The Role of the CHIPS and Science Act on US Semiconductor Manufacturing and Supply Chain Security

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On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

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Introduction

Electronic components made from silicon and other semiconducting materials, such as microchips and integrated circuits (ICs), are commonly referred to as chips or semiconductor devices. The most fundamental and widespread chip component is the transistor, which serves as a switch or amplifier, replacing vacuum tube technology. The transistor was first invented in 1947 at Bell Labs, a milestone in computing that earned its inventors a Nobel Prize [T.E.L., 2025]. Microchips play an integral part in many modern manufactured goods and thus affect a number of commercial and industrial sectors. Military equipment, medical devices, transportation vehicles, and consumer goods all require these chips. Without a supply of chips, the modern form of each of these sectors would eventually fail, along with critical computing infrastructure like the internet. Thus, a reliable supply of both advanced and legacy chips is necessary to maintain economic and societal stability.

From 2020 to 2023, there were significant global chip shortages, including in the US. A mismatch between supply and demand, coupled with production disruptions, were the primary drivers of the shortages, which exposed many vulnerabilities in the global semiconductor supply chain and cost the US GDP an estimated $240 billion in 2021 alone [US Comm. Dept., Apr. 2022]. The Creating Helpful Incentives to Produce Semiconductors (CHIPS) and Science Act was passed by the US Congress in July of 2022 and included funding for many projects and programs intended to strengthen US semiconductor manufacturing and supply chain security (SCS), thus reducing the risk of future shortages. The majority of the funding (>$200 billion) is allocated to government programs at the National Science Foundation, the US Department of Energy, and the US Department of Commerce. Additionally, approximately $52 billion is designated for private sector investments into the semiconductor industry, including $39 billion for semiconductor manufacturing, $11 billion for research and development, and $200 million for workforce development [McKinsey & Co., 2022].

In this paper, I use federal, professional, and commercial reports to investigate the role of the CHIPS Act in US semiconductor manufacturing and supply chain security (SCS). This is followed by a discussion focusing on science, technology, and society (STS) within the semiconductor industry. Specifically, two STS concepts are employed: the first is technological determinism, which views technology as an autonomous force that shapes society. The second is social construction of technology (SCoT), which partly serves as an intellectual counterpoint to technological determinism and argues that social factors shape technological development rather than the reverse. The STS discussion examines the contributions of social factors to the development of the US semiconductor industry, the impact of the industry's technology on society at large, and the interplay between these two dynamics.

The first section of this paper, following the introduction, provides a brief overview of the semiconductor industry and the countries involved, focusing on the manufacturing process and SCS. The second section examines the 2020-2023 semiconductor shortages and the supply chain issues that triggered them. The third section analyzes the CHIPS Act semiconductor funding and its impact on US semiconductor SCS. The fourth section applies the STS lens to explore the relationship between society and technology in the semiconductor industry, followed by a brief conclusion.

SCS Explained

To discuss the security of the semiconductor industry's supply chain, one must also consider the industry's overall dynamics. There are two general categories for chips regarding where they can be manufactured. Mature node chips use older technology with larger transistors (>16 nanometers); the process technologies needed for these chips are cheaper and available in more facilities compared to advanced node chips. Advanced node chips have smaller feature sizes and more advanced designs that are harder to manufacture without newer process technologies. Fig. 1 shows the market share by country and process node for 2023. Note the small number of players that dominate the supply (some unlisted countries have one or two small facilities), and the concentration of production to the East Asia region.

	Advanced Node	**Mature Node**
Taiwan	**68%**	**44%**
United States	**12%**	**5%**
China	**8%**	**31%**
South Korea	**12%**	**6%**
Japan	**0**	**3%**

Figure 1. 2023 Market Shares for Advanced (<16/14nm) Nodes and Mature Nodes by Country [World Population Review, 2025]

The semiconductor supply chain consists of three main ‘links’ based on the full development process of a chip: design, manufacturing, and assembly, testing, and packaging (ATP). Countries with stakes in the semiconductor industry have different strengths; in 2021, the US generated 43% of the total design revenue for the industry, with South Korea ranked second at 21% [Thadani & Allen, 2023]. Converted to 2021 US dollars, those values are $5.7 and $2.8 billion, respectively. The US has maintained its leadership in integrated circuit (IC, or chip) design for decades, and thus one of the main considerations for this component of the supply chain is for the United States to protect its intellectual property (IP) from foreign competitors.

