THE GLOBAL CHIP SHORTAGE: AN ANALYSIS OF SEMICONDUCTOR SUPPLY

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By

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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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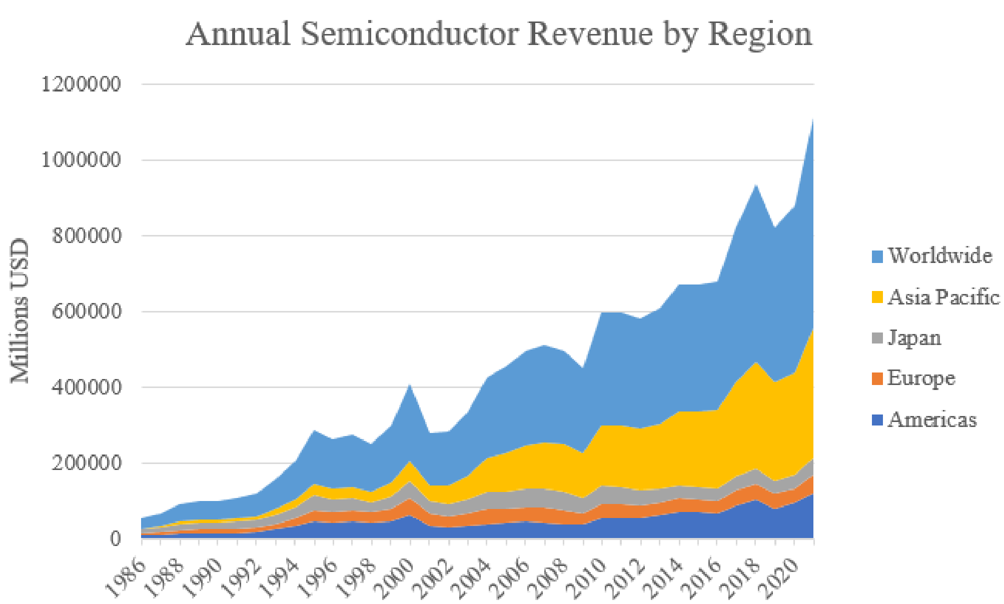
In 2018, for the first time ever, more than 1 trillion semiconductors were sold in a year (Yinug, 2019). The sheer enormity of this figure alone shows the massive impact semiconductor chips have on our daily lives. They can be found just about everywhere; if an object has a plug or a battery, it almost certainly contains a semiconductor. However, the globe is currently facing a shortage of semiconductors, also known as chips, as a result of several factors to be explored. This shortage has impacted the production of goods, research, and education around the world. In fact, the shortage has even reached the technical side of this project. Instructions were given by the technical advisors to ensure that any parts chosen for the technical project have a large quanitity in stock. This instruction is a result of the current volatility of chip supply; if a product goes out of stock, there's no guarantee that the product will be available by the time it is needed. The technical project used several forms of semiconductor technology, including microcontrollers, transmitters, and power control circuits. Our project is the Smart Shoe Insole. Essentially, this is a device that uses sensors and bluetooth to send a real time signal to a display application that maps the pressure points on your feet. This project was completed in Fall 2021, with the help of advisor Harry Powell and team members Kieran Humphries, Merron Tecleab, Ahmad Tamanna, and Xinyuan Zhu. The STS project focuses on the global chip shortage, including its cause, effects on industry, and potential solutions. Specifically, the project looks at the effects of the shortage on the automobile industry, and Actor Network Theory is applied to shed light on the interactions that cost the automobile industry $210 billion in 2021 (Wayland, 2021). Actor network theory is distinct because "it insists that networks are meterially heterogeneous and argues that society and organization would not exist if they were simply social," (Law, 1992, p. 379). This distinction is useful for the purposes of this paper; an exclusively social lens would not be enough to unwrap the issues surrounding the chip shortage.

LEADING FACTORS

Semiconductors have seen growing demand since their invention. As seen in Figure 1, worldwide semiconductor revenue has consistently climbed since the beginning of the World Semiconductor Trade Statistics. Even in more recent years, several new factors have driven the semiconductor supply chain into overload, including the development of 5G, artificial intelligence, and a growing Internet of Things (Voas, 2021). Clearly, this growth indicates that semiconductors have become integrated in our everyday lives. This tight integration results in a market that is very unforgiving to supply chain disruptions, as consumers are constantly purchasing new devices.

Figure 1

Annual Semiconductor Revenue by Region



Note. Regional semiconductor revenue in millions USD. Adapted from Historical Billings Report 36. Copyright 2022 by World Semiconductor Trade Statistics.

