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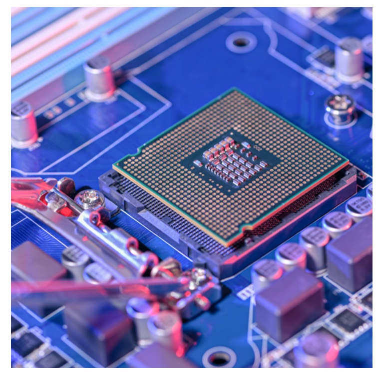
Semiconductors: Encouraging Innovation through Manufacturing and Tax Incentives

Joyce Beebe, Ph.D., Fellow, Center for Public Finance



During his first stop in Asia this May, President Biden emphasized the importance of the semiconductor industry and highlighted the new Samsung plant in Texas and its contributions to innovation and job creation.[1] The increased demand for consumer products that contain chips and pandemic-related disruptions in production have led to a severe shortage of semiconductors over the past two years. Throughout the pandemic, this shortage has had profound effects not only on people's daily activities, but also on economic growth and national security.[2] This issue brief reviews the semiconductor industry's global supply chain issues and their impact on the U.S. economy. It also discusses federal proposals to stimulate semiconductor manufacturing and innovation, with a focus on their tax elements.

OVERVIEW OF THE GLOBAL SEMICONDUCTOR INDUSTRY

Semiconductors and the U.S. Economy

Semiconductors, sometimes referred to as integrated circuits (ICs) or microchips, are widely used in essentially all technological products—from computers and telecommunications equipment to cell phones. Their applications extend to numerous industries including agriculture, energy, transportation, health care, manufacturing, and more.

Even household items such as televisions, refrigerators, garage door openers, and light switches have embedded semiconductors. Military and national security systems and defense infrastructure also rely on semiconductors. Semiconductors are used in an extensive array of consumer and industrial products, many of which the average person is unaware of. A recent study estimated that the current semiconductor shortage has affected nearly 170 industries.[3]

The semiconductor industry was important to U.S. competiveness and economic growth long before the COVID-19 pandemic. According to the Federal Reserve's index of semiconductor and other electronic components, real output from this industry had an 18-fold increase between January 2000 and January 2020.[4] In 2020, semiconductor manufacturers employed approximately 366,000 workers in the United States and generated over $100 billion of the nation's gross domestic product (GDP).[5] These workers represent less than 3% of the U.S. manufacturing workforce,[6] but their average wage ($123,970) is two-thirds more than all U.S. manufacturing workers ($73,397).[7]

The semiconductor industry was important to U.S. competiveness and economic growth long before the pandemic, and the pandemic-related chip shortage has brought semiconductor manufacturing to the forefront of everyone's attention.

Global Semiconductor Manufacturing

The semiconductor value chain is both global and complex: The U.S. semiconductor industry alone generates nearly half of worldwide revenue for this sector.[8] The industry has experienced major structural changes over the last few decades, with a large portion of semiconductors now manufactured overseas. The pandemic

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has further highlighted the importance of ensuring stable supplies of semiconductors—both from industrial competiveness and national security perspectives. As such, it is worth reviewing the semiconductor manufacturing value chain before discussing recent policy responses.

The semiconductor supply chain has been classified in various ways, but this brief separates the process into four major segments: (1) design; (2) fabrication; (3) assembly, testing, and packaging (ATP); and (4) manufacturing equipment and materials. The earliest semiconductor firms, known as integrated device manufacturers (IDMs), performed design, fabrication, and ATP functions all in-house, and they still capture the majority of the semiconductor manufacturing revenue today. Well-known U.S. IDMs include Intel and Texas Instruments. Over time, each step of the process has required increasing specialization, with certain firms only performing one of these functions. One study estimates that as a result of the increased specialization, a semiconductor may cross international borders 70 times before becoming a final product.[9]

Design

The first step of creating any successful product starts with a good design. The design companies generally invest extensively in research and development (R&D) and depend heavily on software. Over time, U.S. companies have increasingly focused on this step of the production process, relying on other companies to fabricate the actual semiconductors. In industry terms, these companies are "fabless." U.S. fabless companies dominate semiconductor design on a global scale. Such specialization is a conscious choice and has generated profitable outcomes: An analysis shows that across the semiconductor manufacturing value chain, the design segment reaps 53% of the value added by industry, fabrication obtains 24%, ATP earns about 6%, and the manufacturing equipment and materials firms receive 11%.[10] Large U.S. fabless design companies include Broadcom, Qualcomm, and NVIDIA.