Similar to its success in chip IP and design, the US controls a 41% share of the semiconductor manufacturing equipment market [Thadani & Allen, 2023]. The US leads with the most semiconductor fabrication facilities (fabs) of any country, whether ranked by fab location (342) or company headquarters (413) [Thadani & Allen, 2023]. The manufacturing ‘link’ includes the equipment and the fabs themselves, but also the materials. The US controls only a 13% share of the global wafer fabrication materials market, whereas Taiwan holds a leading 25% share [Thadani & Allen, 2023]. The US must prioritize fabrication capacity, materials sourcing, and manufacturing equipment (i.e. each part of the manufacturing ‘link’) to strengthen the US semiconductor supply chain. Note that while the US has many fabs, in 2021 it still accounted for only 12% and 5% of the global manufacturing capacity for mature and advanced node products, respectively (see Fig. 1).

The last “link” in the supply chain is the ATP. To clarify, ‘assembly’ refers to the process that cuts the completed wafer into individual chips and attaches them to a substrate/frame. This process includes connecting tiny wires between the chip and the lead frame. ‘Testing’ occurs on the wafer level before assembly to verify the absence of defects and after assembly to check the electrical connections and confirm the chip functions as intended. Testing also occurs after the packaging step to ensure the fully assembled chips operate properly under their rated operating conditions. ‘Packaging’ occurs after assembly and consists of covering the chip with a protective layer while allowing connection to the chip pins. The packaging process protects the chip from physical damage, acts as a thermal regulator, and can improve the ability to integrate the chip into a larger system depending on the application and design. Since the process involves many steps after wafer production to create the final product, some companies outsource these steps. Those who do not are integrated device manufacturers (IDMs) and handle their own ATP processes. Thus, IDMs depend little on other companies, countries, or facilities for the post-wafer manufacturing steps. Companies who do not have integrated ATP depend on outsourced semiconductor assembly and testing (OSAT) companies. This decision adds another layer of insecurity to the supply chain but offers advantages; OSAT companies have significantly lower startup costs and easier scalability (relative to a fab). North America operates 19 IDM facilities and 46 OSAT facilities [Thadani & Allen, 2023]. Comparatively, Taiwan operates 4 IDM facilities and 107 OSAT facilities, while China operates 23 IDM facilities and 111 OSAT facilities [Thadani & Allen, 2023].

Semiconductor Shortage

The worldwide 2020-2023 semiconductor shortage was caused by a mismatch of supply and demand and production disruption. A governmental request for information on the semiconductor supply chain found that the median demand for some chips increased by 17% in 2021 compared to 2019 [US Comm. Dept., Jan. 2022]. Suppliers clearly could not meet this demand. For example, the Covid-19 pandemic caused an increase in demand for consumer electronics, many of which have multiple chips. Another example of a supply-demand mismatch within the industry during this period involved automotive manufacturers, who expected a decrease in demand and thus lowered their chip orders. When chip manufacturers switched to higher demand products, such as those for consumer electronics or medical devices, a significant shortage of automotive chips emerged, which are necessary for new vehicles to function and be sold. Because of the scale of manufacturing, the number of process steps, and the overall complexity of the semiconductor manufacturing process, companies must frequently place orders over 6 months in advance; the industry is very inflexible in that way.

Similarly, semiconductor manufacturing requires hundreds of unique materials. Critical gases for semiconductor manufacturing include neon, silane, hydrogen, helium, oxygen, nitrogen, argon, krypton, xenon, and ammonia. Many other elements also play a critical role in the semiconductor manufacturing process, and the lack of even a single one has the potential to halt the entire process. The supply of neon also posed a challenge during the 2020-2023 semiconductor shortage, as the war in Ukraine disrupted Ukraine's production of 70-80% of the global neon supply [Federal Reserve Economic Data, 2025]. While prices rose sharply in 2022, manufacturing companies still generally managed to operate their fabs using stockpiles, other neon suppliers, and alternative gasses.