THE SPREAD OF COVID-19

When the world shut down as a result of the COVID-19 pandemic, factories shut down as well, causing the materials required for the production of semiconductors to be unavailable for months. While supply had shut down, demand for consumer electronics only increased as a result of quarantines and social distancing (Feder, 2021). With the shift to online life, electronics became even more intertwined with everyday life. Whether it was work, school, a social club, counseling, or even a medical examination, normal in-person activites quickly required the use of a computer to facilitate online meetings. One popular application that allowed students and workers to stay connected through the pandemic is Zoom. According to data from Zoom aggregated by WallStreetZen, Zoom had 58,500 customers with more than 10 employees in the first quarter of 2020. By the first quarter of 2022, that number skyrocketed to 470,000 (WallStreetZen, 2022, Table 1). This sharp spike in demand combined with the kink in the supply chain severely exacerbated the chip shortage, causing manufacturers to rethink the allocation of their remaining chips.

NEW TECHNOLOGIES

Several new technologies are contributing to the lack of stability in semiconductor supply. A major one is 5G cellular networks. According a reporter from Bankr, 15% of the global population had access to 5G networks in 2020; that number is projected to rise to 53% by the end of 2025 (Baltrusaitis, 2022). Considering its promise as a future technology (Mohanty, 2021), companies are looking to fund its research and development. This research demands large quantities of chips, and foundries will accommodate this, as the new, high end chips required for devices using 5G are the most profitable. While this research and development will certainly benefit society once the shortage is resolved, it has caused an increase in demand for semiconductor technology at a time where the demand simply can not be met (Baraniuk, 2021).

The Internet of Things (IoT) is another technology affecting semiconductor supply. The IoT is a network of devices that are connected to the internet and are capable of sharing data with other devices on the network (SAS, 2022). This is not a novel technology; the first items on the internet of things were soda machines and ATMs. However, with the advancements of artificial intelligence and machine learning, IoT is gaining massive value. In fact, IoT revenue is expected to reach $594 billion in 2022 (Watters, 2022). This growth will certainly continue to affect the chip shortage, as every device that gets added to the IoT requires some form of semiconducting chip.

WIDESPREAD IMPACTS

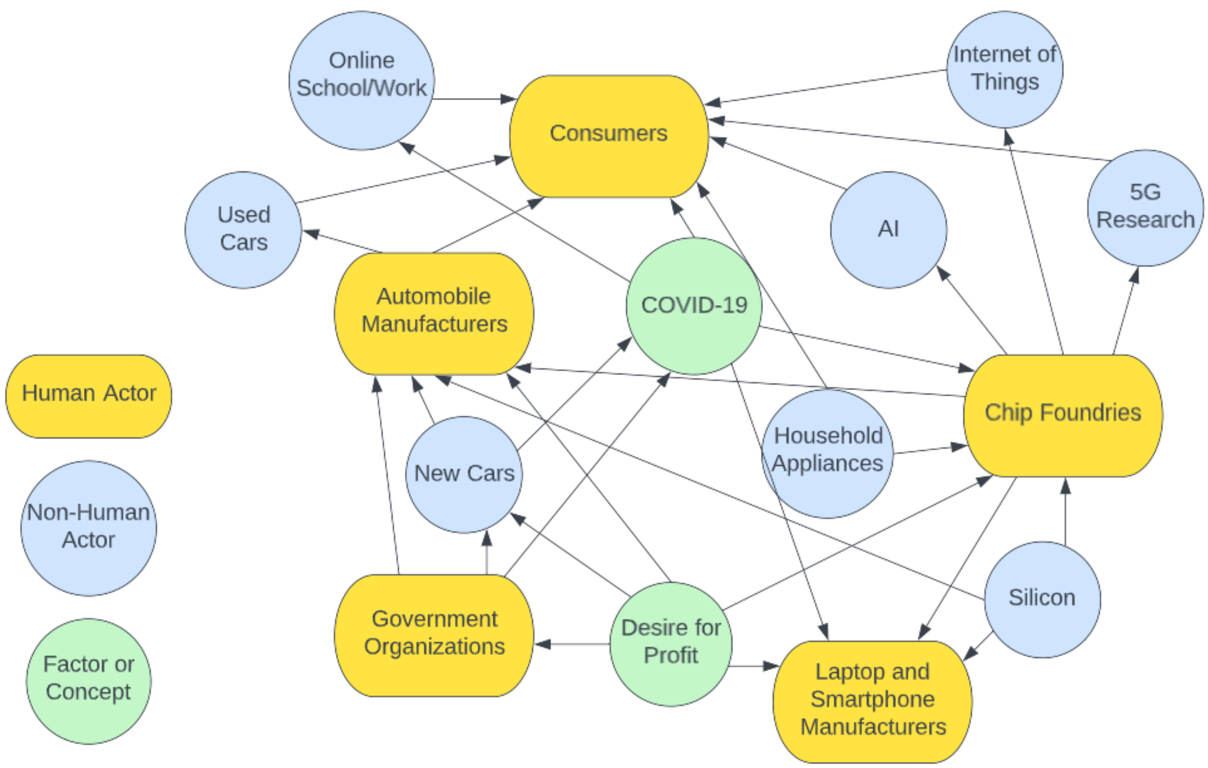
Already, the impacts of the chip shortage can be seen in industries around the world. One area that was hit particularly hard was the production of low-margin electronics, for example household electronics (Shead, 2021). Products like toasters and washing machines require low-end semiconductors, which are not the most profitable option for chip foundries. Foundries have limited production capabilities, but seek to make the most profit, which is done through the production of complex chips that go in products such as phones and computers. Consequentially, products using low-end chips have seen an increase in price and a decrease in supply.

