Focus

FOCUS ON CHINA

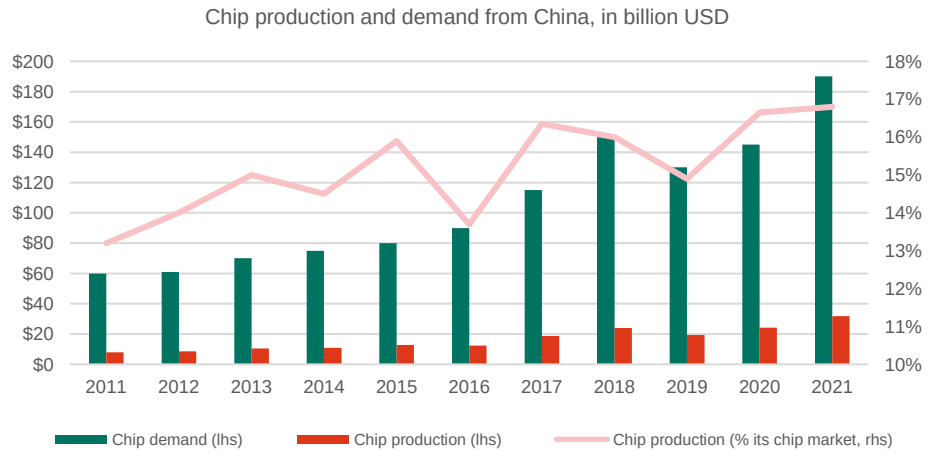
China's quest for autarky in the chip industry

When supply chains began to sputter during 2020 in the wake of the COVID-19 pandemic, one product, in particular, stood out: semiconductors. No electronic device is conceivable without them: From cell phones and laptops to washing machines or refrigerators to cars and airplanes - semiconductors are used everywhere.

China had recognized their importance early on, many years before the Covid crisis became a multi-year semiconductor crisis, and has been trying to build its chip industry since the early 2000s.

The last few years have contributed significantly to the fact that semiconductors are now regarded as one of the key technologies all over the world in society, at board levels, and in politics. In this context, the role of semiconductors in the geopolitical confrontation with China has also been understood in the Western world.

To understand China's development opportunities, it is, therefore, necessary to analyze what access China has to semiconductor technology, how dependent the country is on imports from abroad, or what the prospects are for achieving a certain degree of self-sufficiency in this area. The answers to these questions can already be given in short form at this point: China's dependence on semiconductor imports is exceedingly high, and the prospect of achieving self-sufficiency in this area is very difficult to imagine for the next decade. The culprit here is, in particular, a glaring strategic mistake made by China about ten years ago, which is why the U.S. sanctions are so effective today.



Source: IC Insights, Barclays Research

Content

Semiconductor supply chain
Before taking a closer look at the Chinese chip industry in the following, the supply chain for the production of semiconductors is described, which roughly speaking mainly consists of three production stages:

- First, the design development of the semiconductor, which is realized via complex software. This procedure requires a deep understanding of the electronic components and their interaction, and this process is led globally by the US.
- Second, the physical fabrication of semiconductors (called "lithography"). In this process, a mask is used to transfer a pattern onto the silicon wafer. The pattern is then etched into the silicon wafer to create layers of conductive and non-conductive materials needed to make transistors and other electronic components. The world leader in this production step is Taiwan Semiconductor Manufacturing Company (TSMC), which operates the world's largest and most advanced independent semiconductor foundry.
- Third, the assembly, testing, and packaging of semiconductors. This step is extremely labor-intensive and is therefore performed in low-wage countries in the Indo-Pacific region (65 percent of global capacity is located in Taiwan (50 %) and China (15 %)).

Even with these three stages, the supply chain is not completely described, because upstream of the production process are the producers of the machines that are used to manufacture the semiconductors.

No country can be said to be self-sufficient in the semiconductor value chain, which is spread across a few locations. This fragmentation is due to the need for enormous investment in research and development, design, and manufacturing. It should be noted at this point that the data situation for the coverage of the Chinese semiconductor industry is challenging and there are contradictions between different sources. Overall, however, the data quality should be sufficient to provide a sufficiently comprehensive picture of the semiconductor industry in China.

The emergence of China's semiconductor industry
Early in his presidency, around 2013, Chinese President Xi Jinping recognized the importance of the semiconductor industry for China. As an important input for the production of electronic devices, semiconductors were already reaching increasingly large shares of the country's merchandise imports at that time. For example, semiconductor imports more than doubled from about 270 billion units in 2013 to about 550 billion units in 2020. In terms of value, semiconductor imports accounted for the equivalent of about $400 billion in 2020, or one-sixth of the total import value, making semiconductors even more important to China in this regard than oil imports (about $250 billion).

Developments in the global semiconductor industry have been critically observed by China over the past decade. In a report on technology policy, the Chinese State Council noted that "the scale of investment has increased rapidly and the market share has led to a concentration of dominant companies". Those dominant companies were, first and foremost, Taiwan's TSMC and Korea's Samsung, which the Chinese report said would be difficult to replace. TSMC has a global market share of over 90% in the most advanced semiconductors.

