2000s led to greater consolidation among chip makers. Apple launched its iPhone in 2007, and by 2012, more semiconductors were going into smartphones than into PCs. In 2022, Apple was shipping 55% of all smartphones sold in the U.S. but capturing more than 85% of category profits.

But smartphones and Apple are not the only situation where a fabless chip company has come to singlehandedly dominate a market segment. Nor have these firms obtained these positions through entirely legal means. Qualcomm, dominating the segment for wireless chips, and Broadcom, dominating the market for broadband and network chips, highlight many of these dynamics.

Qualcomm's Patent Abuse

Qualcomm is the dominant company for telecommunications chips, particularly those used in smartphones. Beginning in the 2000s, Qualcomm used its leading patent position to insert its intellectual property into the global 3G and 4G wireless standards. Pioneering aggressive licensing terms, Qualcomm built a massive licensing revenue stream on the backs of nearly every other wireless industry participant. Qualcomm's licensing agreements included minimum prices, elevated royalty rates, exclusive deals, and a refusal to license to competitors despite commitments to license their standard essential patents (SEPs) on fair, reasonable, and nondiscriminatory (FRAND) terms.

These anticompetitive and exclusive licensing arrangements were the subject of an FTC antitrust lawsuit against the company in the late 2010s. The District Court ruled against Qualcomm, finding their practices unlawful, anticompetitive, and a violation of their FRAND requirements, but the decision was overturned on appeal in 2020. These practices stymie competition, create outsized profits for fabless companies like Qualcomm, and limit potential for new entry.

33 Ulrich Naeher, Sakae Suzuki, and Bill Wiseman, "The evolution of business models in a disrupted supply chain," McKinsey, Autumn 2011, https://www.mckinsey.com/~/media/mckinsey/dotcom/client_service/semiconductors/pdfs/mosc_1_business_models.ashx.

Broadcom's Bullying

Broadcom is the dominant chip company for network and broadband chips, and it is an entirely fabless design firm. Its chips are essential for many internet, router, broadband, and smart TV devices, and for many of these categories, Broadcom is the only option.

In the mid-2010s, facing a potential threat to its dominance in this space, Broadcom began imposing a variety of restrictive and exclusive contracts on device manufacturers to which it sold chips. Broadcom bullied others to enforce these contracts when some companies attempted to diversify their chip supply to include other chip makers. In response to violations of these contracts, Broadcom would threaten to discontinue service for legacy chips in existing devices, increase prices for other chips that the manufacturer still purchased, or threaten to cut off supply entirely. The FTC brought a case against the company for this behavior in July 2021. Broadcom agreed to a consent decree but immediately broke the terms and, as of late 2022, was back under FTC scrutiny.[34]

Their anticompetitive practices suppressed competition from other chip companies, increased prices for Broadcom chips, and forced manufacturers to sole-source their chip supply chains, making them more brittle.

FINANCIAL GAMESMANSHIP

Many of these problems contributed to, and were in turn reinforced by, the financialization of the semiconductor industry in recent decades. Cheap capital in the wake of the 2008 global financial crisis kicked off a wave of mergers and acquisitions that severely contracted the industry. Comparing the top firms of 2010 with those in 2020, there is a 44% reduction in independently operating U.S. chip makers, almost entirely as a result of acquisition activity (see graphic on page 34).

Furthermore, as is the case in other industries, the lack of competition in the chip industry has allowed executives to value short-term investor returns over investment, expansion,

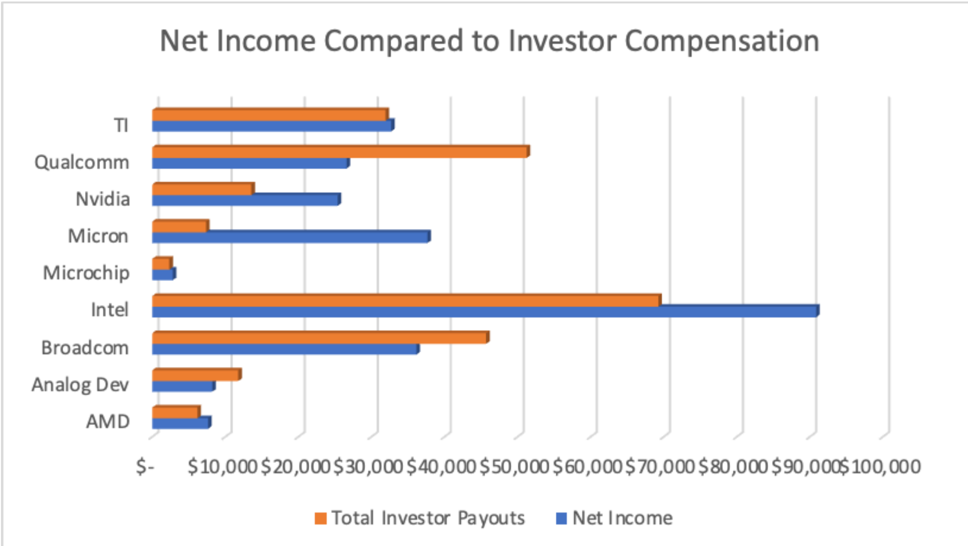
34 Federal Trade Commission, ***In the Matter of Broadcom, Inc.***, Docket No. C-4750, Decision and Order (November 4, 2021), https://www.ftc.gov/system/files/documents/cases/1810205c4750broadcomfinalorder.pdf.

Top U.S. Chip Makers declined by 44% since 2010

- AMD
- ~~Altera~~ (Intel, 2015)
- Analog Devices, Inc.
- ~~Atmel~~ (Microchip Technology, 2016)
- ~~Broadcom Inc.~~ (Avago merger, 2016)
- ~~Cypress Semiconductor~~ (Infineon, 2020)
- ~~Fairchild~~ (ON Semiconductor, 2016)
- Intel Corporation
- Lattice Semiconductor
- ~~Linear Technology~~ (Analog Devices, 2017)
- Marvell Technology Group
- ~~Maxim Integrated~~ (Analog Device, 2021)
- Microchip Technology
- Micron Technology
- ~~Microsemi~~ (Microchip, 2018)
- ~~National Semiconductor~~ (TI, 2011)
- NVIDIA Corporation
- ON Semiconductor
- ~~PMC Sierra~~ (Microsemi, 2016)
- Qualcomm Inc.
- Qorvo (MicroDevices + TriQuint, 2
- ~~Sandisk~~ (Western Digital, 2015)
- Semtech
- Silicon Laboratories
- Skyworks Solutions
- Texas Instruments
- ~~Xilinx~~ (AMD, 2022)

and the long-term health of their companies. Over the last five years, the top nine chip makers[35] spent $239 billion on investor payouts — an amount equal to nearly five CHIPS Acts' worth of capital, or roughly 24 new fabs. As a share of net income, Micron and Nvidia were the most disciplined and wasted the least cash on investor payouts, unsurprising in Micron's case as a competitive memory chip firm. Qualcomm and Broadcom spent more in investor payouts than earned in profits. When Apple is included, the aggregate five-year investor payouts balloon to $698 billion — an amount that dwarfs the CHIPS Act and would have solved the economic and national security concerns that taxpayers are being forced to fund. As described above, chip scarcity provides Apple with a competitive advantage because marginal phone, tablet, or PC OEMs are left waiting for supply while Apple has priority. It's clear why Apple had no intention to address semiconductor supply chain resilience and foundry concentration. As the industry's biggest buyer, Apple benefits from chip scarcity.

35 Texas Instruments, Nvidia, AMD, Intel, Micron, Microchip, Broadcom, Qualcomm and Analog Devices.
36 Federal Trade Commission, *In the Matter of Nvidia Corporation*, Docket No. 9404, Complaint, December 2, 2023, https://www.ftc.gov/system/files/documents/cases/d09404_part_3_complaint_public_version.pdf; Press Release, "Statement Regarding Termination of Nvidia Corp.'s Attempted Acquisition of Arm Ltd.," Federal Trade Commission, February 14, 2022, https://www.ftc.gov/news-events/news/press-releases/2022/02/statement-regarding-termination-nvidia-corps-attempted-acquisition-arm-ltd.



