Public Report on the Use of Mature-Node Semiconductors

Summary

In January 2024, the Department of Commerce's Bureau of Industry and Security (BIS) issued surveys to a representative sample of U.S. industry on the production and use of mature-node semiconductor devices (also known as legacy chips) manufactured by entities based in the People's Republic of China (PRC or China) and used in critical industries and U.S. Government supply chains.[1] The survey aimed to identify how U.S. companies are sourcing mature-node semiconductors. The resulting analysis will inform U.S. policy to bolster the semiconductor supply chain, promote a level playing field for legacy chip production, and reduce national security risks posed by the PRC.[2]

Overall, end users had limited visibility into the origins of the chips used in their products. Some 44 percent of surveyed companies were unable to determine whether their products contained any chips manufactured by PRC-based foundries. Another 38 percent of companies reported that their products contained some PRC chips, while 17 percent of end users were able to affirm they provided products with no chips manufactured by PRC-based foundries. This lack of visibility also suggests that many companies are unaware of the risks, from global shocks to cyber threats, created by potential overreliance on PRC manufacturers.

End users had sufficient visibility, however, to reveal that the use of chips manufactured in PRC-based foundries is pervasive. The data indicate that at least two thirds of respondents' products likely contain chips manufactured by PRC-based foundries.

While the use of these chips is pervasive, it is also shallow. PRC chips account for only about 2.8 percent of all chips by count, and about 1.3 percent of chips by value. In other words, even though PRC chips were present in the vast majority of surveyed companies' products, they currently make up a small proportion of the total chips in most individual products.

In addition to end users, BIS also surveyed suppliers of semiconductors. BIS collected data from 22 organizations on their use of PRC-based foundries for outsourced production. Surveyed U.S. chip suppliers have minimal use of PRC-based foundries: chips manufactured at these facilities account for less than two percent of total chip sales by surveyed companies. That said, several chip suppliers indicated that capacity expansion in China is beginning to cause pricing pressure, and that the combination of subsidies for foundries and downstream industries in China, as well as pressure to use PRC-origin content in China, may impact their competitive positions.

Background: PRC Non-Market Activity in the Semiconductor Space

China's policies in the mature-node semiconductor sector have led to growing market share and rapid capacity expansion that risks investment made and planned by market-driven firms. Over the next three to five years, China is expected to account for almost half of all new capacity to

[1] For the purpose of this study, "manufactured" refers to front-end wafer fabrication. "PRC-based" means organizations headquartered in the People's Republic of China, with manufacturing activities located in China. The survey and this report provided a distinction between "PRC-based foundries", which are contract manufacturing facilities operated in China and owned by PRC-based entities, and "fabrication in China", which includes all semiconductor manufacturing facilities operating in China not owned by China-based entities. The latter category includes companies headquartered in the United States, South Korea, and Taiwan with production in China, such as Texas Instruments, Samsung, and TSMC.

[2] Unless otherwise noted, this report uses the terms "chips," "legacy chips," and "mature-node semiconductors" interchangeably.

manufacture mature-node semiconductors. Many of these investments are fueled by the PRC's non-market practices.

Overreliance on PRC semiconductor supply chains creates significant economic and national security risks. During the COVID-19 pandemic, disruptions to supply chains, including those for legacy chips, led to price spikes in a wide variety of products, including automobiles, consumer appliances, and medical devices, underscoring the risks of overreliance on a few markets for critical inputs. Allowing Chinese firms to dominate the legacy chip market could further threaten supply chains for telecoms, automotive, defense, medical, and other key sectors.
The U.S. government has taken several major actions to reduce the risks of semiconductor supply chain disruption.[3] Through the CHIPS and Science Act, the Department of Commerce is investing more than $50 billion in American semiconductor manufacturing capacity, research, and innovation, and the semiconductor workforce. This will help counteract decades of disinvestment and offshoring that have reduced the United States' capacity to manufacture semiconductors domestically.

In addition, to protect against risks from PRC chips, the U.S. Government is writing rules to implement Section 5949 of the James M. Inhofe National Defense Authorization Act for Fiscal Year 2023, which will prohibit, from December 2027, U.S. Government departments and agencies from procuring products and services that include semiconductors products or services from certain PRC firms.

