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Nations Play Their Chips

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Abstract

Countries rely on technology for defense, prosperity, and the well-being of their citizens. Here, we investigate how a recent scarcity of semiconductor chips has impacted the 3 largest economies and spurred them into action. We only focused on 3, for brevity.

The world faces a semiconductor shortage[1]. This shortage was estimated to cost the U.S. economy $240 billion in 2021[2]. In 2021, chip shortages forced automobile companies to cut scheduled production of vehicles by11.3 million units[3]. The shortage of semiconductors seems to have recently eased due to worldwide GDP declines, but it still remains a concern. An estimate has suggested that automobile companies cut scheduled vehicle production by 3.8 million units in 2022[3].

Semiconductor production activities are highly geographically concentrated. One hundred percent of the world's highly advanced logic semiconductor (smaller than 10 nanometer (nm)) manufacturing capacity is in Taiwan and South Korea[4]. This makes global chip supply chains vulnerable to events such as natural disasters and geopolitical instability[5]. Unsurprisingly, governments in major economies have shown an interest in building a less geographically concentrated semiconductor supply chains. These governments have also realized that public support is required to address this challenge[6].

Here, we highlight the effects of semiconductor shortages in the world's three largest economies: China, Japan, and the U.S. (Table 1). We also focus on how the governments in these countries are responding. This article is the result from surveying much existing literature.

Table 1: The effect of semiconductor shortage in the world's three biggest economies and their policy response

	Current situation	Response
China	• Chip shortage worsened following the U.S export control measures • A huge gray market for chips • A zero-COVID lockdown worsened the situation	• December 2022: Plan to provide a support package of $143 billion over a five-year period. • Tax breaks for investing in assembly, packaging, and R&D of chips
Japan	• Major industries have suffered heavily • Auto companies such as Toyota Motor and Honda Motor Were forced to reduce its car production: profit fell significantly	• Abandoned its economic nationalism in favor of open alliances: current orientation toward the development of the domestic semiconductor **is** in favor of international integration and cooperation • Subsidies for the construction of chip facilities
The U.S.	• Cost the economy $240 billion in 2021 • As of the end of 2021: eight million fewer cars were made	• CHIPS and Science Act: $280 billion package to develop the domestic semiconductor manufacturing including $52 billion in subsidies for research and production of semiconductors • Some states and cities have provided targeted subsidies for specific chip manufacturers

China

Just like other major economies, China started facing a shortage of semiconductor chips when the COVID-19 pandemic started disrupting global supply chains. (Note that there exists a huge gray market for chips in China, which consist of many middlemen. Second-hand or out-of-date chips may be sold at as much as 500 times the original cost.[7])

The shortage has worsened after the U.S. imposed export control measures, which started in October 2022 to cut China off from advanced semiconductor chips and chip-making equipment[8]. The new rules require U.S. companies such as Nvidia and AMD to stop supplying Chinese chipmakers with equipment that can produce advanced chips unless they obtain permission. Export controls have also been introduced to include some semiconductor production items[9]. Moreover, U.S. companies cannot engage in transactions with Chinese firms for some end-uses of certain types of integrated circuits or chips. Companies such as Taiwan Semiconductor Manufacturing Co Ltd (TSMC) are prohibited from producing sophisticated microchips in China[10]. U.S. citizens and green-card holders are also banned from working on certain chip technology for Chinese entities[9]. The Commerce Department's Bureau of Industry and Security argued that China could use these chips to "produce advanced military systems", although the chips can also be used for civilian purpose[10].

While China is the world's largest car producer and global leader in electric vehicles (EVs), the country relies on Europe, the U.S., and Taiwan for almost all advanced chips needed. A zero-COVID lockdown further worsened the situation[11].

Policy response and possible outcomes

China is fighting back. In December 2022, news media reported China's plan to provide a support package of more than 1 trillion yuan ($143 billion) over a five-year period to develop its semiconductor industry. A significant part of the funding will go to the purchase of domestic semiconductor equipment for chip-producing foundries (fabs). Chinese companies will receive a subsidy of up to 20% on the cost of equipment and receive tax breaks for investing in assembly, packaging, and R&D of chips.[12]

Japan

Japanese companies had dominated the global semiconductor market in the 1980s[13]. However, this dominance started to diminish in the late 1980s when semiconductor designers moved towards outsourced manufacturing. In the fabless model, that involves outsourcing the fabrication of the chips, a company designs and sells the hardware and semiconductor chips but relies on chip-making factories known as foundries to manufacture the chips. TSMC has been credited for pioneering the "foundry and fabless" model[1].

In the past 15 years, Japanese companies have not made investments to benefit from the semiconductor production process's evolution[5]. To meet the demands of its electronic device-makers, Japan has relied heavily on chips imported from South Korea and Taiwan[13].