However, the increased focus on design in the United States has resulted in a decrease of U.S. fabrication capacity. In 1990, the United States had 40% of the global fabrication capacity, which gradually reduced to 13.8% in 2015, and 12% in 2020. In 2019, almost 80% of global fabrication was dominated by Asian countries: South Korea (28%), Taiwan (22%), Japan (16%) and China (12%).[11] Although U.S. production capacity has been stable, the continued expansion of manufacturing facilities in Asian countries means the United States generates a relatively smaller share of global production. U.S. production is estimated to be around 10% of global capacity by 2030.[12]

Fabrication

Fabrication essentially converts the designs into physical chips, producing disc-shaped wafers. This process is highly complex, involves advanced technical capability, and requires extreme precision. These fabrication facilities are sometimes called "pure-play foundries," because they do not design or sell any chips of their own but instead act as contract manufacturers for fabless firms. The development of pure-play foundries is driven by the high costs of building and maintaining cutting-edge semiconductor manufacturing facilities. Recent estimates show that, excluding ongoing maintenance and operation, it would cost $12 billion to build a new foundry.

In general, the three main types of semiconductors are logic chips, memory chips, and analog chips. Logic chips accounted for about 42% of revenue in 2020. They are essential to computing, with key applications including central processing units (CPUs), dedicated graphics processing units (GPUs), and field programmable gate arrays (FPGAs). Memory chips account for 26% of revenue and are primarily used for storing information needed for computing. These chips are commoditized and dependent on production volume and economies of scale. A major application of memory chips is the dynamic random-access memory (DRAM). Finally, analog chips account for 14% of revenue, and they are generally less reliant on cutting-edge manufacturing processes.[13]

Separated by type of manufacturer, the vast majority of the logic chips are manufactured by pure-play foundries, whereas IDMs dominate most of the memory and analog chips manufacturing.

Assembly, Testing, and Packaging (ATP)

The back end of the production process involves assembling chips into finished semiconductor components and testing them to verify functionality. Following this, they are packaged to be incorporated into finished products.[14] This process is labor intensive but requires fewer skills than the fabrication process. As such, it generates the lowest added value. This segment is usually the first step to be outsourced when manufacturing specialization takes place.

Both IDMs and outsourced assembly and testing (OSAT) firms perform the ATP process. The most well-known U.S. OSAT firm is Amkor. Taking both IDMs and OSAT firms into account, the U.S. market share for ATP is about 28%. Excluding IDMs, U.S. OSAT companies have about 15% of the global market share.[15]

Manufacturing Equipment and Materials

There are multiple types of firms in this category. As indicated, building a semiconductor foundry requires substantial investment, and a major component of that cost is the complex, front-end semiconductor manufacturing equipment.

These equipment and materials companies typically do not require high-capital expenditure like the fabrication facilities, but a fair amount of R&D is needed. The United States has a leading position in this segment, with Applied Materials, Lam Research, and KLA Corporation collectively accounting for 37% of global revenue.[16] However, most U.S. equipment manufacturers are small- to medium-sized businesses. U.S. Census Bureau data shows that there were 140 semiconductor equipment manufacturers in 2017, 22 of which (15%) had more than 500 employees.[17]

Overall, U.S. companies have been focusing on chip design and have a dominant position in this segment. However, U.S. fabless companies rely on foreign sources for semiconductor manufacturing. In certain cases, these foundries are concentrated across a small number of suppliers in Asia, including countries that are not U.S. allies. This creates a supply chain risk, and many policymakers are concerned that the United States has insufficient fabrication capability.

THE CASE FOR SUPPORTING SEMICONDUCTOR MANUFACTURING

It is against this backdrop that lawmakers are accelerating the discussion about how to encourage domestic semiconductor manufacturing. To date, there are two major federal proposals that seek to expand U.S. semiconductor manufacturing capacity and ensure long-term technological leadership.

Federal Proposals

The Senate passed the United States Innovation and Competition Act (USICA, S. 1260) in July 2021,[18] and the House passed the America COMPETES Act (H.R. 4521) in February 2022.[19] Currently, the Senate and the House are working to resolve their differences in the hopes of advancing one bill. Although each proposal is over 2,000 pages long, both support investing in domestic semiconductor manufacturing and scientific R&D to strengthen U.S. competitiveness.