The U.S. Government is also leveraging tariffs to counteract PRC non-market activity in the semiconductor industry. Following an in-depth review by the Office of the United States Trade Representative, in April, the President announced a suite of tariffs to counteract China's unfair trade practices regarding technology transfer, intellectual property, and innovation across a variety of strategic sectors such as steel and aluminum, semiconductors, electric vehicles, batteries, and critical minerals. As part of that effort, the tariff rate on semiconductors is increasing from 25 percent to 50 percent by 2025.

Finally, the United States is engaging with Allies and partners to ensure a coordinated approach to protect chip investments from the effects of non-market overcapacity and economic coercion. The United States and the European Union share concerns about non-market economic policies and practices that may lead to distortionary effects or excessive dependencies for mature-node semiconductors. Accordingly, both the United States and the European Union have committed to collect and share non-confidential information and market intelligence about non-market policies and practices, consult each other on planned actions, and consider joint or cooperative measures to address distortionary effects on the global supply chain for mature-node semiconductors.

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[3] Examples include the passage of the CHIPS and Science Act in 2022 and the associated CHIPS Incentive Program (https://www.nist.gov/system/files/documents/2023/02/28/Vision_for_Success-Commercial_Fabrication_Facilities.pdf); a prohibition on U.S. government agency procurement of semiconductor products or services manufactured by entities connected to the government of the PRC (Section 5949 of the James M. Inhofe National Defense Authorization Act for Fiscal Year 2023), and executive action to protect American workers and businesses from China's unfair trade practices (https://www.whitehouse.gov/briefing-room/statements-releases/2024/05/14/fact-sheet-president-biden-takes-action-to-protect-american-workers-and-businesses-from-chinas-unfair-trade-practices/)

Methodology for Survey

Two industry groups were surveyed. The first group surveyed were end users (companies incorporating chips or chip-containing components into their products) in industries with concentrated use of legacy chips. The second group surveyed were companies that supply chips in the United States with expected use of semiconductor foundries based in China.

BIS received data from 97 end users representing nearly $3 trillion in annual revenue with an estimated total chip content of $111 billion—more than one-sixth of global chip sales value in 2023. The surveyed end users were focused in six industrial categories that are significant users of legacy chips: Aerospace/Defense, Automotive, Consumer Products, Industrial, Medical and Healthcare, and Technology Hardware and Software/Services.

Among suppliers of semiconductors, BIS surveyed 22 organizations on their use of PRC-based foundries for outsourced production and their visibility into the end uses of the chips they had manufactured in China.[4] This data is supplemental to the significantly larger data collection completed in 2023 as part of BIS's *Assessment of the Status of the Microelectronics Industrial Base in the United States*.[5] That collection involved approximately 200 organizations responsible for substantially all sales of chips in the United States and over 60 percent of global chip sales.

End User Survey

End users in the legacy chips survey had limited visibility into the origin of the chips used in their products. Just 17 percent of end users were able affirm they provided products with no chips manufactured by PRC-based foundries, while 38 percent of end users had products with some level of such chips. The largest share—44 percent—were unable to definitively determine whether or not their products contained any chips manufactured by PRC-based foundries. The lack of direct interaction between product manufacturers and PRC-based chip suppliers, and the fact that chip foundry information generally is not conveyed with purchases of chip-containing products, presents challenges for companies interested in increasing supply chain resilience. Despite a lack of complete knowledge of chip origin at the product level, based on the information respondents were able to provide, BIS estimates that 2.8 percent of the chips (by count) contained in end users' products were manufactured by PRC-based foundries.[6] As discussed below, these chips were nevertheless broadly used, meaning that most of respondents' products contain or likely contain low levels of PRC-origin chips. Most products used in U.S. Government and defense industrial base supply chains likely contain at least one PRC-origin chip.