Industries in Japan have suffered. In September 2022, Toyota Motor announced that, due to semiconductor shortages, it would reduce its production to about 800,000 vehicles worldwide in the following month from its original plan of 900,000 vehicles. Likewise, Honda Motor was forced to reduce its car production by up to 40% at two of its plants in Japan in October[14].

This has had a clear impact on corporate bottom lines. In 2022Q2, Toyota's profit fell by 18% compared to 2021Q2[15]. Likewise, Honda's profit in the same period fell by 33%[16].

Policy response and possible outcomes

According to the Ministry of Economy, Trade and Industry (METI), Japan's share of the world's semiconductor market was 50% in 1990; that was reduced to 10% in 2021**[17]**. Japan

hopes to recapture at least 20% of the global semiconductor market by 2030[5]. Japanese policy makers know that drastic measures are needed.

Prime minister Fumio Kishida's recent engagement with his counterparts in the U.S. and the European Union (EU) have focused on improving Japan's global connections[5]. In May 2022, the Japanese METI minister visited the semiconductor research facility Albany NanoTech Complex in upstate New York to discuss cooperation on developing next-generation semiconductor production technologies[18].

The Japanese government has realized that semiconductor is an area in which policy intervention and support such as subsidies are critical. In June 2022, the METI announced $3.5 billion subsidies for the construction of an $8.6 billion chip factory in the Kumamoto prefecture. The factory is a joint venture between TSMC and two Japanese companies, Sony and Denso. The production will begin by the end of 2024. The factory is expected to be the most advanced production facility in Japan. Likewise, in July 2022, the Japanese government announced a $690 million subsidy to a joint venture between Japanese company Kioxia and the U.S. firm Western Digital to upgrade a chip facility in Kansai[5].

Japanese policy makers think that investments by TSMC and partnerships with companies from allied nations such as the U.S. would serve as an insurance policy against the
uncertainties associated with possible disruptions semiconductor supply chain[5.]

The production capacity of these companies would only satisfy a fraction of the total chip demand. For instance, the monthly production volume for TSMC's facility is expected to be 50,000 to 60,000 silicon wafers a month[5]. The wafers are materials that are used in the production of semiconductor chips. In 2021, Japanese automakers manufactured around 16.46 million vehicles at production facilities outside of Japan[19] and 7.85 million in Japan[20]. A typical car requires between 50 and 150 semiconductors[21] and a modern car may use as many as 3,000[22]. Especially electrified vehicles and cars that are equipped with advanced driver-assistance systems require more semiconductors per vehicle[23].

According to the Japan Electronics and Information Technology Industries Association, the chip sector may also face a challenge in securing enough manpower to innovate and operate the factories. To fill the demand of talent required by their investments in the next 10 years, the country's eight big producers will have to hire about 35,000 engineers[24]. Universities have started training hundreds of new engineers to meet the industry's manpower demand[5].

The U.S.

According to Goldman Sachs, 169 industries in the U.S. use semiconductors in their products. And more modern products utilize more chips. Solving the semiconductor shortage is becoming increasingly challenging due to rapidly rising demands of products utilizing chips. For instance, in 2021, demand for semiconductors was 17% higher than in 2019[25]. In 2022, the U.S. semiconductor production accounted for 12% of the global total compared to 37% in early 2010s[26].

Due to semiconductor scarcity, U.S. automakers such as GM and Ford are selling vehicles with some missing convenient features such as HVAC chips and heated seat controls[3]. As of the end of 2021, eight million fewer cars were made in the U.S., which cost automakers about $210 billion in revenue[2].

The current shortfall of chips has been even more pronounced in "less-advanced" chips because the world's biggest semiconductor producers have focused on "cutting-edge" chips that offer higher profit-margins.

Policy response and possible outcomes

In August 2022, President Joe Biden signed the CHIPS and Science Act into law. The Act provides a $280 billion package to develop the U.S. domestic semiconductor manufacturing including $52 billion in government subsidies for research and production of semiconductors[27].

In addition, some states and cities have also provided targeted subsidies for specific chip manufacturers. For instance, in 2020, the City of Phoenix approved financial incentives and support for TSMC, which included US$200 million to develop roads, sewers and other infrastructure and US$500,000 for additional set of traffic lights[28]. Likewise, the state of Ohio promised to provide Intel more than $2 billion in economic development subsidies. This was reported to be the largest single-project subsidy in the State's history[29].

These subsidies and other forms of support have shown some encouraging results. In 2020, TSMC announced a plan to spend $12 billion to build a semiconductor plant in Arizona (known as "Fab 21"), which is expected to be completed in 2024. The facility's opening ceremony was held in December 2022[26].