Nvidia's Attempted Acquisition of Arm

Nvidia, one of the more successful fabless firms, dominates the segment for graphics processing units (GPUs) and has engaged in the same problematic acquisition-over-investment strategy. In September 2020, Nvidia announced plans to acquire Arm, the developer of Arm Processor Technology, an essential chip architecture licensed to most logic chip firms. Valued at $40 billion, the deal would have allowed Nvidia to leverage Arm's technology to disadvantage its competitors in the CPU markets it did compete in, by increasing prices for Arm services, withholding technical or service support, or preferencing its own designs. In short, the deal would have given one of the largest fabless firms control of a central node in the industry.

In December 2021, the FTC filed to block the acquisition, and after only four months of litigation, the deal was called off.[36] Today, Nvidia has flourished as the leading chip maker for AI, while Arm went public and is trading above its proposed acquisition price. This is a successful policy intervention, and these sorts of large transactions are precisely the anticompetitive financial engineering that should be proscribed by the CHIPS Act and any recipients of its funding.

Thus, particularly in the market for leading-edge logic chips, the CHIPS Act faces several overlapping challenges to its success, the result of past mistakes in the industry: the outsourcing of direct manufacturing, resulting in leading-edge dominance by a single foreign firm in TSMC; rampant anticompetitive conduct; patent abuse by dominant fabless firms; and a principal business strategy of favoring financial games — high dividends, stock buybacks, and acquisitions — over operational improvements, national security, and investment.

MATURE-NODE CHIPS, SHORTAGES, AND DOMESTIC RESILIENCE

Whereas the leading-edge logic chip segment faces a real monopoly problem, the other side of the industry, with so-called "mature-node" chips, is characterized by market instability and brittle resilience more than domination by monopoly. Representing older manufacturing processes with lower value added, the margins earned from mature-node chips are so thin that many American chip makers ceased to produce them or invest in new mature-node capacity. At the same time, large chip buyers like Apple, automotive companies, and other original equipment manufacturers have relentlessly chased the lowest costs possible, pushing production of mature-node chips abroad. Mature-node fabrication is now concentrated in China, in no small part because China's industrial strategy aims to dominate the mature-node segment as a first step toward control over the entire semiconductor industry.[37] To overcome these challenges, CHIPS Act implementation will need to go beyond subsidizing the construction of domestic mature-node fabs, and more directly manage a resilient domestic base for mature-node fabrication.

"Mature node" refers to chips produced using older manufacturing processes, resulting in chips with lower transistor density, meaning the number of transistors that can fit within a certain volume in a chip. The CHIPS Act defines legacy-node chips, for logic, as those with processes above 28nm,[38] whereas in practice, leading-edge logic chips tend to range between 3nm and 7nm. With higher transistor density, all else equal, chips can perform more complex functions faster while using less energy. This is why the denser leading-edge chips are so important for cutting-edge computational needs like AI, and why profits are so much higher for those chips.

However, mature-node chips still account for a majority of chips produced, even in advanced electronics. For example, the iPhone is estimated to use 60% mature-node

37 Dan Strumpf, "China Chases Chip-Factory Dominance—and Global Clout," *Wall Street Journal*, July 24, 2022, https://www.wsj.com/articles/china-bets-big-on-basic-chips-in-self-sufficiency-push-11658660402.
38 15 U.S. Code § 4652, https://www.law.cornell.edu/uscode/text/15/4652.

chips.[39] The automotive industry in particular has dramatically increased its demand for mature-node chips, with the industry turning to electrification, increased connectivity, and potentially autonomous vehicles.

However, for much of the industry's history, few fabs were constructed for the stated purpose of producing mature-node chips. Instead, as process technology has improved and leading-edge chips moved to smaller topographies, the older fabs that had once been leading-edge simply repurposed to produce mature node.[40] These fabs tended to be fully depreciated as a capital expenditure, and as a result they were traditionally able to produce mature-node chips for mere pennies and still turn a profit. When this industry practice met the global demand for mature-node chips, this was an effective way to make use of older fabs. However, because of the high cost of new fabs, and the years it can take to get one into production, chip makers and chip buyers found it to be uneconomical to build new mature-node fabs in response to demand spikes, preferring to repurpose older leading-edge fabs. The margins for mature-node chips are generally too low to profitably operate a greenfield fab in a commoditized category.

The pandemic, in conjunction with the rapid increase in demand for mature-node chips from carmakers, exposed cracks in this system. When the pandemic hit, it not only shut down production in a number of fabs in East Asia but also led to a collapse in demand for a number of chip-dependent products while dramatically increasing demand for others. Sales for the automotive sector, in particular, collapsed, whereas simultaneously with the shift to work-from-home, demand for laptops and other consumer electronics exploded. Car manufacturers cancelled a range of orders for mature-node chips as their own production ceased, and consumer electronics manufacturers expanded their orders to fill production queues.[41] Thus, once demand for cars recovered, automotive manufacturers found themselves at the back of the chip production queue. As a result, car manufacturers could not get the chips they needed on the timeline required and had no choice but to shut down their production lines for lack of small chips worth dollars or cents. Car chip shortages are ongoing but have mostly recovered, and they are a key area of need for mature-node chips.

These risks have been further exacerbated in the past year by China's industry strategy with respect to chips. In October 2022, the Department of Commerce's Bureau of Industry and Security (BIS) expanded export controls on advanced semiconductors that could be used for military applications, essentially cutting off China's access to the needed

39 Techovedas, "Why China is investing 100s of Billion Dollars on Older Tech Nodes?," August 26, 2023, https://techovedas.com/why-china-is-investing-100s-of-billion-dollars-on-older-tech-nodes/.
40 Doug O'Laughlin, "The Rising Tide of Semiconductor Cost," Fabricated Knowledge, November 22, 2021, https://www.fabricatedknowledge.com/p/the-rising-tide-of-semiconductor.
41 Michael Wayland, "How Covid led to a $60 billion global chip shortage for the auto industry," CNBC, February 11, 2021, https://www.cnbc.com/2021/02/11/how-covid-led-to-a-60-billion-global-chip-shortage-for-automakers.html.

technology to be a player in leading-edge logic or memory chips.[42] While Huawei and Semiconductor Manufacturing International Corporation (SMIC, a Chinese state-affiliated chip maker) were able to produce a respectable, leading-edge 7nm chip despite these controls,[43] the setback in leading-edge chips has pushed China to refocus on expanding its capacity and dominance in mature-node chips, where leading-edge chip-making controls are not a concern. As a result, China is expanding its capacity in mature-node fabs, with key Chinese firms like SMIC and Yangtze Memory Technologies Corp (YMTC) expanding both output and new fab construction for mature nodes.[44] As this additional capacity well exceeds domestic Chinese demand for mature-node chips, China is poised to dump mature-node chips on international markets.[45] This will have the effect of further eliminating any remaining mature-node industrial base in the United States and elsewhere, making the U.S. dependent on China for its supply of those workhorse chips.

The origins of the resilience problem for mature-node chips go further back than these recent events. While the automotive sector is central to the sudden rise in demand, mature-node chips are also used in almost every electronic device that we use today. And the leading manufacturers of those devices — cars, consumer electronics, appliances, and so on — have for years gone across borders to chase the lowest costs, pushing production more and more to geopolitically risky regions connected only through fragile supply chains.