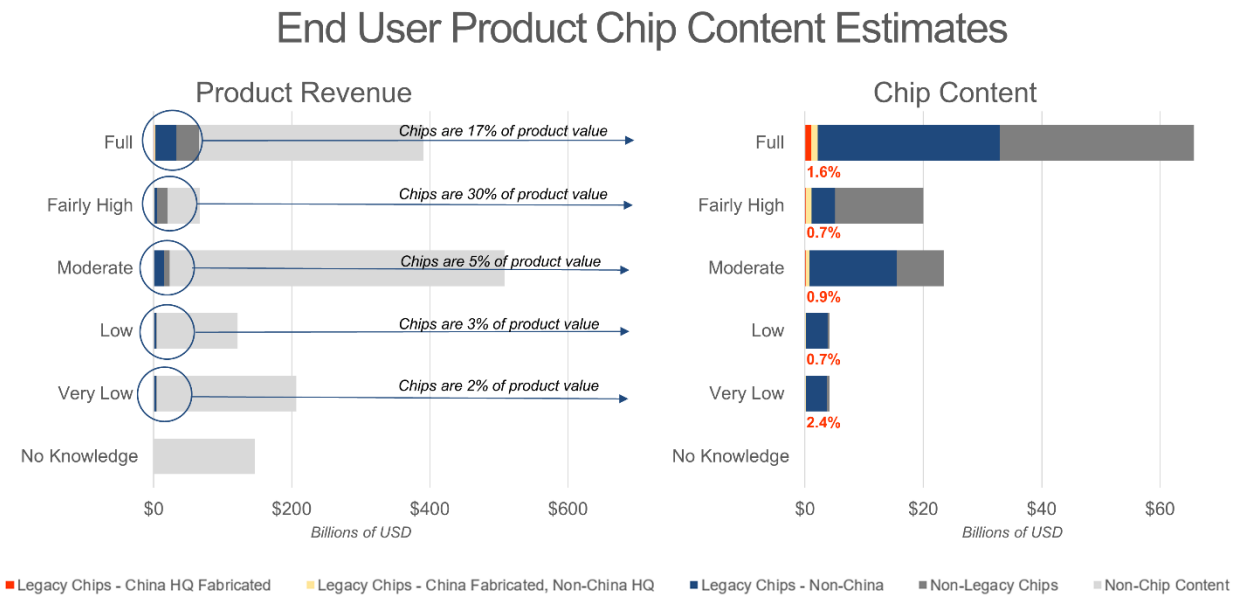
Respondents' confidence in their estimates of their products' chip content and its origin varied significantly, but the estimated portion of chip content fabricated in China was consistent across

[4] Survey respondents included both corporate and business unit level organizations. They are typically referred to as "respondents" or "organizations" throughout the report.

[5] The *Assessment of the Status of the Microelectronics Industrial Base in the United States*, available at https://www.bis.doc.gov/index.php/documents/technology-evaluation/3402-section-9904-report-final-20231221/file is the initial report completed pursuant to section 9904 of the William M. (Mac) Thornberry National Defense Authorization Act for Fiscal Year 2021 (15 U.S.C. §4654)

[6] By value this figure is 1.3 percent, largely due to specialization by PRC-based foundries in lower cost types of chips.

confidence levels.[7] Respondents with "Full" or "Fairly High" confidence in their knowledge of their products' chip content estimated that legacy chips fabricated in China by PRC-owned foundries represented 1.6 percent and 0.7 percent of their overall chip value, respectively.