The major differences between the two proposals center on trade policy and foreign policy, primarily when China is involved. For instance, both bills seek to limit U.S. exposure to Chinese technology; however, they differ when it comes to countering Chinese human rights violations. Both versions also propose to establish a new directorate at the National Science Foundation, but the House bill specifically requires the candidate to address climate change and inequality.

In terms of semiconductor manufacturing, both bills fund three programs to support investment in domestic semiconductor manufacturing and R&D: (1) Creating Helpful Incentives to Produce Semiconductors (CHIPS) for America Fund ($50.2 billion from FY 2022 to FY 2026), which authorizes the Commerce Department to support R&D and chip manufacturing and provide incentives to invest in facilities that fabricate, assemble, test, and package semiconductors; (2) CHIPS for America Defense Fund ($2 billion), which gives the Department of Defense funds for R&D, chip testing and evaluation, and workforce development needs; and (3) CHIPS for America International Technology Security and Innovation Fund ($500 million), which allows the Department of State to fund global IT security and supply chain initiatives.[20]

Another major difference between the two proposals is that the House version allows up to $6 billion of loans and loan guarantees under the CHIPS for America Fund, which is not mentioned in the Senate version. The House bill also provides broader eligibility for funds, such as allowing the materials and equipment used in manufacturing semiconductors to qualify for incentives.

Tax Incentives

Although neither proposal involves tax incentives, some lawmakers want tax provisions to be considered as part of the final package. Generally, the incentives would be delivered through the investment tax credit (ITC) despite slightly different structures across proposals. For instance, the Facilitating American-Built Semiconductors Act (FABS Act, H.R. 7104) proposes adding a new Section 48 D, the semiconductor manufacturing investment credit, to the Internal Revenue Code.[21] The new provision would provide a 25% credit to qualified investments, with respect to any semiconductor manufacturing facility property and design expenditures. A highly similar Senate version (FABS Act, S. 2107) proposes a 25% credit using the same Section 48 D instrument, but it is limited to manufacturing facilities.[22]

On the other hand, Supporting American Printed Circuit Boards Act of 2022 (H.R. 7677) proposes a new Section 45 M, providing a 25% credit for the purchase or acquisition of printed circuit boards (PCBs) manufactured in the United States. As such, researchers, manufacturers, and buyers of PCBs made in the United States would benefit from this credit.[23]

The two FABS Acts include a "direct pay" option, which essentially allows calculated credit amounts to be treated as payments of tax and any credits that exceed tax liability to be refunded to taxpayers. The mechanism of direct pay first appeared over a decade ago, but it recently generated much attention associated with the renewable energy industry and several legislative proposals.

Because of the capital-intensive nature of the semiconductor manufacturing process, large initial capital expenditures are required. From this perspective, the renewable energy industry is similar to semiconductor manufacturing in that constructions for wind turbine or solar farms also require large upfront investment. The tax code does provide incentives to the renewable energy industry. However, current tax credits are non-refundable, meaning that credits are only valuable when there is a corresponding tax liability to offset against the credits. During the construction phase, operators usually do not generate any revenue and therefore do not have any tax liabilities. The tax credits are claimed during the later stages of the facility's lifecycle.

As a result, many renewable energy project developers who need to monetize tax credits early turn to tax equity markets to get upfront cash. Tax equity investors essentially allow developers to trade future tax benefits for early capital. However, there are mixed views on the effectiveness of tax equity financing. Some observers have raised concerns that because many investors are major financial institutions, a fair portion of the ITC benefits banks instead of renewable energy projects. Others believe that tax equity investors play the role of validating these projects—experienced institutional investors would not invest in unqualified projects with unworthy returns. They also monitor the projects' performance as the development continues.[24]

ITC supporters for the renewable energy industry have long advocated for making the ITC refundable. Last year, the Build Back Better Act (H.R. 5376) also included the direct pay option for the renewable energy industry.[25] However, none of the proposals that incorporate direct pay have become law. The main objections include potentially considerable federal tax revenue losses and equality concerns. Some practitioners point out that refundable tax credits have generally been reserved for providing support to low-income households (e.g., the Earned Income Tax Credit). Allowing businesses to claim a refundable tax credit may not be consistent with how the tax credit was historically used. These reasons for disallowing a refundable ITC or direct pay for the renewable energy industry also apply to semiconductor manufacturing.[26]

Reactions to Adding ITC

There are different reactions as to whether tax credits should be included in the package. Although some legislators believe tax provisions will stimulate the industry, others worry that they will complicate the negotiation process. Still others disapprove using tax credits to benefit one particular industry. For instance, if the current obstacles of bringing products to market involve the entire supply chain, the problem will likely not be solved by only targeting incentives for semiconductor manufacturing.

