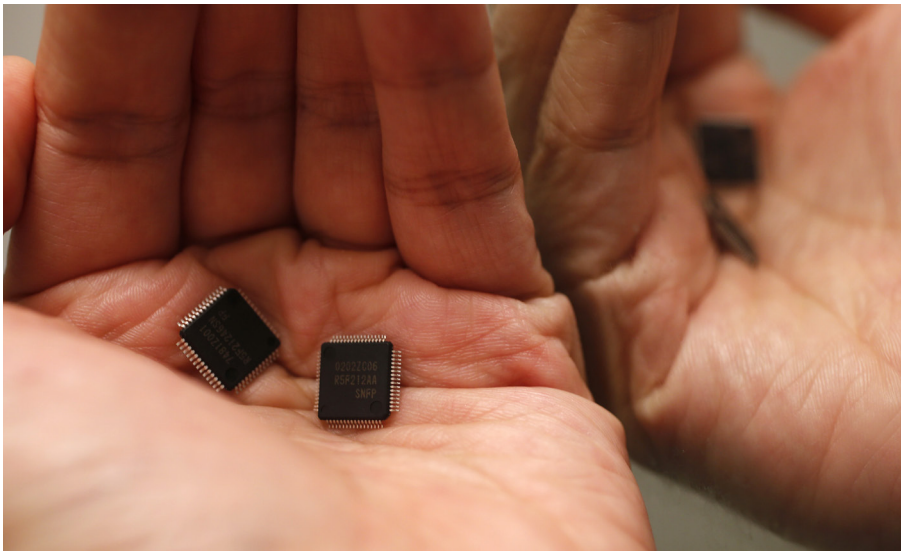
Microchips: Small and Demanded

The interplay of a pandemic, extreme weather events and geopolitical power dynamics have exposed the fragile networks underpinning the semiconductor industry. Because microchips are almost indispensable in daily life, the current shortage situation raises questions about supply chain security.

By Julian Kamasa



Microcontroller chips manufactured by Japanese semiconductor company Renesas Electronics, Tokyo, May 2012. *Kim Kyung-Hoon / Reuters*

Microchips are thinner than a centimeter and are an indispensable part of daily life. They are built into almost all modern devices – ranging from computers and smartphones to refrigerators and washing machines – and perform essential control, computing and storage functions. The complex assistance systems in cars, delivery vehicles and trucks, as well as new means of transportation such as electric scooters or e-bikes, also only work with built-in chips. Generating electricity from solar energy is impossible without chips. A global shortage of microchips, which was already intensifying in the spring of 2021, led to a situation in the fall that came to be known as "Chipageddon." For example, numerous car manufacturers have had to scale down their production capacities to such an extent that they are below the crisis levels of 2020. This has clear consequences for employees, suppliers, and consumers, including in Switzerland (see box on page 4).

The chip shortage reflects three simultaneous developments: the COVID-19 pandemic, geopolitical tensions, and climate change. The pandemic has severely unbalanced supply and demand. Increased home office use has caused a sharp short-term increase in demand for electronics, while reduced mobility patterns have caused a significant drop in demand for newly manufactured transportation equipment. Large orders need to be planned months in advance due to complex production processes (see box on page 2). This means that the demand for means of transport, which has increased earlier than expected in the meantime, cannot be met by the supply of chips. This issue is amplified by disruptions within supply chains resulting from measures imposed to contain the coronavirus.

The ongoing COVID-19 pandemic differs from geopolitics and climate change by having a time horizon likely to be short- to medium- rather than longer-term in nature. Nevertheless, it has exposed structural weaknesses in crisis-prone production processes and supply chain security deficiencies. Yet geopolitics and climate change pose an even greater challenge to supply security, as an intensification of the *status quo* is within the realm of possibility. Worth mentioning here is China's clearly stated territorial claim – and their willingness to use military force if necessary – over Taiwan, which is a key location for the global supply of chips. Likewise, increased lack of rains, prolonged droughts or extreme cold spells

can severely jeopardize water and power supply, which affects the production capacities of chip manufacturers. The current supply crisis, exacerbated by the coronavirus, thus illustrates the security and policy challenges that states can face when resources are scarce and when major chip production sites are the focus of geopolitical disputes.