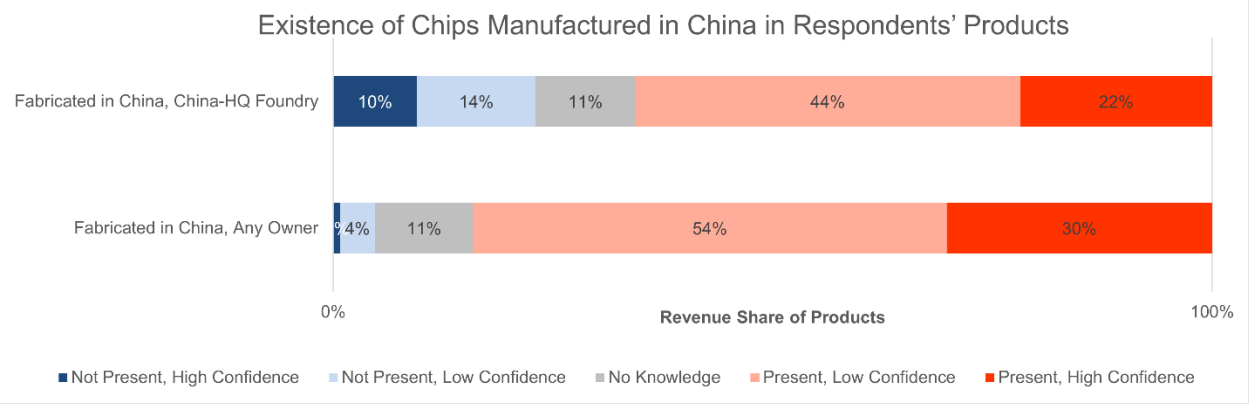
Respondents with lower confidence in the source of their chip content provided similar chip estimates to those with high knowledge, as a group indicating that 1.1 percent of the chips in their products (by value) were fabricated in China by PRC-owned foundries. For 10 percent of products (by value), respondents indicated they had no knowledge at all of the products' chip content. While these products may have higher levels of PRC-origin chip content that the respondents are unaware of, disproportionate use by these end users would likely not be significant enough to meaningfully raise the overall levels of PRC-origin chips across all respondents. On the whole, end users estimate that 1.3 percent of the chips (by value) in their products were fabricated in PRC-owned facilities. Virtually all of these chips were sourced from U.S. or European-based chip designers.

While the estimated share of PRC-origin chip content is generally consistent across varying levels of respondents' supply chain visibility and knowledge, it is also important to note that the overall data points are heavily impacted by a limited set of companies with both greater-than-average knowledge of their supply chains and large volume of PRC chip use. Three large respondents in industries with intensive chip use accounted for over half of respondents' total identified mature-node chip usage, and 80 percent of estimated PRC-origin chip usage.

Because of the sheer number of chips used, most respondents' products contained at least one chip manufactured in China. Products containing legacy chips often contain hundreds or even thousands of chips; thus, although PRC-fabricated chips account for a small share of overall chip usage, they are used consistently across many products. The average car reported by survey

[7] The complete breakdown of respondents' confidences levels is as follows: Full 17 percent, Fairly High 17 percent, Moderate 26 percent, Low 13 percent, Very Low 8 percent, No Knowledge 19 percent.

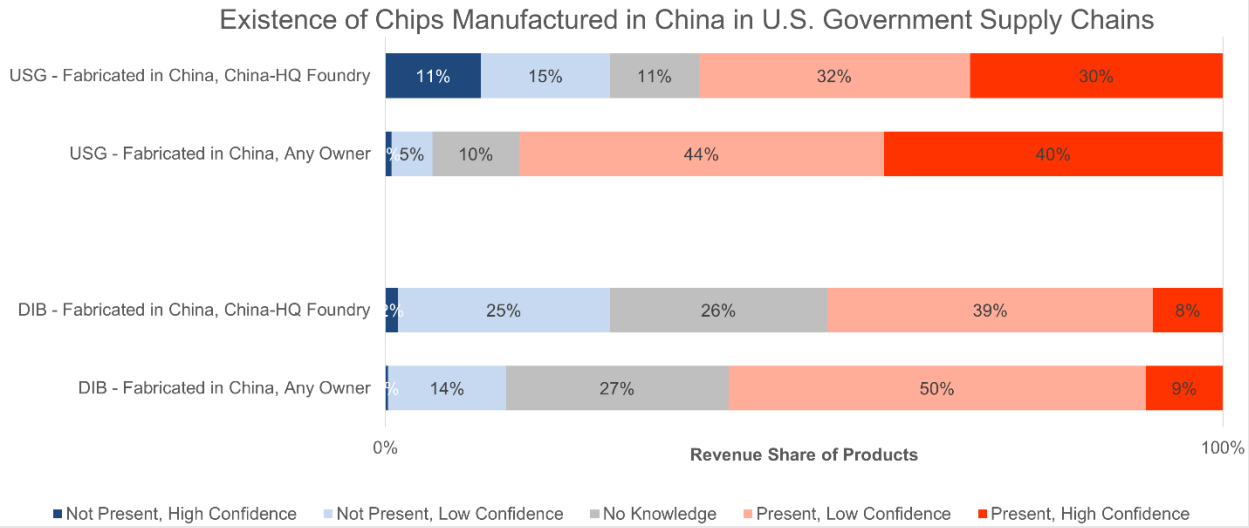
respondents, for instance, contains over 1,700 chips. While the survey data indicates under three percent of these are manufactured in China, PRC chips exist in most cars.