This calls for a rethinking of resilience combined with more comprehensive public management of the market in this space. As a result of all of these factors — the long lag times to construct a mature-node fab, the risk of Chinese overcapacity and dumping, the very thin margins for mature-node chips, and the sudden booms and busts in demand — the market for mature-node chips can resemble an unstable commodity market more than a market for specialized electronics. And markets for such commodities have historically been regulated to avoid these dynamics. The United States maintains a strategic oil reserve, for example, and once regulated agricultural supply to alleviate these boom-and-bust cycles. The issue, therefore, is less a supply problem — as with leading-edge fab

42 Department of Commerce, "Implementation of Additional Export Controls: Certain Advanced Computing and Semiconductor Manufacturing Items; Supercomputer and Semiconductor End Use; Entity List Modification," Vol. 87, No. 197, October 13, 2022, https://www.govinfo.gov/content/pkg/FR-2022-10-13/pdf/2022-21658.pdf; Brian Egan, "New US Semiconductor Export Controls Signify Dramatic Shift in Tech Relations With China," Just Security, October 24, 2022, https://www.justsecurity.org/83744/new-us-semiconductor-export-controls-signify-dramatic-shift-in-tech-relations-with-china/.
43 Anton Shilov, "Huawei's New Mystery 7nm Chip from Chinese Fab Defies US Sanctions," Tom's Hardware, September 3, 2023, https://www.tomshardware.com/news/huaweis-new-mystery-7nm-chip-from-chinese-fab-defies-us-sanctions.
44 Anton Shilov, "Chinese Chip Industry to Focus on Perfecting Mature Nodes: Report," Tom's Hardware, May 10, 2023, https://www.tomshardware.com/news/chinese-chip-industry-to-focus-on-perfecting-mature-nodes.
45 Alan Patterson, "China Gears Up for Chip Dumping, Ex-DoC Official Says," *EE Times*, September 23, 2023, https://www.eetimes.com/china-gears-up-for-chip-dumping-ex-doc-official-says/; Andy Xie, "Fallout of US-China chip war could be global overcapacity across industries," *South China Morning Post*, April 4, 2023, https://www.scmp.com/comment/opinion/article/3215839/fallout-us-china-chip-war-could-be-global-overcapacity-across-industries.

capacity — but more a demand problem to defend the economic viability of U.S.-based mature-node fabs against Chinese dumping and OEM race-to-the-bottom practices.

The CHIPS Act is an important step on this front, providing the necessary financial resources to de-risk mature-node fab expansion in the United States, but it does not itself provide long-term solutions to these underlying problems. The CHIPS Act will likely succeed in subsidizing the reshoring of mature-node fabs, particularly at the current moment, when chip makers and buyers are aware of supply chain problems. However, if major chip buyers continue to chase the lowest-cost chips, or the Chinese chip industry aggressively dumps their excess capacity on world markets, or another demand shock hits the industry, the mature-node capacity created by the CHIPS Act could be lost and moved offshore once again.

Traditional trade policy tools, such as antidumping and countervailing duties (AD/CVD) are unlikely to sufficiently address the mature-node chip supply chain problem. AD/CVD measures against dumped and subsidized mature-node chips would have limited effect considering that chips often make their way into the U.S. market as components of finished consumer electronic products. AD/CVD duties are imposed on the imported product in the affected market, which is usually the same product that is being dumped or unfairly subsidized.

The supply chain for chips, running from chip fabrication to assembly, testing, and packaging (ATP), and then to final assembly by an OEM, is complex and crosses many national borders before products are imported to their final markets for sale. As a result, the chips themselves are rarely, if ever, imported into the United States. Rather, for example, Chinese chips would be sent to a third country for final electronics assembly, after which the end product is imported to the United States.

Theoretically, the United States could initiate an anti-subsidy probe against certain types of electronic products that benefit from distorting Chinese subsidies for chips, but the absence of a robust electronic product assembly industry in the United States would pose technical and practical hurdles. The imposition of AD/CVD measures traditionally requires the existence of a domestic industry in the United States that is harmed by the dumping or subsidization of the imported product. For electronic products using chips, such as phones, this means that such an anti-subsidy policy would be based on the harm caused to the final stage of the supply chain — final electronics assembly — which has a negligible presence in the United States. Thus, AD/CVD measures on semiconductor components would not effectively ensure the survival and resilience of U.S.-based mature-node chip makers.

WHAT THE CHIPS ACT DOES

The CHIPS and Science Act of 2022 provides over $50 billion in direct subsidies for American semiconductor research, development, manufacturing, and workforce development. It seeks to reshore the fabrication stage of production, so the U.S. economy is less dependent on highly concentrated overseas supply chains.

Success in its implementation, however, will depend on whether policymakers address the root problem: patent abuse by incumbent firms, the financial pressures to favor fabless business models, exclusionary conduct by market incumbents, the monopsony power of a few larger buyers, and the threat of Chinese dumping of mature-node chips on the global market.

Funding Sources	Available Funding as % of Project Capital Expenditure	CHIPS Act Budget
Direct Funding	5-15%	$38B
Loans and Loan Guarantees	Up to 35%	$75B
Tax Incentives	25%	No Limit

CHIPS ACT FUNDS

The CHIPS Act is a supply-side program. The funds go to manufacturers to build fab capacity and to offset their R&D investments. This is the opposite end of the value chain from other big Biden administration programs like the Inflation Reduction Act (IRA). The IRA is largely a demand-side program that incentivizes consumers to purchase heat pumps, electric vehicles, and solar panels, with some demand-side incentives like mandating domestic production of EVs and batteries in order to be eligible for the consumer subsidy.

The CHIPS Act allocates funds in six general categories:[46]

1. $38 billion of directly funded incentives allocated to qualifying semiconductor manufacturers at 5-15% of the total capital expense for a new fab. $28 billion is allocated for leading-edge fabs and $10 billion for mature and current-generation fabs where the chips are produced for the military and critical commercial sectors (autos, information and communications, medical devices).

2. $75 billion of direct loans or loan guarantees for qualifying manufacturers.

46 Press Release, "Fact Sheet: CHIPS and Science Act Will Lower Costs, Create Jobs, Strengthen Supply Chains and Counter China," White House, August 9, 2022, https://www.whitehouse.gov/briefing-room/statements-releases/2022/08/09/fact-sheet-chips-and-science-act-will-lower-costs-create-jobs-strengthen-supply-chains-and-counter-china/.

3. $11 billion in R&D and workforce development. The National Institute for Standards and Technology (NIST) will stand-up a new National Semiconductor Technology Center (NSTC), a new National Advanced Packaging Manufacturing Program, up to three new Manufacturing USA Institutes, and additional research funding for other NIST programs.[47]

4. $500 million for international information communications technology (ICT) security and semiconductor supply chain activities.

5. $1.5 billion to promote innovation and development of wireless technologies and open, interoperable radio access networks.

6. A 25% investment tax credit for capital expenses for semiconductor manufacturing and related equipment. This credit is handled through the Department of the Treasury, not the Department of Commerce. This is estimated to be worth $24 billion over the next five years.[48]

From the perspective of a semiconductor manufacturer, there are actually three pots of money: direct funding, loans and loan guarantees, and tax incentives. The CHIPS Program Office (CPO) issued the first Notice of Funding Opportunity (NOFO) on February 28 to start the process on direct funding. The direct federal investment from the CHIPS Incentives Program in an individual project may not exceed $3 billion unless certified by Congress.[49]

STACKING INCENTIVES

New Fab Capital Expense:	$10.0B
Direct Funding (up to 15%):	$ 1.5B
Loan Guarantee (up to 35%):	$ 3.5B
Tax Incentives (25%):	$ 2.5B
Total Federal Support:	$ 7.5B

The benefit to semiconductor manufacturers is material. For a $10 billion fab, a semiconductor manufacturer could feasibly receive various subsidies and incentives equal to 75% of the new factory cost.