Key Players in East Asia

The chip industry is marked by a high degree of fragmentation and specialization. Therefore, there is no state in which companies perform all tasks from raw material mining, design, research and development, mechanical engineering, contract manufacturing, testing, assembly, and packaging. Consequently, no state is self-sufficient in chip manufacturing. Nevertheless, there are regions such as East Asia where many dominant players are located. This is particularly true in segments such as contract manufacturing (see chart on page 3). These companies are also called "foundries." Their customers specify the chip design and order volume in advance. Taiwan is home to many contract manufacturers, which have a 63 percent share of the world market. The globally dominant player, TSMC, enjoys control of over 52 percent of the market and supplies the world's leading manufacturer of graphics processors for computers and servers, Nvidia, in addition to TSMC's largest customer, Apple. Taiwan is also home to ASE, a world leader in testing and assembly.

South Korea is another important location, particularly for the foundry Samsung, which has 17 percent of the global market and has established itself as the second most important player after TSMC. With billions of dollars invested in logic chips needed for artificial intelligence, Samsung aims to challenge TSMC for control of the market. As for wafer manufacturing and coating, many companies are based in Japan. The world's largest silicon wafer manufacturer, Shin-Etsu, counts TSMC and Samsung among its customers. Renesas Electronics, a company specializing in the production of chips for the automotive industry, is also based in Japan and is considered the third largest company for this segment. The March 2021 fire at a Renesas production facility further exacerbated the semiconductor shortage for the automotive industry. China is home to SMIC, the fifth largest contract manufacturer, which is partly state-owned. Among other factors, SMIC's connections to the Chinese government has led to the company being on the US sanctions list since December 2020. Meanwhile, the Chinese government is trying to promote the domestic chip industry with programs such as "Made in China 2025," to reduce the gap between countries such as the USA, Taiwan, South Korea and Japan and to gain more autonomy. Meanwhile, billion-dollar support programs for the chip industry are also planned in South Korea, Taiwan, and the United States.

US and Europe

There are no foundries with significant global market shares on either side of the Atlantic, so both the US and Europe are highly dependent on firms in Taiwan and South Korea. However, companies in the Euro-Atlantic region offer products that are in high demand in East Asia, demonstrating how geographically fragmented the chip industry is. The largest chip vendor in the United States is Intel, which has been active in this field since 1968 and is a leading global full-range chip supplier. This means that Intel is responsible for everything from technological design to production. The California-based company is particularly dominant in computer microprocessors, where it has a global market share of around 80 percent. Intel announced in March 2021 that it intends to enter the foundry business. To this end, the company will invest 20 billion USD and open two factories. This move is predominantly aimed at the supremacy of TSMC and Samsung, whose dominance is to be challenged by Intel Foundry Services. In addition to Intel, there is a whole ecosystem of companies in the US that specialize in chip design or building machines for semiconductor manufacturing. In addition, numerous foreign-based companies have opened branch offices around Austin in Texas to solidify their foothold in the American market. Samsung, for example, supplies its chips to IBM, Tesla and Intel, among others.

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In Europe, the chip shortage has been particularly severe, as the ever-important automotive sector has not been able to recover from the crisis year of 2020. In response, the EU Commission drafted a stimulus package worth billions of euros. This "Chips Act" includes three aspects: a clear European research strategy, the development of production capacities, and international partnerships and cooperation. The most important European semiconductor company, ASML, is based in the Netherlands and is one of the most valuable corporations in the world. The company has distinguished itself in the market by specializing in production machines for highly complex chips, which are required for 5G smartphones among other applications. ASML is a global leader in this field. The customers for these machines include all foundries such as TSMC, Samsung, and SMIC, and each machine nets roughly 120 million EUR. Beyond that, Europe is home to companies such as Infineon, Bosch, or NXP, which produce chips for the automotive industry. Other sectors, including the chemical industry, have also branched out into creating related materials for microchips; companies like BASF, Linde, or Merck now produce the chemicals required for semiconductor coating.