Across all respondents' products, 66 percent (by revenue) contained or likely contained at least one chip manufactured by PRC-based foundries, with an additional 11 percent having no knowledge to form an estimate. For just 10 percent of product sales, respondents were able to say with high confidence that the product contained no chips manufactured by PRC-based foundries. Including chips fabricated in China by organizations not headquartered in China,[8] 84 percent of product sales likely contained chips manufactured in China, with less than one percent having high confidence these products contained no chips manufactured in China.

Products with use in U.S. Government supply chains[9] showed similar patterns, although with higher levels of confidence in the existence, or absence, of chips manufactured in China. Products with known use in the defense industrial base (DIB)—covering 24 percent of listed products—contained markedly lower levels of known presence of PRC-origin chips, and higher levels of expected products with no PRC-origin content. However, a majority of these products are still expected to contain at least one chip manufactured in China by PRC-based facilities. This level of PRC-origin chips may complicate organizations' efforts to comply with FY23 NDAA Section 5949 requirements to eliminate semiconductors produced by certain PRC firms from U.S. Government supply chains.[10]

[8] For example, at TSMC, Samsung, or Texas Instruments facilities in China
[9] While 72 percent of identified products had some level of use in USG supply chains, just 10 percent of product sales were to USG supply chains, and 2.3 percent of the overall chip content identified in the survey was used in USG supply chains
[10] For more information, see Rhodium Group, *Thin Ice: US Pathways to Regulating China-Sourced Legacy Chips*, https://rhg.com/wp-content/uploads/2024/05/Thin-Ice-US-Pathways-to-Regulating-China-Sourced-Legacy-Chips.pdf.



Beyond the knowledge or expectation that their products used in the defense industrial base contained PRC-origin chips, respondents had significant uncertainty as to which company or foundry that performed the chip fabrication. Most companies providing defense products had no visibility into the location of fabrication, and many made significant shares of their chip purchases through distributors.

Even companies with knowledge of the original chip supplier often had no basis to know whether that company itself fabricated the chip or whether they outsourced manufacturing, and which company may have performed the manufacturing. Respondents were able to identify the foundry in China that manufactured the chips for just 23 percent of the products with DIB use and known or expected presence of PRC-origin chips.

Respondents stated that unless the information is conveyed from the original chip provider, it is difficult to determine the location in which a chip is fabricated. Even if a company were to break down its own products and components into individual parts and were able to determine the original chip designer for all contained chips, the company that fabricated the chip is often different from the company that designed it, and there are frequently no apparent physical characteristics that would indicate which company fabricated the chip or where it did so.

One company laid out their challenges in identifying chip origin:

"We are addressing challenges that exist [in identifying chip origins], including instances where [company] purchases finished electronics goods, uses … contract manufacturing arrangements, or buys components from distributors. In these cases: 1) Suppliers may consider detailed component information proprietary and refuse to share it. 2) [Company's] current systems may lack the necessary metadata for tracking specific attributes like process node, wafer size, and materials due to confidential (proprietary) information. 3) [Company] may not be the Buyer of Record for many components due to distributor involvement."

Supplier Survey

Survey data suggests that companies that supply chips in the United States use foundries in China for few of their products. Three-quarters of the chips sold by U.S. companies are from

companies that do not use PRC-based foundries at all. Those U.S. companies that do use PRC-based foundries use them for six percent of their overall production.