The production disruptions resulted primarily from Covid-19-related factory shutdowns, but factory fires, winter storms, and energy shortages also contributed [US Comm. Dept., Jan. 2022]. These disruptions manifest in a measured decrease of capacity utilization, i.e. factory production level relative to full capacity. Like nuclear plants, engineers design most semiconductor fabrication plants (fabs) to operate continuously, aiming for capacity utilization to reach ~90%, especially in times of high demand. The total capacity utilization of US fabs dropped from 82.6% in December of 2019 to 77.1% in May of 2020 [Federal Reserve Economic Data, 2025]. While this may seem insignificant considering that the US contributes only a small portion of global manufacturing capacity, global sales reached ~1 trillion chips in 2023 [S.I. Assoc., 2024]; therefore, assuming the US accounts for 10% of total global production, a 5% drop means 5 billion fewer units produced. So, even a small change in capacity utilization can significantly impact supply, affecting many other industries that depend on the chips produced. Keep in mind, this occurred when demand far outweighed supply for many chip types, so manufacturers faced intense pressure to operate fabs as often as possible, yet utilization remained low because of factory shutdowns.

CHIPS Act and SCS

The CHIPS Act allocates ~$52 billion for semiconductors in total, with $39 billion for semiconductor manufacturing, $11 billion for research and development, and $200 million for workforce development [McKinsey & Co., 2022]. The CHIPS Act provides an additional $24 billion for a 25% tax credit for qualifying capital expenditures for semiconductor fabrication/manufacturing facilities, and another $500 million for the International Technology Security and Innovation Fund (ITSI Fund) [McKinsey & Co., 2022]. The ITSI Fund will support efforts to enhance telecommunications network security and strengthen and diversify the semiconductor supply chain [S.I. Assoc., 2025]. Fig. 2 below shows the efforts the ITSI Fund supports regarding semiconductors, verbatim from the US Department of State.

Securing Critical Material Inputs	Semiconductor fabricators require access to critical minerals such as aluminum, arsenic, cobalt, copper, and rare earth elements. Several nations around the world have relevant mineral resources, and the Department will lead an effort to bring new, more diverse and resilient mining, refining/processing, and recycling capacity online to support global chip production, including in the United States.
Strengthening International Policy Coordination	In conjunction with the Department of Commerce, the State Department will coordinate with partner economies to support a more resilient and diverse semiconductor supply chain. These activities include developing common or complementary approaches to industry incentives, as well as improving coordination during supply disruptions.
Expanding and Diversifying Downstream Capacity in the Indo-Pacific and the Americas	The ITSI funding will be deployed to promote the expansion of the international assembly, testing, and packaging capacity needed to diversify the global semiconductor supply chain. The United States will engage with like-minded partners to identify key regulatory and policy levers to attract semiconductor supply chain investments, identify workforce and infrastructure development needs, and engage in targeted capacity-building to help fill those gaps. This will also include ensuring countries have the necessary measures in place to safeguard leading-edge chips and technology from diversion and misuse.
Protecting National Security	Some uses of advanced semiconductors can pose national security risks. The mechanisms to mitigate those risks – including collaboration with international partners on export controls and licensing policies – require strengthening. The Department will facilitate the development and close coordination of such policies and practices with supply chain allies and partners.

Figure 2. ITSI Fund: Semiconductor Policies Supporting SCS [S.I. Assoc., 2025]

The ISTI Fund semiconductor policies aim to protect the materials and ATP sections of the supply chain and to ensure relationships with other countries contribute to our semiconductor SCS rather than undermine it. Of the $39 billion for semiconductor manufacturing, the CHIPS Program Office (CPO) has already announced $32.5 billion [S.I. Assoc., 2025]. The CPO oversees the disbursement and monitoring of the ~$52 billion allotted specifically for semiconductor manufacturing. These grants support projects with a total investment of over $380 billion over the next twenty years, and analysts widely agree that federal funding for the industry has spurred corporations to make large investments in the semiconductor sector [S.I. Assoc., 2025]. Many projects receiving investment will either directly or indirectly benefit US semiconductor SCS. The CPO has invested in wafer suppliers, manufacturing equipment, and fabrication facilities, all of which are domestic [US Comm. Dept., 2024]. Furthermore, the CPO expects to allocate additional funding awards to material suppliers for the critical chemicals and gasses required for chip production [US Comm. Dept., 2024]. Since some of these materials lack known sources within the US in sufficient quantities, the US must form and maintain strong relationships with other countries with domestic access to these materials.