The CHIPS Act provides financial inducements to encourage positive investments in domestic fabs and research. However, to maximize the policy benefits, the CHIPS Program Office should coordinate its policy decisions with other federal agencies and government bodies. The objective should be the alignment of policy tools to both encourage positive investments as well as discourage illegal or harmful commercial conduct by certain semiconductor firms. This includes the antitrust agencies, the United States Trade

47 National Institute of Standards and Technology, "A Strategy for the CHIPS for America Fund," September 28, 2022, https://www.nist.gov/chips/implementation-strategy.
48 Justin Badlam, Stephen Clark, Suhrid Gajendragadkar, Adi Kumar, Sara O'Rourke, and Dale Schwartz, "The CHIPS and Science Act: Here's what's in it," McKinsey and Co., October 2022, https://www.mckinsey.com/industries/public-sector/our-insights/the-chips-and-science-act-heres-whats-in-it.
49 CHIPS Program Office at NIST, "Notice of Funding Opportunity (NOFO): CHIPS Incentives Program – Commercial Fabrication Facilities," February 28, 2023, https://www.nist.gov/system/files/documents/2023/06/23/CHIPS-Commercial%20Fabrication%20Facilities%20NOFO%20Amendment%201.pdf.

Representative, as well as state and local governments considering supplementing CHIPS subsidies with additional grants or loans.

AUTHORITIES UNDER THE CHIPS ACT

In allocating these funds, the Secretary of Commerce has relatively sweeping authority regarding the criteria by which CHIPS funds are allocated and disbursed, and the overall strategy in doing so. Not only does the CHIPS Act explicitly provide for that authority, but the grant programs generally provide a great deal of administrative discretion for implementation. The CPO has already used that discretion not only to expand the Act's limitations on buybacks and dividends but also to encourage recipients of CHIPS funding to ensure affordable childcare.

Section 9909 of the CHIPS Acts gives the Secretary of Commerce broad authority to enter into contracts, grants, and cooperative agreements; make advance payments or require payments to the Department of Commerce; retain experts; use facilities and personnel from other agencies; and, centrally, "establish such rules, regulations, and procedures as the Secretary considers appropriate."[50]

In fact, the CHIPS Program Office has already used some of the discretion afforded to it under the statute in multiple ways, in some cases for very positive action.

First, the CPO has been clear that it will prioritize funding to firms that abstain from stock buybacks and dividends for the duration of the funding period. The statutory text of the CHIPS Act already prohibits the exact funding appropriated to be used for stock buybacks or dividends.[51] However, money is fungible, and the likely recipients of CHIPS funding are

50 Section 9909 reads:

"(a) IN GENERAL.—In carrying out the responsibilities of the Department of Commerce under this division, the Secretary may—

"(1) enter into agreements, including contracts, grants and cooperative agreements, and other transactions as may be necessary and on such terms as the Secretary considers appropriate;

"(2) make advance payments under agreements and other transactions authorized under paragraph (1) without regard to section 3324 of title 31, United States Code;

"(3) require a person or other entity to make payments to the Department of Commerce upon application and as a condition for receiving support through an award of assistance or other transaction;

"(4) procure temporary and intermittent services of experts and consultants in accordance with section 3109 of title 5, United States Code;

"(5) notwithstanding section 3104 of title 5, United States Code, or the provisions of any other law relating to the appointment, number, classification, or compensation of employees, make appointments of scientific, engineering, and professional personnel, and fix the basic pay of such personnel at a rate to be determined by the Secretary at rates not in excess of the highest total annual compensation payable at the rate determined under section 104 of title 3, United States Code, except that the Secretary shall appoint not more than 25 personnel under this paragraph;

"(6) with the consent of another Federal agency, enter into an agreement with that Federal agency to use, with or without reimbursement, any service, equipment, personnel, or facility of that Federal agency; and

"(7) establish such rules, regulations, and procedures as the Secretary considers appropriate." CHIPS Act, Public Law 117-167, 117th Congress, Sec. 9909, https://www.congress.gov/117/plaws/publ167/PLAW-117publ167.pdf.

51 CHIPS Act of 2022, Amendment to H.R. 4346, https://www.commerce.senate.gov/services/files/CFC99CC6- CE84-4B1A-8BBF-8D2E84BD7965.

multibillion dollar companies that can use CHIPS funds to free up earnings that would have otherwise gone to productive investment and then use internal transfer accounting to redirect cash toward dividends or stock buybacks. This is why the CPO's consideration of long-term commitments to refrain from such payouts is so important.[52]

Second, while the strategy and criteria were left relatively open, with wide discretion, Congress did provide a general sense of the goals that the CHIPS program should pursue. Section 10301 gives guidance to the Secretary of Commerce for how the funds should be strategically allocated:

"SENSE OF CONGRESS.—It is the sense of Congress that, in carrying out subsection (a), the Secretary should allocate funds in a manner that—

> "(1) strengthens the security and resilience of the semiconductor supply chain, including by mitigating gaps and vulnerabilities;
>
> "(2) provides a supply of secure semiconductors relevant for national security;
>
> "(3) strengthens the leadership of the United States in semiconductor technology;
>
> "(4) grows the economy of the United States and supports job creation in the United States;
>
> "(5) bolsters the semiconductor and skilled technical workforces in the United States;
>
> "(6) promotes the inclusion of economically disadvantaged individuals and small businesses; and
>
> "(7) improves the resiliency of the semiconductor supply chains of critical manufacturing industries."[53]

In its implementation and calls for funding thus far, the CHIPS Program Office has outlined several points regarding its strategy to date. At the leading edge of logic chips, a Notice of

52 "The CHIPS Program Office will require all applicants to detail their intentions with respect to stock buybacks over five years, including whether they intend to refrain from or limit them, and will consider the extent of the applicant's commitments to refrain from stock buybacks in the application review process." CHIPS for American, "Funding Opportunity – Commercial Fabrication Facilities FACT SHEET: CHIPS Program Office Launches Notice of Funding Opportunity," February 28, 2023, pg. 4, https://www.nist.gov/system/files/documents/2023/02/28/CHIPS_NOFO-1_Fact_Sheet_0.pdf.
53 CHIPS Act, Public Law 117-167, 117th Congress, Sec. 10301

Funding Opportunity was released in February 2023,[54] along with a "Vision for Success" document outlining their industrial strategy.[55]

The CPO outlines several primary goals, foremost of which is the creation of two domestic "clusters" of semiconductor fabs for leading-edge logic chips, by which the CPO means "geographically compact areas with multiple commercial-scale fabs owned and operated by one or more companies; a large, diverse, and skilled workforce; nearby suppliers; R&D facilities; utilities; and specialized infrastructure."[56]

The CPO recognizes some of the core problems that this report highlights — that the foundry model and rise of fabless firms have led to a loss of the leading-edge chip fabrication that came with the IDM business model in the past[57] — but does not specifically address how to change the business incentives that created this business model in the first place, or how the creation of two leading-edge clusters, on its own, will sustainably change those dynamics.

Our recommendations provide a roadmap for the CPO, NIST, and Department of Commerce to implement the CHIPS Act in a manner that fully meets Congress' intent.

Apple Will Make or Break the CHIPS Act

Apple's iPod launch in 2001 changed the company. To make the product, Apple developed a new operating system and bought the entire global supply of a unique compact hard disk drive. This innovative product coupled with a content ecosystem, great marketing, and a moat around key components allowed Apple to own a category and capture high margins. Apple would repeat this product strategy when the iPhone launched in 2007. Not long after, mobile phones passed PCs as the biggest category for semiconductors.

Apple is legendary for grinding down suppliers and squeezing every penny out of them. Apple also demands exclusivity and tends to lock up supply of leading-

54 NIST CHIPS Program Office, "NOTICE OF FUNDING OPPORTUNITY (NOFO): CHIPS Incentives Program – Commercial Fabrication Facilities," February 28, 2023, available at: https://www.nist.gov/system/files/documents/2023/06/23/CHIPS-Commercial%20Fabrication%20Facilities%20NOFO%20Amendment%201.pdf.