IMPACT ON AUTOMOBILE INDUSTRY

The automotive industry got hit particularly hard by the semiconductor shortage. One estimation for the losses experienced by the industry sits at $210 billion (Tung, 2021). If the monetary value is not enough to describe the impacts of the shortage, contextual evidence may provide a clearer picture: it was hit so severely that some people were able to sell their used cars for more than they purchased them for. This was a result of the shortage; companies wanted to sell new cars, but did not have the chips necessary to complete the vehicles. As a result, they bought back used vehicles in order to repurpose the chips (Radcliffe, 2021). Actor Network Theory can be applied to understand the context of this reality. Figure 2 was created to simplify the complex web of relationships surrounding the chip shortage. Each previously defined aspect of the shortage can be found in the network, and the arrows indicate that two factors have an influence on one another. The factor of interest is the automobile industry, but COVID-19 was selected as the central factor, as it is the most influential actor.

Figure 2

Actors Surrounding the Automobile Industry



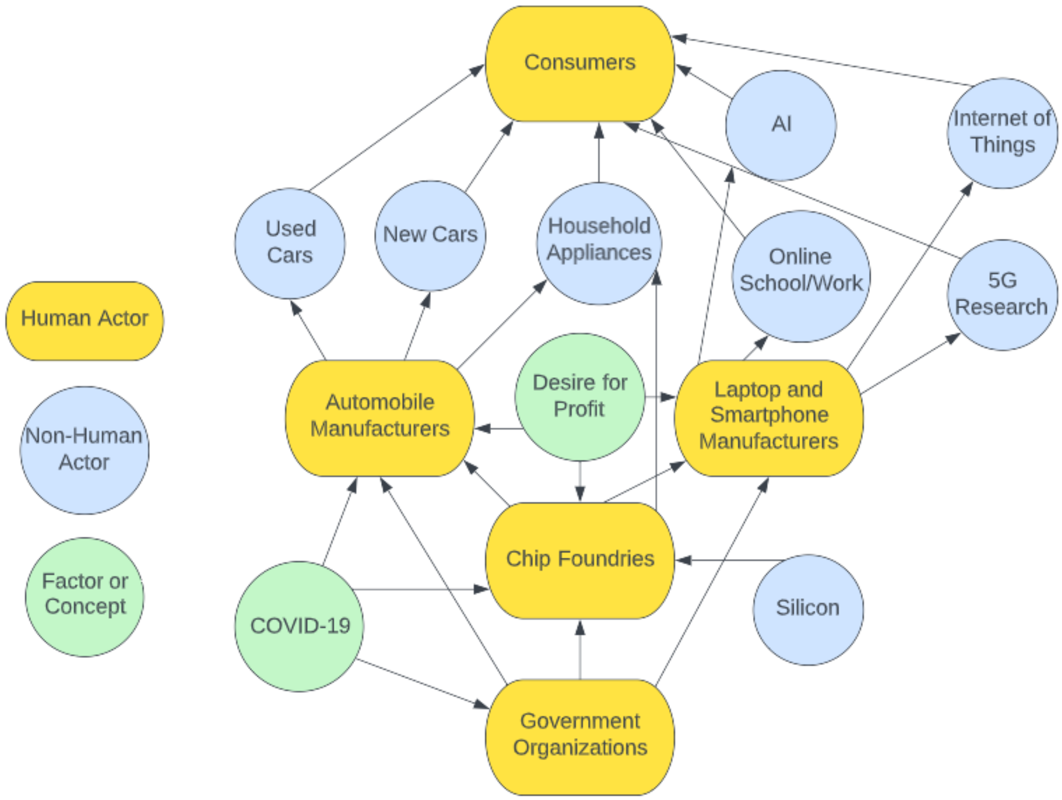
Note. The factors, concepts, and actors involved in the shortage are presented to show the lack of organization in the current market.