The $200 million in workforce development and the $11 billion in research and development aim to maintain the US's competitiveness in IC design and ensure capable human resources for the new domestic fabs. Research focuses on advancing ATP facility proficiency and efficiency and shortening the time needed to start production of advanced node chips [NIST, 2025]. Thus, the CHIPS Act provides support for each part of the manufacturing process: design, fabrication (including raw materials and equipment), and ATP. All of this logistical and financial support will help improve the US's semiconductor SCS and provide the means for increased domestic trade within the industry.

Consider a 100% domestically sourced US semiconductor supply chain: The US would need to source every material, machine, and design necessary to run many large-scale fabs within its borders. Even then, the semiconductor supply chain still faces risks, such as IP theft, purposeful sabotage, and other issues the US may be unprepared for. The more straightforward approaches to strengthening the semiconductor supply chain also prove the most effective: The semiconductor funding from the CHIPS Act aims to boost domestic semiconductor manufacturing capacity. In fact, analysts expect this manufacturing capacity to triple from 2022 to 2032, marking a huge increase in production that will drastically reduce the US's dependence on other nations for semiconductor manufacturing [BCG & S.I. Assoc., 2025]. For perspective, analysts project this will only increase the US's share of global semiconductor manufacturing capacity from 10% (2022) to 14% (2032) [BCG & S.I. Assoc., 2025], because many other countries also heavily invest in the semiconductor industry, particularly in chip manufacturing fabs. This creates a double-edged sword: while a larger chip supply emerges, which should help stabilize the market, a greater demand for manufacturing resources arises.

The investments in research and development will provide the United States with the technical ability to maintain its leadership in chip design, to improve fab efficiencies, and to advance the domestically manufactured equipment necessary for fab operation. The investments in manufacturing and ATP will greatly reduce reliance on the numerous OSAT facilities in East Asia. The policies designed to improve foreign relations in the semiconductor sector and beyond should contribute to improved resource availability and a more reliable materials supply chain. Most of the funding will take years to have an impact, but the effect so far and the projected impact appear highly positive for securing the US semiconductor supply chain.

Semiconductors, Government, and Society

Transistors enabled the development of more advanced and compact devices, including radios, hearing aids, and calculators in the early years (1960s, '70s, and '80s). During the advent of the semiconductor industry, the government actively funded many research projects which led to breakthroughs in the industry. The following is an excerpt from a Consensus Study Report discussing public policy effects in emerging industries, authored by the National Academies of Sciences, Engineering, and Medicine:

> ***"The U.S. Signal Corps was the prime funder of the R&D that led to development of the transistor and semiconductors for three decades and purchased most of the initial output. The military funded the first pilot production lines of Western Electric, General Electric, Raytheon, and Sylvania and construction of production capacity far in excess of demand. From the late 1950s through the early 1970s, the federal government funded between 40 to 45 percent of U.S. R&D in semiconductors. Military purchases of semiconductors enabled the industry to establish the scale that led to a dramatic drop in prices between 1962 and 1968, making them more practical for commercial use."***
> [US National Library of Medicine, 2012]

From 1968 to 1984, the MOSFET (transistor) process node went from 20 micrometers to 1 micrometer [The Register, 2011]. As the technology scaled down, engineers applied it to an increasing number of commercially available products. During the 1980s and 1990s, manufacturers produced logic, memory, and specialized chips in large quantities for computers and other electronic devices. As engineers continued to advance the technology, applicable products and company profits both soared; By 1990, Intel had reached a yearly revenue of $3.9 billion [Intel, 1990]. Fast forward to 2025, and Taiwan Semiconductor Manufacturing Company (TSMC) is opening its 2 nanometer process node fab, the first of its kind [TSMC, 2025]. Due to TSMC's historical strategic decision to focus on the foundry model, in which TSMC manufactures other companies' chip designs, Morris Chang (who founded the company in 1987) built the largest semiconductor manufacturing company in the world. The foundry strategy enabled Chang to start earning revenue from and working with his would-be competitors; he knew that companies like Texas Instruments, Motorola, and Intel would outsource their chip manufacturing to cut costs; plus, he secured government aid through Taiwan's National Development Fund.