55 NIST CHIPS Program Office, "Vision for Success: Commercial Fabrication Facilities," CHIPS Incentives Program, February 28, 2023, available at: https://www.nist.gov/system/files/documents/2023/02/28/Vision_for_Success-Commercial_Fabrication_Facilities.pdf.

56 Ibid.

57 The CPO recognizes that our current circumstances are "in part due to the 'pure-play foundry' business model pioneered by East Asian firms. Unlike integrated device manufacturers, which design and manufacture their own chips, pure-play foundries manufacture chip designs from a variety of customers on a contract basis. As a result, many American firms have become 'fabless,' leading the world in semiconductor design while outsourcing manufacturing to East Asian foundries." NIST CHIPS Program Office, "Vision for Success: Commercial Fabrication Facilities," CHIPS Incentives Program, February 28, 2023, pg. 5, available at: https://www.nist.gov/system/files/documents/2023/02/28/Vision_for_Success-Commercial_Fabrication_Facilities.pdf.

edge components to keep them away from competitors. The iPhone drives Apple's profits, in large part due to agreements with American mobile operators, which are obligated to subsidize the phones, meet sales targets, and contribute hundreds of millions of dollars in marketing funds for the right to display their name next to Apple in advertisements.

As the world's largest purchaser of semiconductors and one of the largest fabless chip makers, Apple can make or break the CHIPS Act. If Apple pursues the same free-rider component sourcing strategy that compelled them to undercut Micron and strike a deal with China's memory chip champion, YMTC (see above), then these new U.S.-based fabs will be at risk. To date, Apple has shown little willingness to pay a premium for U.S.-made components. U.S. policy must adapt to curb Apple's bad practices and compel them to make long-term demand commitments to new U.S. fabs.

Following Apple's lead, there is a growing trend among the tech monopolies — Google, Amazon, Facebook, Microsoft — to build their own logic chips using a fabless model. Apple was first, but the others are gaining momentum. Amazon's 2016 acquisition of Israel-based Annapurna Labs removed a viable Intel and AMD competitor from the market. Amazon then directed the startup to design chips (fabricated by TSMC) that would give Amazon Web Services (AWS) a competitive edge over rivals Microsoft Azure and Google Cloud.[58] Collectively, Big Tech is spending billions to design AI accelerator chips to replace Nvidia and server chips to replace AMD and Intel.[59] On one hand, Big Tech's move into chips is one more signal of high prices and weak logic chip competition. On the other hand, it is a dangerous trend for America's semiconductor industry when the only chip competition is coming from Big Tech monopolies who seek only to expand their market power.

58 Janakiram MSV, "How An Acquisition Made by Amazon in 2016 Became the Company's Secret Sauce," Forbes, March 10, 2019, https://www.forbes.com/sites/janakirammsv/2019/03/10/how-an-acquisition-made-by-amazon-in-2016-became-companys-secret-sauce/?sh=5944712b2f67.
59 Anissa Gardizy, "Google and Microsoft's Other AI Race: Server Chips", The Information, May 8, 2023, https://www.theinformation.com/articles/google-and-microsofts-other-ai-race-server-chips.

POLICY RECOMMENDATIONS TO PROMOTE COMPETITION AND INNOVATION

Our recommendations seek to correct the market and policy failures that have weakened the U.S. semiconductor industry. As we have seen from past bursts of creativity in the 1950s, 1970s, and 1990s, unwinding market power and incubating creative new entrants is the key to long-term industry vibrancy.

While some of these recommendations are implementable as a matter of discretion in the CHIPS Program Office's choices for funding recipients, many of these recommendations would also be implementable under the general authority in Section 9909(a)(7) to "establish such rules, regulations, and procedures as the Secretary considers appropriate."

We recommend a set of measured, targeted policies to restore semiconductor competition and innovation, both through the CHIPS Act and in coordination with other agencies and authorities:

To address the monopoly problem in leading-edge logic chips:

1. **Incubate entrants with a goal of four independent, leading-edge logic foundries.** In allocating funding for new leading-edge fabs in the United States, we recommend that the CPO pursue a strategy of having four independent, leading-edge logic foundries. Even with the problems associated with the industry's fabless/foundry model, TSMC's dominance in the foundry market — 58% revenue share and over 80% profit share — independently creates too brittle of a supply chain and too concentrated of a center of semiconductor economic power. There is little reason to believe that the global market cannot support at least four leading-edge logic foundries with all four operating fabs in the United States.

   This implies that, rather than simply subsidizing the already-dominant TSMC as it moves some of its leading-edge logic capacity to the United States, the CPO should instead prioritize larger amounts of funding to the second-tier foundries, such that they can upgrade their capacity and sophistication over time to compete in higher value-added logic segments. TSMC already dominates the foundry industry profit pool, will benefit from CHIPS Act tax incentives, and is independently facing pressure from Apple to move capacity to the United States. As TSMC's largest customer, Apple is in a better position than the U.S. government to invest in TSMC's U.S.-based operations. Furthermore, TSMC's stumbles with its much anticipated Arizona fab provides all the justification policymakers need to direct CHIPS funds to incubate more leading-edge fab competitors.[60]

2. **Include Federal Trade Commission review and consultation in CHIPS program.** Given the central role of anticompetitive behavior in creating today's concentrated market, the CPO should work in consultation with antitrust enforcers at the FTC to allocate CHIPS funding and set criteria for funding recipients.

   As they oversee funding distribution, the CPO and FTC should take into consideration (a) past mergers where chip companies intentionally bought and shuttered low-cost competitors, (b) past and ongoing violations of antitrust policies, and (c) any future plans for intra-sector acquisitions. The semiconductor market is already concentrated and thin, with limited buyers and sellers in any given segment. Broadcom's attempt to acquire Qualcomm, and Nvidia's attempt to acquire Arm were both, fortunately, rejected. However, Qualcomm's $1.4 billion acquisition of Nuvia, Microchip's acquisition of three adjacent rivals, Amazon's $350 million acquisition of Annapurna Labs, and Apple's efforts to sink innovative RISC-V start-up Rivos, collectively undermine innovation and competition. Further concentration will be harmful particularly in areas like CPUs, where Intel, AMD and Apple lead, or mobile processors, where Qualcomm, Apple, and MediaTek dominate.

   As part of this oversight, criteria for receiving CHIPS funding should include a series of clear commitments to not take part in a range of practices that likely violate the antitrust laws. The list of such anticompetitive practices should include exclusive dealing, tying, discriminatory pricing arrangements, predatory pricing, and other coercive contracts.

3. **Develop thicker markets** by (a) protecting new fabs through long-term demand contracts from both government and private-sector buyers, (b) developing a set of chip-making standards that lower switching costs and promote interoperability, and (c) ensuring foundries operate under a quasi-common carrier principle. While this on its own will not diminish the buyer power of big fabless customers, such as Apple, it should prevent Apple or others from locking up foundry capacity as a backdoor to undermine rival chip makers.

60 Lee Harris, "Chipmaker's Scramble to Build Marred by Mistakes and Injuries," *The American Prospect*, June 22, 2023, https://prospect.org/labor/2023-06-22-tsmc-semiconductor-factory-phoenix-accidents/.

4. **Pass legislation to require dual-sourcing.** In order to create thicker markets and a broader range of players, ideally the largest fabless chip companies (Apple, Qualcomm, AMD, Nvidia, etc.) would be required to buy from multiple foundries and commit to purchase at least 30% of their global volume from U.S.-based fabs. However, as fabless firms are broadly not receiving direct assistance through CHIPS Act funding, this could be supplemented with legislation that would require the fabless firms to use dual-sourced contracts. In all contracts, the federal government procurers must demand dual-sourced, U.S.-based foundries.