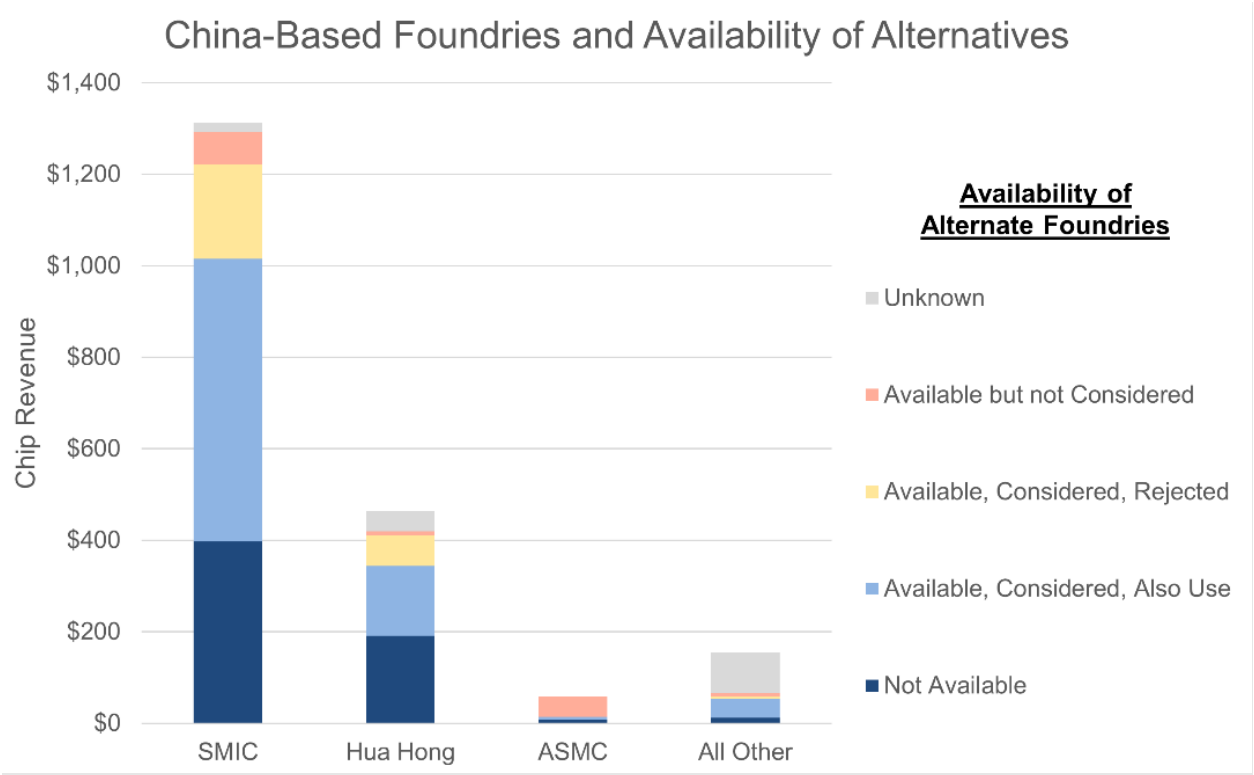
When respondents to the chip supplier survey chose to use PRC-based foundries, the primary reason was cost. Respondents identified cost-associated reasons for foundry choice for 54 percent of their listed products. Among the wafers for which respondents had comparable pricing, 72 percent were cheaper at the PRC-based foundry than at a non-China alternative; the median price at PRC-based foundries was 10 percent lower.

Secondary reasons for using PRC-based foundries included supply chain diversification, specialized technology, and availability of production. Respondents also used PRC-based foundries out of necessity or as part of a multiple-sourcing strategy. For 31 percent of the respondents' chips that were fabricated in PRC foundries, respondents indicated that no other foundries were available to make the chips. For an additional 41 percent, respondents indicated they used both PRC-based foundries and other foundries to produce the chips.