The Challenge of Geopolitics

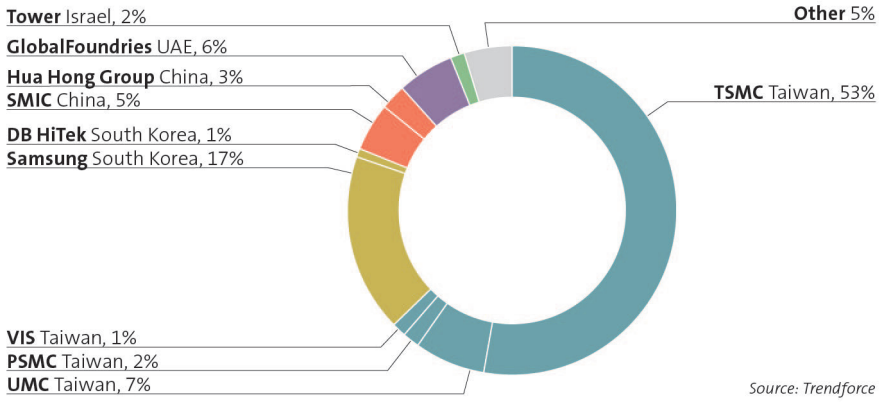
The chip industry has become a key element in the competition for technological supremacy between China and the US.

Chip Manufacturing Process

Chips are often used interchangeably with semiconductors. This is because a microchip is made of semiconductor material, which can conduct small amounts of electricity and is usually made of the raw material silicon. The semiconductor material is formed into 0.2–0.7 mm thin circular disks, called "wafers," with a diameter of 2–30 cm. The wafer is the foundation of the chip, and transistors and circuits are applied to it layer by layer, in some cases up to a total of 50 billion transistors per chip. With these transistors, the conduction of current can be controlled according to the binary principle of conducting/non-conducting. Together with circuits, they can execute commands and store data. A transistor is about 700 times smaller than the width of a human hair. The production must take place in clean rooms with stable temperature and dust-free air, as the smallest impurities render the wafer unusable. The entire chip development and manufacturing process can take years, as not only the design of the chips must be carefully planned, but also the production facilities intended for them. Moreover, planning processes must also always anticipate further technological development.

Two aspects stand out here. Firstly, neither of the two great powers is independent enough to support a microchip industry alone. Secondly, as a consequence of the interconnected, transnational nature of microchip production, companies from third countries are sometimes pulled into geopolitical competition. The US currently enjoys a clear advantage in microchip production as compared to China. This is particularly true of intellectual property from chip design, device manufacturing and non-wafer materials. In the area of assembly and testing of chips as well as semiconductor manufacturing, the two countries are on an equal footing. The US, under former President Donald Trump, imposed export controls to prevent intellectual property or essential chip equipment from entering China via third countries. This has put a lot of pressure on TSMC, for example, whose second most important customer was Huawei. Ultimately, the Taiwanese company stopped supplying chips to Huawei. ASML from the Netherlands, for which the Chinese company SMIC is an important customer, faces a similar threat. These geopolitical clashes have the potential to further destabilize fragile supply chains.

Market Shares of Foundries in Q2 2021



Source: Trendforce

The primary point of contention is related to Taiwan. This is because, in Beijing's view, the island state is not an independent state, but rather a part of mainland China that will inevitably be reintegrated into the People's Republic. To secure their interests, Chinese use of military force is not ruled out. For the US, the ability to support Taiwan is a reflection of the credibility of the entire US-led alliance system, with potential consequences for the international order. Therefore, some experts believe that Taiwan could be the place where a direct or at least indirect military confrontation between Beijing and Washington is most likely to occur. This is a key challenge for the global economy because Taiwan is home to dominant players who could not supply the world with chips in the event of a military conflict. Beijing's implicit threats of invading Taiwan are thus not only a test of the US' ability to stand by its allies, but also a very real threat to chip-dependent industries and thus to the supply chain security of numerous countries.