In December 2022, TSMC revealed its plan to further increase its investment in the Arizona fab to $40 billion and build a second plant on the site. The second phase of Fab 21 will produce 3-nanometer chips. The production is expected to begin in 2026[30].

The first plant will produce 20,000 5 nm advanced process wafers per month[31]. After the completion of the second plant, TSMC's capacity is expected to expand to around 50,000 wafers per month[32]. TSMC will create 13,000 high-technology jobs in the area[30]. TSMC also estimated that the two plants will generate an annual revenue of $10 billion when they open. In addition, TSMC customers are expected to have annual sales of $40 billion from products using TSMC chips manufactured in Arizona plants[26].

TSMC is expected to see significant costs increase in its U.S. plants. For instance, the Arizona fab's total cost of ownership (TCO) is estimated to be more than five times of its TCO in Taiwan[33]. However, on the plus side, the company has received or will receive significant subsidies for its Phoenix, Arizona plant. About $40 billion of the $52 billion subsidies in the CHIPS and Science Act is allocated for providing incentives for chip manufacturers such as Intel, Samsung and TSMC. Likewise, as mentioned, Phoenix has provided TSMC with significant financial incentives.

Likewise, in November 2021, Samsung announced a plan to build a $17 billion semiconductor factory in Taylor, Texas[34]. In January 2023, the company's chief executive reported that the facility's construction was progressing, and that production will start by the end of the year. The company's plan has been to produce 3 nm chips in the beginning and move to 2 nm chips in 2025[35]. And in February 2021, Intel announced a plan to spend $20 billion to build chip factories in Ohio. The plant is scheduled to open in 2025 and employ at least 3,000 people[2].

Conclusion

The semiconductor shortage has presented significant costs to national economies**.** One important lesson from Taiwan and South Korea is that government support played a key role in the growth of their semiconductor industries. The governments of the world's three biggest economies are realizing that some form of public support is probably needed to develop this industry locally.

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References

[1] J. Voas, N. Kshetri & J. DeFranco." Scarcity and Global Insecurity: The Semiconductor Shortage" IEEE IT Professional 23(5), 78 – 82, 2021.

[2] O. Villafranca "Chip shortage cost U.S. economy billions in 2021" January 28, 2022 https://www.cbsnews.com/news/chip-shortage-cost-us-economy-billions-in-2021/

[3] B. Vigliarolo "US car industry leads the world in production cuts over chip shortages" 9 Aug 2022, https://www.theregister.com/2022/08/09/car_chip_shortage/

[4] "SIA urges U.S. government action to strengthen America's semicon-ductor supply chain," Semiconductor Industry Association, Washington, D.C., Apr. _, ____. [Online]. Available: https://www.semiconductors.org /sia-urges-u-s-government-action -to-strengthen-americas-semiconductor-supply-chain/

[5] B. Dooley & H. Ueno, *"*Japan Once Led the World in Microchips. Now, It's Racing to Catch U*p",* Aug. 7, 2022, https://www.nytimes.com/2022/08/04/business/japan-semiconductors-chips.html

[6] N. Kshetri & J. Voas," Where's the Silicon?" IEEE *Computer* 54(8):11-12 (2021)

[7] Bloomberg News "Woman with Fake Baby Bump Caught Smuggling Computer Chips Into China" December 2, 2022 https://www.bloomberg.com/news/articles/2022-12-02/woman-with-fake-baby-bump-caught-smuggling-computer-chips-into-china

[8] S. Mellor "China's chip shortage is so bad a woman was just caught smuggling semiconductors inside a fake baby bump" Fortune, December 2, 2022

9 V. Harrison & M. Farrer "What do US curbs on selling microchips to China mean for the global economy?" 19 Oct 2022 https://www.theguardian.com/world/2022/oct/19/what-do-us-curbs-on-selling-microchips-to-china-mean-for-the-global-economy

[10] B. Harris "How Biden's microchip ban is curbing China's AI weapons efforts" Jan 12 https://www.defensenews.com/global/asia-pacific/2023/01/12/how-bidens-microchip-ban-is-curbing-chinas-ai-weapons-efforts/

[11] "How China Became Ground Zero for the Auto Chip Shortage" July 22, 2022 , Reuters, https://www.voanews.com/a/how-china-became-ground-zero-for-the-auto-chip-shortage-/6670710.html

[12] M. Gooding "China has a $143bn semiconductor plan to beat US chip sanctions" December 13, 2022 https://techmonitor.ai/technology/silicon/china-semiconductor-manufacturing-us

[13] S. Hasan, "Can Japan's semiconductor industry make a comeback?" 14 Dec 2022 https://www.trtworld.com/magazine/can-japan-s-semiconductor-industry-make-a-comeback-63529