Some chip suppliers indicated that they have been unable to find foundries outside of China that are willing to take the business they use PRC-based foundries for, in part because there are not sufficient market incentives to manufacture these chips outside of China. This finding highlights a major concern related to the expansion of PRC-based capacity: that continued capacity expansion in China prevents foundries outside of China from making the necessary investments that would allow the sustainable production of these chips. China's non-market practices threaten to limit alternative suppliers for U.S. chip consumers.

U.S. companies are thus using PRC-based foundries to a limited extent, driven primarily, but not solely, by cost considerations. Of the foundries in China, respondent chip suppliers most frequently used SMIC—the world's third-largest pure-play foundry[11]—and foundries owned by the Hua Hong Group. These two accounted for 78 percent of the chips produced by U.S. companies at PRC-based foundries. For three-quarters of the products respondents had fabricated at these foundries, either no alternative options existed, or other foundries were already in use, with SMIC and Hua Hong serving as second sources. Several respondents noted they used PRC-based foundries primarily to support their sales into Chinese end markets.

[11] https://www.cnbc.com/2024/05/23/chinas-smic-is-now-worlds-third-largest-chip-foundry-counterpoint.html

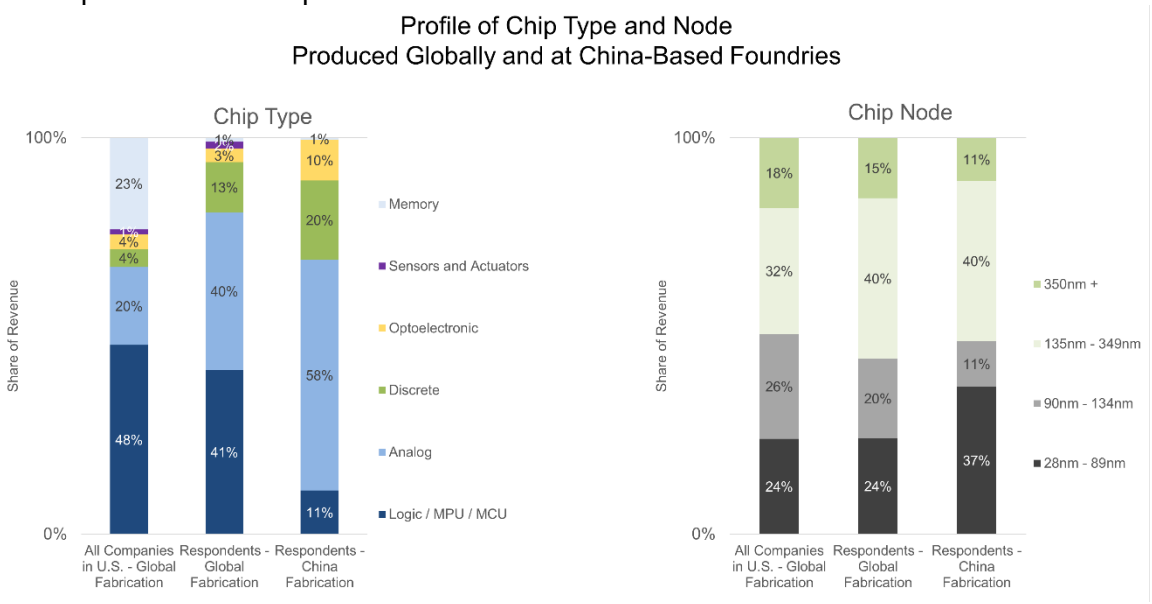


Respondents provided several comments reflecting the interactions of cost, availability, and customer demand:

- *"We will grow business in China for mature node discretes and CMOS mature node dual sourcing as no other region is growing mature node capacity like China."*
- *"Usage in China will focus on mature nodes to be used to support localization requirements in China."*
- *"Some customers are focused on supply chain resiliency and others appear to prioritize decisions based primarily on price. It remains to be seen how industry will value resiliency when making sourcing decisions and the extent to which they will commit to taking the capacity they indicate is needed from localized supply chains."*
- *"The primary factor in determining our foundry partners is their ability to execute the technical specifications we require for the fabrication of our products. A secondary factor is cost. To stay competitive, [we] must consider partnering with foundries with facilities around the world. Who to partner with is ultimately driven by technical ability and cost, and also the ability to manufacture at the scale our business requires."*
- *"We are not aware of commercially-available, cost-effective U.S.-based 22nm or 40nm foundries with sufficient capacity."*