Economic, social, and political forces have clearly influenced the semiconductor industry's technological advancements since its inception. The research grants provided, the product demand, and the national policy attention reflect how human factors shaped and continue to shape the industry. Conversely, the technology developed through the semiconductor industry has significantly driven the development of many societal norms and numerous modern industries. Semiconductor technology is driving social change via its critical and widespread applications. Scholars call these sets of ideas, or 'frameworks', social constructivism and technological determinism, where social constructivism describes social factors shaping technological development and technological determinism refers to technology driving societal changes.

The most relevant example of society shaping technology is the CHIPS Act, which was in part a response to the semiconductor industry's 2020-2023 supply chain issues. The funding and planning this act provides will have a huge impact on the US semiconductor manufacturing industry and greatly increase SCS. The funding and news of these events might inspire undergraduate computer engineering and materials science students to pursue careers in semiconductor manufacturing. The constant demand for increasingly advanced chips for phones, radars, medical devices, artificial intelligence, and much more pushes the industry to ever-increasing production levels and innovation. These social forces manifest as billions of dollars for manufacturing and research and development programs, and as new business ventures looking to supply resources and services to improve SCS in the United States. A secure supply chain enables a manufacturing industry to maintain stable production in its market, and a stable chip market supports a stable economy, both nationally and internationally. Thus, policymakers should prioritize strengthening the US semiconductor manufacturing industry to ensure a consistent chip supply for integration into other products.

In the beginning, governments provided substantial funding because of the high costs of semiconductor research, reflective of the advanced technology. Semiconductor production requires costly technology; thus, fabs typically operate as large-scale facilities producing chips in massive quantities. These pecuniary decisions have significantly influenced the industry's development, but they reflect a technological determinant rather than a social one. The semiconductor industry has operated at the forefront of scientific application since its inception, and the strong social drive for computational advancement has kept the industry's demands there. Of course, the cost of ever-improving, massively-scaled precision remains high, and this has driven the emergence of OSATs and fabless design companies to split the value chain and minimize costs at every step of the manufacturing process, from design to packaging. Semiconductor technology offers numerous examples of shaping society, such as the positive and negative effects of integrating computers, cell phones, and the internet into the daily lives of billions of people.

A company's ability to recognize the influences of technology on society and society on technology in any industry goes a long way in ensuring the company's success. Businessman and electrical engineer Morris Chang did so, enabling TSMC to achieve a net worth of over $800 billion in 2025 [Stock Analysis, 2025]. Governments have always provided funding for semiconductor research, development, and manufacturing and will likely continue as nations economically compete with one another. Semiconductor manufacturing and research technologies shaped the business model for semiconductor manufacturing, but unfortunately, splitting the value chain by outsourcing production steps complicates the supply chain and weakens SCS. Analysts may never fully understand the CHIPS Act's total effect on semiconductor technology, but its improvement to the US semiconductor supply chain is definitively positive.

Conclusion

Each step of semiconductor development—design, manufacturing (including fabrication capacity, equipment, and materials sourcing), and ATP—plays a critical role in ensuring semiconductor supply chain security (SCS). The CHIPS Act strongly supports the domestic semiconductor sector, particularly in manufacturing and supply chain resilience, though executive branch policy shifts pose risks to sustained progress. To mitigate supply-demand mismatches, strategies like increased production capacity, standby fabs for high-demand chips, and stockpiles of critical chips can be employed to enhance manufacturing flexibility and prevent shortages. Since many material sources originate in specific regions, the United States must strengthen diplomatic ties with allies and explore domestic sourcing opportunities. The CHIPS Act exemplifies social constructivism by channeling societal priorities—spurred by the 2020-2023 shortages—into technological advancements, while its outcomes drive technological determinism, enabling chips to transform industries like healthcare, defense, and AI. From government-funded transistor research to TSMC's foundry model, social and economic forces have shaped the semiconductor industry, just as its technologies have reshaped society through computers, smartphones, and the internet. By sustaining the CHIPS Act's momentum, fostering global partnerships, and embracing innovative business models, the United States can secure its semiconductor supply chain, ensuring economic stability, societal resilience, and technological leadership in an increasingly competitive global landscape.

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