Even if lawmakers can reach an agreement to include tax incentives in the package, there are also debates over whether the federal or state government should be leading the policy discussion, and whether there should be incentives at both the federal and state levels.

Currently, many state and local governments compete with each other to attract semiconductor manufacturers to their locations by offering tax incentives. Some believe that if a project already receives state incentives, it should not qualify for federal incentives, and vice versa.

Others disagree. They state that, because the cost of building and operating a U.S. semiconductor manufacturing facility is 25% to 50% higher than in Asia, and 40% to 70% of this gap is attributable to lower U.S. government incentives, increasing tax incentives will make the United States a more attractive location.[27]

As a result, they believe a federal-level policy is better than state incentives when it comes to acquiring the support of critical industries. States may not have enough capacity to provide tax incentives large enough to attract multinational companies to the United States, let alone sway companies to consider their state over others as a place to build their facilities. Federal tax incentives release the pressure from states to provide substantial incentives to attract investments to the United States, especially when many countries already provide tax incentives for their semiconductor firms.[28] For instance, China has a national-level semiconductor policy to spearhead their development.

Finally, lawmakers have contemplated the different purposes of federal and state tax incentives—one attracts companies to the United States, whereas the other influences the location decision once the firm has already made the decision to come to the United States. However, at the state level, this does not resolve the long-lasting concerns over the effectiveness of state tax incentives—specifically, how much additional investment occurs because of the tax credit versus the investment that would have taken place even without the credit.

Tax incentives will definitely stimulate the industry; however, some disapprove using tax credits to benefit one particular industry. Other objections include potentially considerable federal tax revenue losses and equality concerns if tax credits are refundable.

CONCLUSION

Semiconductors and their applications are used extensively in many industries, and their influence on national and economic security is far-reaching. The pandemic has brought semiconductor manufacturing to the forefront of everyone's attention, and policymakers have responded by proposing the USICA and America COMPETES Act. However, several disagreements remain over how these proposals address climate change, foreign relations, trade issues, and more. The question over tax incentives also remains contentious.

The Biden administration believes these proposals will combat inflation and provide better jobs. They could also resolve key supply chain issues: Because so many sectors use semiconductors as inputs, a steady supply will increase competition and reduce input prices. While these are desirable long-term outcomes, adding tax provisions will definitely prolong the discussion and increase the costs of the package if no offsetting provisions are proposed. Overall, any final bill should focus on boosting U.S. innovation, technological development, and economic growth—even if this means no tax incentives are included.

ENDNOTES

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11. John F. Sargent Jr. and Karen M. Sutter, "Semiconductors, CHIPS for America, and Appropriations in the U.S. Innovation and Competition Act (S. 1260)," Congressional Research Service, IF 12016, January 13, 2022, https://crsreports.congress.gov/product/pdf/IF/IF12016.

12. Different publications show slightly different statistics for the U.S. share of semiconductor production, but the dominance of Asian countries' manufacturing capacity is consistent across publications. For instance, the White House's "Building Resilient Supply Chains, Revitalizing American Manufacturing, And Fostering Broad-Based Growth," shows that in 2019, the vast majority of semiconductor manufacturing—by IDMs and pure-play foundries—takes place in the following countries (in order): Taiwan (20%), South Korea (19%), Japan (17%), China (16%), and the United States (12%). Europe accounts for 9%, and the rest of the world accounts for 6%.

13. The remaining 18% of the industry revenue comes from the non-integrated circuit semiconductors such as discrete, optoelectronic, and sensors. The market in this segment is highly fragmented.

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17. This is classified under NAICS 333242: Semiconductor Machinery Manufacturing.

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28. Molly F. Sherlock, "Supporting Semiconductor Fabrication with an Investment Tax Credit," Congressional Research Service, IN11923, May 11, 2022, https://crsreports.congress.gov/product/pdf/IN/IN11923/3.

AUTHOR

Joyce Beebe, Ph.D., is a fellow in public finance at the Baker Institute. Her research focuses on tax reforms in the U.S. and computable general equilibrium modeling of the effects of tax reforms. Her other research interests include wealth accumulation over a person's lifetime and, generally, how public policies influence decision-making.

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