5. **Address the long-term incentives for the underlying fabless business model** by (a) requiring more open patent and IP licensing practices and (b) disincentivizing extractive financial practices, like buybacks and dividends, that divert retained earnings from long-term investments in R&D, fabs, and workers.

   Open Patent Practices. Semiconductor firms commonly use the patent system to protect their market power by litigating against competitors. CHIPS funding recipients should be held to stringent requirements to openly and fairly license their patents as well as fairly compensate those innovators from whose patents the big chip makers profit. The terms of CHIPS grants can include requirements to abide by FRAND licensing policies, and Section 9909(a)(1) of the CHIPS Act allows the Secretary of Commerce to enter into agreements, which in this case could include an open patent pool of all CHIPS funding recipients for semiconductor technologies.[61]

   Finally, for forward-looking semiconductor technologies, the new National Semiconductor Technology Center (NSTC) will function as an innovation hub to advance critical semiconductor research and development. Membership should come with a FRAND (fair, reasonable, and nondiscriminatory) commitment so that all parties — industry (foundry, fabless, and IDM), academia, and government — within this complex ecosystem can work collaboratively and benefit from broad-based technological advances and innovations, without fear of anticompetitive retaliation.

   Limit buybacks and dividends based on a sliding scale tied to investment. While the CHIPS Act prohibits CHIPS funding from being directly used for stock buybacks and dividends, money is fungible, and simple accounting maneuvers

61 Section 9909(a)(1) gives the Secretary of Commerce the authority to "enter into agreements, including contracts, grants and cooperative agreements, and other transactions as may be necessary and on such terms as the Secretary considers appropriate."

can substitute resources such that CHIPS funds could nonetheless facilitate such investor payouts. BAE's receipt of a $35 million CPO grant despite $3.3 billion of investor payouts is exactly what must be avoided. To encourage participation in the CHIPS program and simplify oversight, we propose that CHIPS funding recipients not be entirely barred from any investor payments, but rather that the total volume of stock buybacks and dividends be tied, on a sliding scale, to increases in investment in domestic fab construction or R&D.

As a starting proposal, we suggest the following system. CHIPS funding recipients should be required to meet a minimum ratio of direct investment to investor payouts based on three variables:

- Average annual capital expenditure on fabs and R&D (investment) for 5 years prior to CHIPS Act;
- Average annual buybacks and dividends (investor payouts) for 5 years prior to CHIPS Act; and
- Total CHIPS funding received, including direct support, tax subsidies, and state and local subsidies.[62]

Then, the minimum ratio would be

(5-yr average investment) + 2 x (total CHIPS funds) : (5-yr average investor payouts)

To explain, use the example of a hypothetical chip company:

5-year average investment: $25 million per year
5-year investor payout: $50 million per year
CHIPS funding amounts to $25 million

Should the company accept CHIPS funding, the new ratio they would be required to meet would be:

= (prior average investment) + 2 x (CHIPS funding) : (prior average investor payout)
= $25m + 2 x $25m : $50m
= 3:2

62 The CPO is unfortunately requiring that companies seeking funding from the CPO to come with additional, committed local subsidies in hand. See NIST CHIPS Program Office, "NOTICE OF FUNDING OPPORTUNITY (NOFO): CHIPS Incentives Program – Commercial Fabrication Facilities," February 28, 2023, pg. 8, available at: https://www.nist.gov/system/files/documents/2023/06/23/CHIPS-Commercial%20Fabrication%20Facilities%20NOFO%20Amendment%201.pdf. These should be counted as support for the purposes of these buyback and dividend requirements.

Over the term of the grant, for every $3 spent on investment, the company would be allowed to spend $2 on investor compensation.

This schema could be enforced by releasing the CHIPS funding incrementally over the course of a given project, and cutting off funding should these commitments not be met.

To shore up domestic resilience for mature-node semiconductor production:

As described above, the effectiveness of traditional trade policy tools in this space is limited. Where applicable, the CPO should use the market information gathered by implementing the CHIPS Act to work closely with the International Trade Administration (ITA) to monitor international trade trends and, if warranted, the Department of Commerce should self-initiate antidumping and countervailing investigations on foreign producers of mature-node chips in the presence of evidence indicating dumping or unfair subsidization. Given the small cost and thin margins of most mature-node chips, and China's massive buildup of capacity in mature-node market segments, in order to stay in business, Chinese chip firms will likely need to either rely on government subsidies or dump their excess capacity abroad, or both.

However, policymakers must look beyond traditional trade remedies to address the mature-node chip supply chain problem.

6. **Increase most-favored nation tariff rates on end-use chip products.** Tariffs could play a key role in diversifying the final assembly stage of the chip supply chain because consumer electronics are the products that are actually being imported into the United States. Given the low value-add of final electronic assembly relative to the costs of doing assembly in the United States, an increase of the most-favored nation (MFN) tariff rate on final electronics products is likely to encourage some portion of that final stage of the supply chain to diversify away from its concentration in East and Southeast Asia and move to Western Hemisphere free trade agreements (FTA) partners.

   However, to create a truly diversified and resilient chip supply chain for these essential mature-node chips, intervention is necessary further up the supply chain, to ensure the durability of a domestic base of mature-node fabrication. This is the goal of the CHIPS Act's subsidies for the construction of domestic fabs, but in light of China's apparent plans for mature-node dominance, more action is necessary. We propose two policy options:

7. **Legislation to create an American Semiconductor Supply Chain Resiliency Fee (ASSCR).** In practice, given the thin margins for mature-node chip

production, and the looming possibility that Chinese or other foreign producers may dump their excess chip capacity on American markets or on offshore American OEM manufacturing operations, the United States needs a long-term system to maintain the resilience of domestic mature-node production.

We propose that this could be done through a tax on mature-node chip products[63] that rely almost exclusively on foreign-sourced chips, to incentivize domestic production and to create a reserve fund for American mature-node producers to weather downturns in industry cycles. This new fee — the American Semiconductor Supply Chain Resiliency (ASSCR) Fee — would require original equipment manufacturers (Apple, Samsung, Dell, HP, Lenovo, Amazon, Google, Sony, LG, etc.) to either source a certain percentage — for example, 30% — of their products' semiconductor value added from U.S.-based fabs or pay a marginal but non-negligible fee on all products with a retail price of $300 or higher, on the order of $10-$20 dollars per device.[64] The program would be managed by the CPO with the intent to protect domestic semiconductor makers from both unfair foreign competition and OEM supply chain practices that run counter to Congress' intent in the CHIPS Act. OEMs could either choose to invest in American production at a limited but sufficient production to maintain a resilient domestic base or pay the fee to directly fund the maintenance of that production base.

8. **Pass legislation to establish demand-side subsidies for electronics manufactured with domestic chips.** As a possible alternative to the ASSCR, Congress could accomplish many of the same goals by establishing domestic content subsidies in the form of tax credits for consumers that purchase electronics manufactured with domestic chips or through incentives for OEMs that purchase their mature node chips from domestic fabs. This could follow the same tax funding structure as many of the subsidies from the Inflation Reduction Act, used to support various clean energy technologies — solar panels, heat pumps, electric vehicles, etc. — and lead OEMs to favor domestic sourcing. However, given the administrative and logistical difficulties of ensuring domestic content for the IRA, policymakers should be aware that any such supplement to the CHIPS Act would likely lead to similar difficulties.

63 Chip products could be defined as any final product where a minimum value-added of chips is used in its manufacture. The term should be defined to ensure the inclusion of the key products using mature-node chips: smartphones, cars, and other consumer electronics.

64 The exact domestic origin requirements, and the exact the scale of the fee should be based on ongoing market analysis by the CPO. Some flexibility will be necessary based on market dynamics, where, for example, a capacity glut in mature-node chips could necessitate this fee being higher for a time to ensure that CHIPS-funded domestic fabs can remain in business.