The Challenge of Climate Change

The pursuit of reducing greenhouse emissions has resulted in new forms of mobility, including the electrification of transportation means such as cars, delivery vans, and trucks. Due to the interaction between the battery and the computer-based control systems, electric vehicles are much more dependent on microchips than traditional combustion engines, though microchips are still required for their assistance and control systems. Similarly, so-called "smart homes," where heating or cooling systems may be controlled in a more demand-oriented manner and thus lower emissions, are dependent on chip technology. This also applies to solar cells, where chips are essential for generating electricity. The scarcity of chips is thus slowing down the energy transition. However, the production of chips requires a lot of resources. TSMC alone consumes 212 million liters of water per day for cooling and cleaning processes, which roughly equates to the daily consumption of around 1.5 million Europeans. In addition, the mining of silicon, the raw material needed for semiconductors, is known to be resource intensive.

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Climate change is also directly affecting the most important manufacturing locations. Taiwan, for example, is experiencing increasingly severe periods of drought. Spring 2020 saw no typhoon at all, which is important for water reserves, and winter rainfall was also 80 percent below the normal level. This negatively impacted not only the general water supply, but also the power supply, which is dependent on hydroelectric power and failed twice in the spring of 2021. As a result, TSMC had to reduce water consumption by 15 percent in April 2021 on government orders. There is no shortage of ideas for countermeasures. Pipelines for water transport may enable a more demand-oriented supply, increased efforts to recycle water are expected to reduce consumption by 30 percent, and seawater desalination plants are also projected to increase the amount of available water. Looking towards the US, the record-setting winter storm in Texas in February 2021 resulted in a power outage lasting several days that had severe repercussions on the state's budding chip industry. Delays and disruptions were exacerbated further by the complexity of the manufacturing process. Similarly, China is also feeling the impacts of climate change on its microchip industry. Because Beijing no longer imports coal from Australia for geopolitical reasons and is otherwise prioritizing more renewable energy sources, the power supply in the country deteriorated drastically in late summer 2021. As a result, companies had to reduce their production capacities, which has consequences for the supply of the semiconductor industry with the raw material silicon.

Outlook

The chip shortage represents a combination of three prevailing megatrends. First, the COVID-19 pandemic has led to huge market imbalances between supply and demand. This is aggravated by the fact that even at normal times, chip manufacturing requires months of run-up time and cannot be flexibly scaled up. Second, geopolitical turmoil between China and the US has led to various trade restrictions in the high-

Switzerland and Chips

Swiss suppliers are directly affected by the production shortages in the German automotive industry. The most important customer of the large company EMS Chemie AG is the automotive industry, which is responsible for 60 percent of its sales. The company's largest sales are generated in Germany, which has been hit particularly hard by the lack of microchips. For Swiss consumers, the chip shortage is most keenly felt through long waiting times. For example, not all e-bikes can be delivered. The waiting period for the most popular car sold in Switzerland between January and September 2021 is also around four months, as production capacities in the Czech Republic have been shut down.

tech sector, which has affected global supply chains. Taiwan is particularly exposed to these shocks due to China's inherent claim to the island nation, as well as being arguably the most important chip manufacturing base. Third, new, innovative technological solutions that require microchips are critical to tackling the climate emergency, but their production ties up resources such as water or electricity, which are likely to become increasingly scarce due to climate change.

Building up industrial capacity is a long-term matter.

The year 2021 has demonstrated to European industry in particular how dependent it is on smoothly functioning global supply chains. It is likely that, moving forward, the nations of Europe may seek to strengthen their own production capacities to avoid these types of vulnerabilities in the future. Yet despite even their best efforts, European countries will remain dependent on imports of raw materials such as silicon. The EU Commission's promising "Chips Act" can build on partially existing chip production industries, especially in the Netherlands and Germany. Indirectly, this should also be beneficial to Switzerland. Building up industrial capacity, however, is a long-term matter. After all, even experienced and well-organized companies like TSMC need significant time to expand production capacities. For example, TSMC does not expect to start production at a planned plant in Japan before 2024. Unlike in other fast-moving tech industries, this relatively long time horizon shows that in the complex chip industry, increased demand cannot be countered flexibly and quickly. In addition, medium and long-term factors such as geopolitics and climate change are also likely to contribute to a shortage of chip supply.

For more on perspectives on Socio-technical resilience, see CSS core theme page.

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