There is some misalignment between the target market of semiconductor manufacturers and the chips desired for automobile manufacturing. Chip manufacturers are interested in creating complex semiconductors for the latest smartphones and computers. On the other hand, automobile manufacturers are interested in utilizing older, cheaper chips, as this will save costs. During the second quarter of 2020, automotive manufacturers "shut down, as did most of the world, but as they did that they canceled orders from a lot of the supply chain," (Shein, 2021, p. 1). The major issue here is that chip foundries were hardly even interested in manufacturing lower-end chips. They had already begun to shift production to focus on high-end chips, as selling these to companies producing laptops and smartphones is their most profitable option. This shift in production caused them to sell the rest of their low-end chips, leaving automobile manufacturers scrambling as the chips they needed quickly sold out to companies producing household products and other simple electronics. All of a sudden, new cars were much more difficult to produce, and the value of old cars skyrocketed.

In the past, the leaders of chip manufacturing have shifted. The industry was created by the U.S. in the 1960's, but China has been another major figure in production since the 1970's. Recently, China has been the world's leading manufacturer of chips by a large margin, and this is certainly affecting American automotive companies. If the U.S. was responsible for the production of more chips, it could have meant smoother communication between chip foundries and the automobile industry. It is certainly possible for the U.S. to produce more chips; the US government has a history of bailing out essential industries in times of crisis (Glass, 2021). Had there been more domestic chip production capability at the time of the pandemic, chip production could have been bolstered by government funds. Figure 3 depicts this potential solution to the shortage, showing the actors being linked productively.

Figure 3

Actors Linked in a Productive Manner



Note. Factors, concepts, and actors involved in the shortage, organized to depict the solution of a regulated market without COVID-19 as a central factor.

While COVID-19 is still at large in the world, it no longer has such a central effect, and shouldn't have as big of an impact on production, so it is no longer central to the network. A bottom-up approach with government at the bottom could provide a stable basis for having enough capital to produce new chips. In fact, bills that could provide just this have been introduced in congress. In March 2022, the CHIPS for America Act was passed by the United States Senate and introduced to the House of Representatives. This bill was drafted to address two primary problems being faced by the United States semiconductor supply chain. The first is the lack of organization and consistency in policies related to microelectronics. By having some sort of agency to oversee the distribution of chips, supply allocation problems such as the one inflicted on automobiles could be avoided. This agency should not have complete control, as ultimately we do live in a capitalist society, and chip foundries are privately owned. However, without some sort of inter-industry structure, society is vulnerable to supply issues like those seen with today's economy. The bill would establish a trust fund, which would get its funds from a variety of foreign government partners (CHIPS for America Act, 2021). The legislation will solve the first problem by promoting tranparency in supply chains and alligning with foreign, non-market economies. The second major problem is a lack of domestic semiconductor production. To combat this, the bill "provides an income tax credit for semiconductor equipment or manufacturing facility investment through 2026,"(CHIPS for America Act, 2021, p. 1). While the Chips for American Act is not yet official, companies have already announced plans to build foundries in the states. Intel has plans for a $20 billion factory in Ohio, while Samsung is investing $17 billion towards a factory in Texas (Drew, 2022). Factories like these will ensure a steady supply of semiconductors for the ravenous American demand.

SILICON ALTERNATIVES

Another potential method of getting out of the chip shortage is to focus on alternatives to our current production of semiconductors. There are three main alternatives that could replace the now-mainstream silicon semiconductor technology. The first is germanium. This material was used in original semiconductor devices, while they were undergoing development. While this material is technically viable, development is necessary to match silicon's performance, and it would be a massive undertaking to shift production methods from silicon back to germanium. Another candidate are metal oxides. This technology was promising in the past, but modern day chips push this technology past its limits. Metal oxides are unreliable when their scale is shrunk to the level of modern-day silicon semiconductors. Therefore, further development would be necessary in order to meet consumer demand. The last potential technology is III-V compounds. These semiconductors utilize indium, allowing them to have electron mobility up to 50 times higher than that of silicon. This is a very desirable quality, but there currently is not a reliable supply of these compounds, which make them a much less promising candidate (Hopkinson, 2015).

THE FUTURE OF THE SHORTAGE

While it would be possible to shift to a new technology for society's semiconductor needs, all possible alternatives would require a huge amount of capital to even create the necessary production facilities. Factories would have to be redesigned, and new mass-production techniques would have to be developed. Consequentially, the best option is to bolster the current methods of production. By creating new foundries, organizing the distribution of semiconductors, and providing subsidies in times of crisis, a way out of the shortage could be navigated, and the predicament could be avoided entirely in the future. As this shortage is ongoing, work on this project could easily continue. By keeping track of the major changes in the shortage, the suggestions posed in this project could be reevaluated. In the future, a better way out of the shortage may come to light.

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