These two proposals resemble several other categories of policies frequently used by governments to stabilize commodity markets — such as oil or agricultural commodities — where boom-and-bust cycles often make prices and supply volatile. That volatility creates price swings and shortages for consumers and makes it difficult for domestic producers to remain in business during market downswings. Many governments use price stabilization funds for commodities, where, for example, commodity exports are guaranteed at a certain price to producers and any excess is retained by the fund to subsidize the producer when commodity prices collapse again.[65] Correspondingly, the United States Department of Energy maintains the Strategic Petroleum Reserve to reduce the disruptions created by price volatility of oil.[66] Each of these proposals — the ASSCR and demand-side subsidies — operate on a similar logic in seeking to provide a stable market for domestic fabrication of mature-node chips, but they are more targeted to account for the fact that these chips are both only quasi-commodified and are unique components of sophisticated electronics.

Our policy recommendations either fall within Commerce's discretionary authority as provided under the CHIPS Act or propose Congress supplement the CHIPS Act to carry out its original intent. These policies will break the stranglehold that a handful of semiconductor firms have over the U.S. economy. Our recommendations require that the CHIPS Program Office look beyond fab incentives and R&D subsidies to undertake a "whole of government" approach to reinvigorate semiconductor competition. For example, the CPO should partner with the Patent and Trademark Office and leverage NSTC membership to address patent abuse. The CPO should also work with the antitrust agencies to apply a market power lens, as well as having firms forswear past anticompetitive practices. Reshoring fabs, developing workers, and investing in R&D must be the semiconductor industry's priorities. Industrial policy must go hand-in-hand with competition and resilience.

65 See, for example, International Monetary Fund, "The Fiscal Role of Price Stabilization Funds The Case of Côte d'Ivoire," 1988, https://www.elibrary.imf.org/view/journals/001/1988/026/article-A001-en.xml#A01lev1sec2.
66 Office of Cybersecurity, Energy Security, and Emergency Response, "About the Strategic Petroleum Reserve," https://www.energy.gov/ceser/strategic-petroleum-reserve.

KEY TERMS

ARM - Advanced RISC machine chips are the dominant chip architecture for mobile devices because of their balance of power efficiency, performance, and cost. The UK-based company Arm provides most of the designs and intellectual property behind ARM-based chips. Ninety-five percent of mobile devices are powered with ARM chips.

ASIC - The application-specific integrated circuit is a specialized logic chip typically designed for specific-use cases. As an example, Broadcom's chips for networking, WiFi, Bluetooth, and storage are considered ASICs. Industry pundits often refer to Apple's chips as ASICs but this paper categorizes them as CPUs and MPUs.

CPO - CHIPS Program Office within the National Institute of Standard and Technology.

CPU - Central processing unit (CPU) is a general-purpose logic chip that is capable of many functions.

CURRENT-GENERATION FACILITIES - Defined by the CPO as semiconductor fabs that are not leading-edge but produce at 28nm nodes and below, including logic, analog, radio frequency, and mixed-signal devices.

DRAM - Dynamic random access memory is typically used for the main memory of a computer because it reads and writes quickly but is considered "volatile" because it requires constant power to retain the information.

DUV - Deep ultraviolet lithography was developed by IBM in the 1980s and commercialized in the 1990s. Canon, Nikon, and ASML lead the category. DUV is limited to 10nm feature size.

ENTITY LIST - The list of foreign firms with which U.S. companies are restricted from doing business without a Department of Commerce license. Chinese mobile chip company HiSilicon, memory chip maker YMTC, and telecommunications firm Huawei are on the list.

EUV - Extreme ultraviolet lithography was developed under the U.S. government-sponsored SEMATECH program. The Lawrence Livermore and Sandia National Labs provided early research into the fundamental technologies. Intel provided most of the capital to bridge the development between the labs and the first commercial product. Dutch firm ASML was the first to commercialize EUV, releasing the first system in 2014. EUV is required to make the most sophisticated chips, and ASML is the only manufacturer globally of EUV gear. ASML pays royalties to the EUV-LLC, whose membership includes multiple U.S. national labs and semiconductor firms.

FAB - A semiconductor manufacturing facility. Shorthand for fabrication.

FABLESS - A semiconductor firm that designs, sells, and supports chips but outsources manufacturing, assembly, and test to "foundries." Examples include Qualcomm, Apple, AMD, NVIDIA, Broadcom, and many others.

FinFET - Fin-field effect transistor is a type of advanced chip design that makes it possible to increase the density and reduce the power consumption of leading-edge semiconductors.

FOUNDRY - Independent manufacturing facility that builds semiconductors for companies that design and market their chips but don't manufacture them. These firms follow a "manufacturing-as-a-service" business model. TSMC, Samsung, UMC, and GlobalFoundries are the largest. Intel is entering this space.

FPGA - Field programmable gate arrays. A type of universal logic chip that finds the most use in low-volume but high-complexity systems like medical devices, automotive, and defense.

FRAND - The fair, reasonable, and nondiscriminatory obligation generally requires patentees to license freely to all qualified participants, whether or not they are competitors of the patent holder. The FRAND system ensures competition from two directions: (a) by offering both new and incumbent firms equal opportunity to insert their intellectual property into a standard, and (b) by making it more difficult for patent holders to unfairly dominate a market or selectively exclude certain competitors.

GAA - Gate all-around. A new type of leading-edge chip design that improves the transistor density and power performance over finFET.

GPU - Graphics processing units are specialized chips used to improve the speed and quality of images on a display device. Because GPUs are designed to handle many tasks in parallel, they have become the preferred chip for AI applications and complex mathematical computations.

INTEGRATED DESIGN MANUFACTURER (IDM) - Vertically integrated semiconductor manufacturer in which design, fabrication, packaging, and sales are all done in-house. Examples include Intel, Micron, Samsung, and Texas Instruments.

LEADING-EDGE FACILITIES - Defined by the CPO as the most advanced fabs, which produce chips at high volume using EUV lithography tools for logic chips, or are capable of producing DRAM chips of 13nm or less.

LITHOGRAPHY - The technology to etch circuit designs onto silicon wafers by using light to transfer a pattern from a photomask to a light-sensitive chemical (photoresist) on the wafer.

MATURE-NODE FACILITIES - Defined by the CPO as generations of logic and analog chips that are not based on finFET or post-finFET transistor architecture, or any sub-28nm transistor architectures.

MPU - Mobile processor unit refers to the logic and ASIC chips used to power mobile designs. Qualcomm, MediaTek, and HiSilicon are category leaders. Nearly all MPUs rely on the ARM architecture.

NAND - Not-And (NAND), also known as “flash” memory, is used in solid-state and USB drives. It offers higher density but is slower than DRAM. NAND is non-volatile, meaning that the information persists even without power.

NM - Nanometer. One billionth of a meter.

NODE - Represents a technology generation. A 5nm node is a generation ahead of a 7nm node, which is a generation ahead of a 10nm node. Each node step represents roughly a doubling of transistor density, making successive generations both more computationally powerful and more energy efficient. Each node improvement represents a step-function in a chip’s processing power and commercial value.