[14] "Toyota's October vehicle output to be weighed down by chip shortage", Sep 22, 2022, https://www.japantimes.co.jp/news/2022/09/22/business/toyota-oct-chip/

[15] "Toyota profit down as chips shortage keeps customers waiting" August 05 2022, https://www.hurriyetdailynews.com/toyota-profit-down-as-chips-shortage-keeps-customers-waiting-175861

[16] "Honda sees declining profits on semiconductor crunch", August 10, 2022, https://www.asahi.com/ajw/articles/14692079

[17] M. Duchâtel "Racing for the New Rice - Japan's Plans For its Semiconductor Industry", 4 August 2021 https://www.institutmontaigne.org/en/analysis/racing-new-rice-japans-plans-its-semiconductor-industry

[18] "Minister Hagiuda Visits the United States of America" May 6, 2022, https://www.meti.go.jp/english/press/2022/0506_003.html

[19] "Total overseas vehicle production volume of Japan's automotive manufacturers from 2012 to 2021*(in million units)", https://www.statista.com/statistics/658861/japan-overseas-automobile-production/#:~:text=In%202021%2C%20Japanese%20automakers%20manufactured,million%20in%20the%20previous%20year.*

[20] "Total production volume of motor vehicles in Japan from 2012 to 2021*(in million units)*" https://www.statista.com/statistics/675241/japan-motor-vehicle-production/

[21] H. Ziady "The global chip shortage is going from bad to worse. Here's why you should care" May 4, 2021 https://www.cnn.com/2021/04/29/business/chip-shortages-smartphones-consumer-goods/index.html

[22] "A Tiny Part's Big Ripple: Global Chip Shortage Hobbles the Auto Industry" Oct 14, 2021 https://www.nytimes.com/2021/04/23/business/auto-semiconductors-general-motors-mercedes.html#:~:text=One%20big%20reason%20automakers%20can,have%20more%20than%203%2C000%20chips

[23] "Toyota's October vehicle output to be weighed down by chip shortage", Sep 22, 2022, https://www.japantimes.co.jp/news/2022/09/22/business/toyota-oct-chip/

[24] "Japan's biggest chipmakers from Toshiba to Sony brace for engineer shortage", Jun 25, 2022 https://www.ft.com/content/b90da329-a2e5-486a-860f-a20a3afc707a

[25] "Results from Semiconductor Supply Chain Request for Information", January 25, 2022, https://www.commerce.gov/news/blog/2022/01/results-semiconductor-supply-chain-request-information

[26] S. Holland & J. L. Lee "TSMC triples Arizona chip plant investment, Biden hails project", December 7, 2022, https://www.reuters.com/technology/biden-visit-taiwans-tsmc-chip-plant-arizona-hail-supply-chain-fixes-2022-12-06/

[27] M. Kelly "Biden signs $280 billion CHIPS and Science Act"Aug 9, 2022, https://www.theverge.com/2022/8/9/23298147/biden-chips-act-semiconductors-subsidies-ohio-arizona-plant-china

[28] "Phoenix approves TSMC incentives" Nov 20, 2020, https://www.taipeitimes.com/News/biz/archives/2020/11/20/2003747217

[29] K. Tarczynska, "Opinion: Massive Ohio subsidy deals need transparency, accountability" October 27, 2022, https://www.cincinnati.com/story/opinion/contributors/2022/10/28/opinion-massive-ohio-subsidy-deals-need-transparency-accountability/69596057007/

[30] E. Huang "TSMC's U.S. tool-in ceremony is over, what's next? " December 11, 2022 https://english.cw.com.tw/article/article.action?id=3346

[31] H. Chang "What is TSMC doing building a fab in the American desert?" October 17, 2022 https://english.cw.com.tw/article/article.action?id=3162

[32] A. Shilov "TSMC Unveils Major U.S. Fab Expansion Plans: 3nm and $40 Billion by 2026" *December 7, 2022 https://www.anandtech.com/show/18682/tsmc-unveils-major-us-fab-expansion-plans-3nm-and-40-billion*

[33] "Taiwan Semiconductor: Trapped In Costly Arizona", Jan. 12, 2023, https://seekingalpha.com/article/4569500-taiwan-semiconductor-trapped-in-costly-arizona

[34] "Samsung says it will build $17 billion chip factory in Texas", November 24, 2021, https://www.asahi.com/ajw/articles/14487832

[35] P. Mehra "Samsung's US chip plant to be completed by end of 2023, confirms CEO" 16 Jan, 2023 https://www.techcircle.in/2023/01/16/samsung-s-us-chip-plant-to-be-completed-by-end-of-2023-confirms-ceo/