U.S. chip suppliers reported disproportionately using PRC-based foundries for analog integrated circuits, discrete, and optoelectronic chips, with increased use also in feature sizes smaller than 90 nanometers. Companies that use PRC-based foundries were already significantly more focused on analog and discrete chips than other chip producers; analog chips, for instance, represent 20 percent of the revenue of all chip companies that operate in the United States, but

twice that level for respondents' global production, and nearly three times (58 percent) as high for the chips that these companies have fabricated at PRC-based foundries.



The outsized use of PRC-based foundries for analog, discrete, and optoelectronic chips and for feature sizes smaller than 90 nanometers aligns with reporting on capacity and investments in capacity in China. China is the region with both the greatest current capacity for analog/discrete/mixed-signal/power chips and with the biggest planned increase. The same is true for chips with node sizes between 20 and 60 nanometers, with capacity in China for 20 to 40 nanometer chips expected to more than triple based on announced investments.[12] Use of PRC-based foundries by U.S. companies reflect the current concentration of capacity and may be further amplified by expected changes in production capacity, which are forecasted to skew heavily toward China. Several respondents noted they have begun to see increased price competition in China. While some users of PRC-based foundries anticipate it could benefit them by lowering their cost of production, others express concern that a combination of low wafer prices in China, subsidies for PRC-based competitors, and PRC pressure on downstream companies to use PRC-based suppliers will weaken their competitive position. Comments of note include:

- *"We already see China based companies competing with us with very low prices made possible by the China government subsidies of local competitors."*
- *"Investments by China could lead to overcapacity for certain mature-node products in the second half of the decade, assuming continued and material state funding. Chinese domestic content requirements and domestic standards that differ from international standards could also impact business."*
- *"As China builds out mature-node capacity we anticipate that over time they will take share from U.S. / European semiconductor companies due to a desire for indigenous supply. We see this starting today. As mature-node capacity ramps, we also expect to*

[12] Rhodium Group, *Thin Ice: US Pathways to Regulating China-Sourced Legacy Chips*, https://rhg.com/wp-content/uploads/2024/05/Thin-Ice-US-Pathways-to-Regulating-China-Sourced-Legacy-Chips.pdf. Projections are based on "announced fab investments as of December 2023."

experience material downward price pressure, and we may need to drop pricing to preserve share."

- *"Massive Chinese government subsidies to its semiconductor industry are a serious concern and are leading to an unbalanced playing field with other continents. … Unconstrained investment, specifically in legacy [chips], can quickly lead to overcapacity which negatively impacts our ability to compete and generate a reasonable return on investment."*
- *"We anticipate that, absent trade restrictions, increased global investment in mature-node capacity (including such investment in China) will lead to lower fabrication costs and more globally-competitive products."*

Despite potential price cuts and availability pressures, U.S. chip suppliers expressed concern about overreliance on PRC-based foundries and generally expect to limit their use of PRC-based foundries relative to foundries in the rest of the world. Seventy-seven percent of chip supplier respondents expected to increase their global use of foundries through 2032, while 32 percent expected to increase their use of PRC-based foundries.

Conclusion

Overall, end users generally do not have the level of visibility into the chips contained in their products or the fabrication location of those chips to be highly confident mapping their supply chains. Respondents had "full" or "fairly high" confidence in their knowledge of their products' chip content for just under one-third of their products. The data companies had suggest that there are relatively few PRC-fabricated chips in respondents' products, but that use of PRC chips is widespread. With respect to U.S. chip suppliers, cost is the leading reason that suppliers use PRC-based foundries. Several chip suppliers indicated that capacity expansion in China is beginning to cause pricing pressure, and that the combination of subsidies for foundries and downstream industries in China and pressure to use PRC-origin content in China may impact their competitive positions.