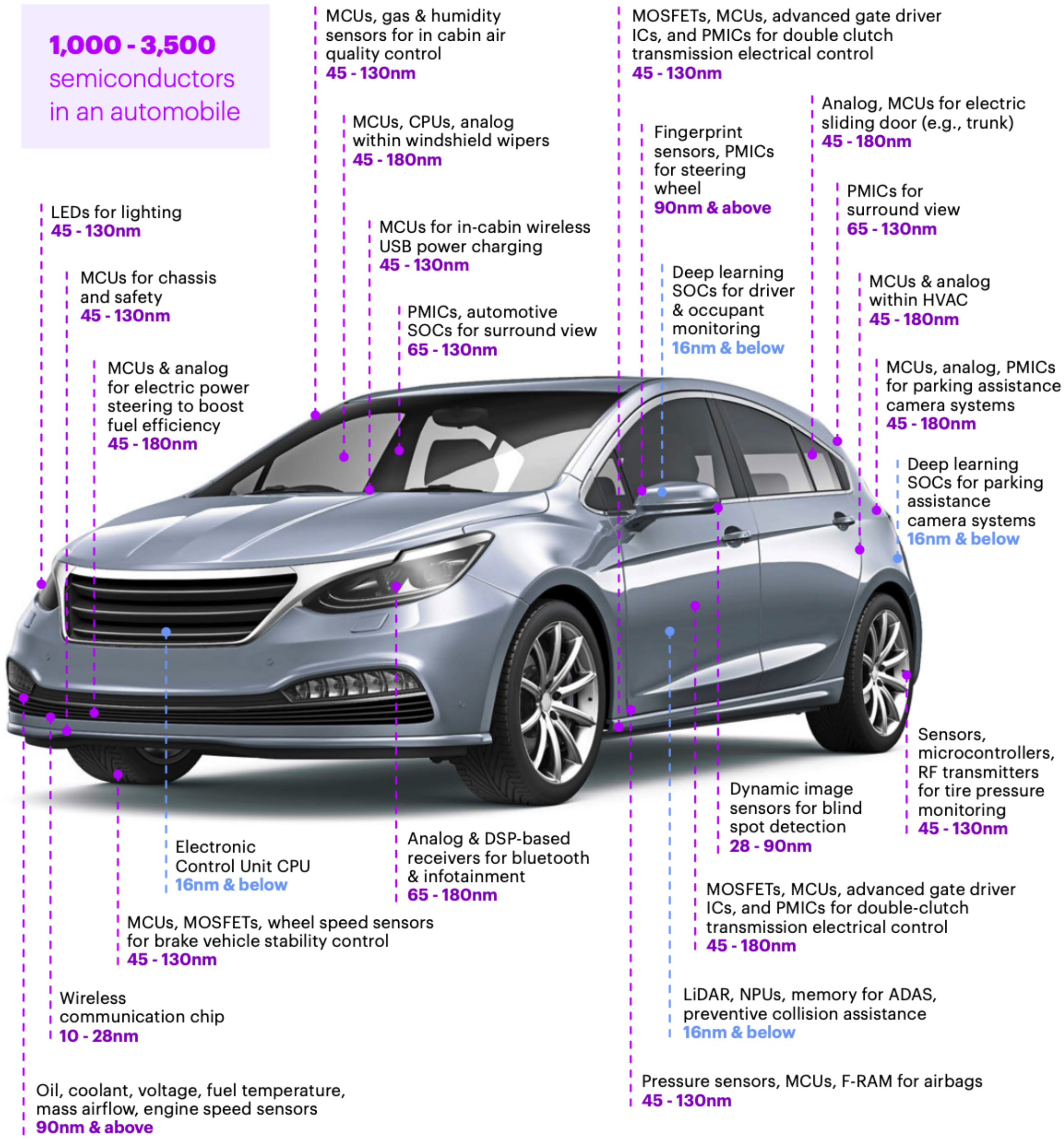
RISC - Reduced instruction set computing is an alternative processing architecture to x86 and is the basis for ARM logic chips. Developed at UC Berkeley in the 1970s.

SEP - Standard-essential patents are patents that are essential for a technology standard (e.g., 4G or WiFi) and which the owners are required to license on FRAND terms.

x86 - Intel’s instruction set architecture for CPUs, which is the global standard for personal computers and servers.

APPENDIX

1. Chips in a Car (Source: Accenture, 2022), by Node Type

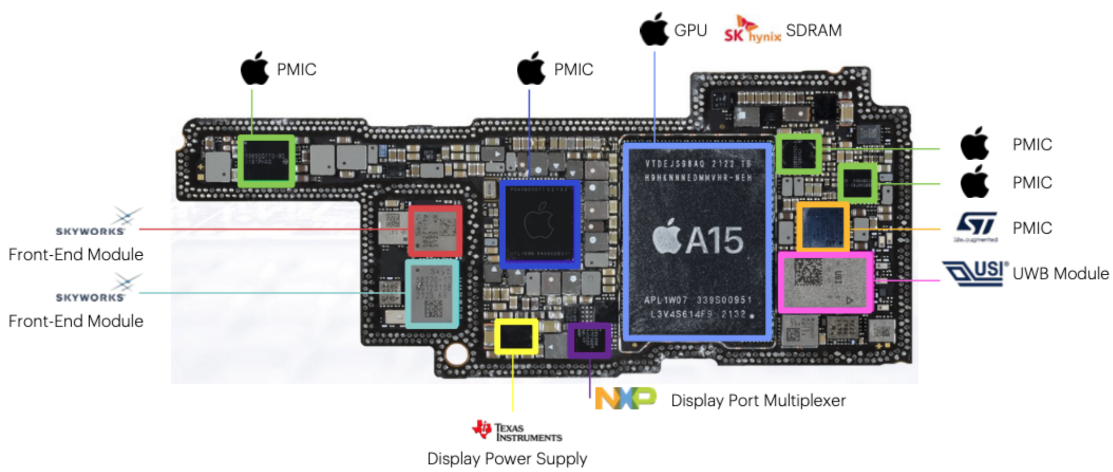


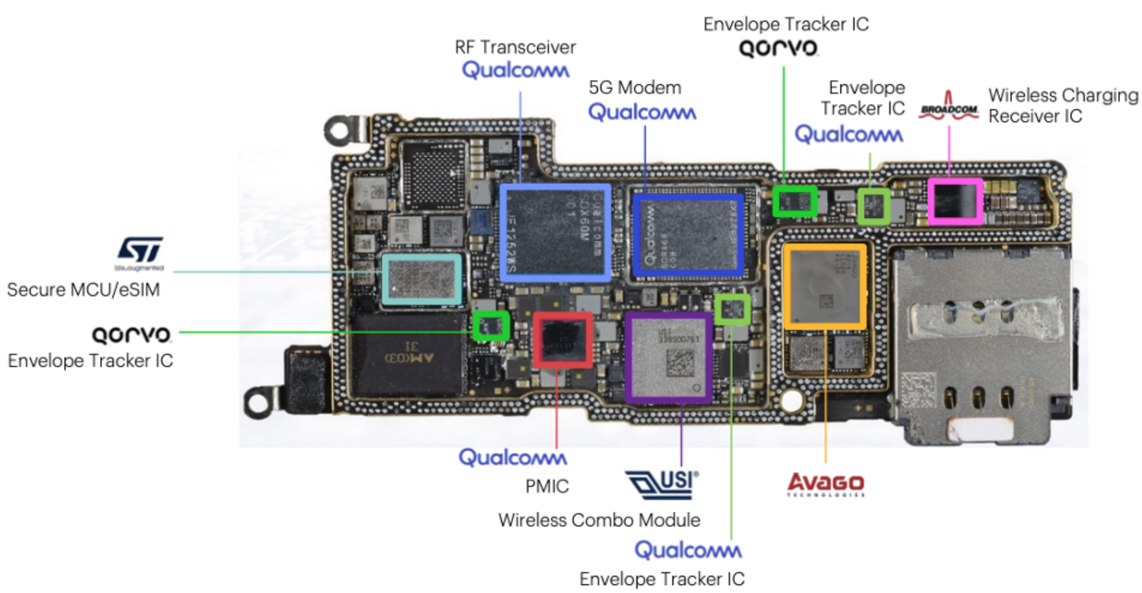
2. Chips in a Smartphone (Source: Accenture)

3. Chips in a Coffee Machine (Source: Accenture)

4. Apple iPhone 13 Pro Circuit Board and Key Chips (Source: Tech Insights)

- PMIC → power management integrated circuit that manages power levels to other ICs
- Front-end module → filters and process radio signals
- Secure MCU/eSIM → secure microcontroller unit that holds subscriber credentials.





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