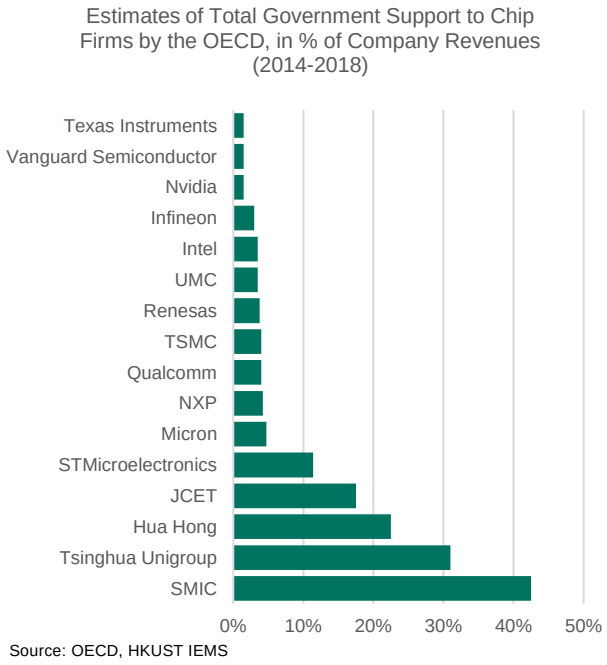
China's "Made in China 2025" Plan
This quasi-monopolistic position of TSMC was interpreted by the Chinese leadership, which had already early and successfully focused on future trends such as cloud computing, artificial intelligence, autonomous driving, the "Internet of Things" (IoT), and Big Data, as a threat to its future ambitions. Therefore, in May 2015, the government officially proclaimed the "Made in China 2025" plan, which aims to reduce the share of Chinese imports in semiconductor production from 85% in 2015 to 30% in 2025.

The dream of a self-sufficient semiconductor industry in China goes back to the Cultural Revolution under Mao in the mid-1960s. It was not until the turn of the millennium that the Chinese managed to establish a company like SMIC (Semiconductor Manufacturing International Corporation). The key to success was the move away from purely state-financed corporations to partially state-owned companies, which came more than a decade later. SMIC's breakthrough came with its "Big Fund" program, launched in 2014. The Big Fund raised money on the capital market, but still, the main investors were state-owned: the Ministry of Finance, the Chinese Development Bank (CDB), and numerous other state-owned groups. Although some spoke of Chinese "venture capital à la Silicon Valley," the model was far removed from the Californian model, and not only geographically. It should also be noted that this "success" in the form of SMIC is technologically half a decade behind the leading semiconductor producers.

Ineffective subsidies
It is difficult to quantify how many subsidies have flowed into the Chinese semiconductor industry to date, as the web between private and state actors is difficult to penetrate. Nevertheless, the OECD has ventured an estimate and concluded that the major semiconductor groups from China (SMIC, Tsinghua Unigroup, Hua Hong, and JCET) receive about 15-40% subsidies based on their total sales. Major players outside China, such as TSMC, Intel, Infineon, or Nvidia, are below 5% in subsidies.

Subsidies to Chinese companies are not always well-targeted and efficient: One example is the semiconductor factory of Wuhan Hongxin Semiconductor Manufacturing, in which the

local government invested several billion yuan together with private investors from Beijing. This manufacturing plant had to close in 2021 due to financial difficulties. Corruption in China does not stop at the country's chip fund, which is yuan 34.27 billion (U.S. $5.05 billion). Ahead of this year's 20th National Congress, where President Xi effectively secured a third term, there have been many arrests surrounding this corruption scandal and speculation about the future of the fund.



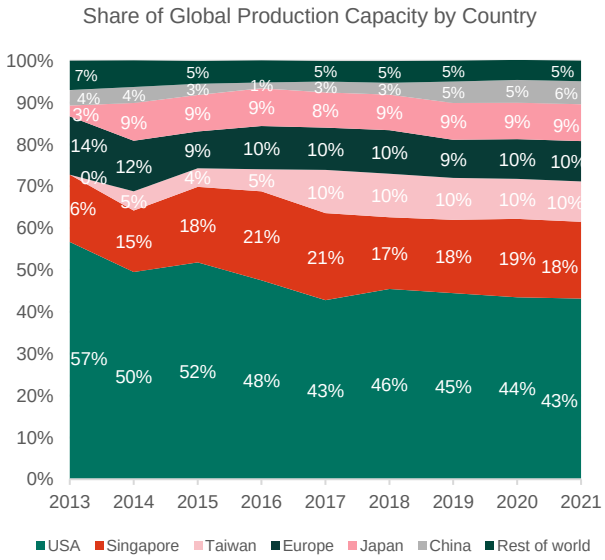
Source: OECD, HKUST IEMS

China lags far behind international competitors

China's self-sufficiency in chips remains low. In 2021, China consumed $187 billion worth of chips, or about 37% of global chip consumption, according to Barclays. 83% of the consumption is due to imports being covered and only 17% were manufactured in China. Furthermore, of the $ 31 billion worth of chips produced in China, only $12 billion (about 40%) were produced by Chinese companies, with the remainder produced by foreign companies (such as TSMC, Samsung, and SK Hynix) with production facilities in China.

China not only has problems with semiconductor production but is also weak in semiconductor design. After all, the governmental efforts to become self-sufficient in foreign technology, the dominance of rival nations, such as Taiwan, Japan, South Korea, or the USA, has not been broken. The software tools to design a chip are dominated by the USA (65%), while China has a market share of only 2%. In the area of patents, i.e. intellectual property on the blueprints of all transistor patterns based on which many chips are manufactured, China plays no role at all. In terms of intellectual property, the U.S. (63%), Europe (19%), and Taiwan (17%) dominate. Overall, it can be said that China also lags massively behind international competitors in the research and development (R&D) and capital-intensive segments of the chip supply chain.

At least, some successes of the Chinese chip policy are observable: China's global share in final assembly, testing, and maintenance of chips is 21%, and in pure semiconductor fabs (which does not produce its integrated circuit products) it is 11%. Both manufacturing stages are dominated globally by Taiwan.



Source: Semiconductor Industry Association (SIA)

Along the entire value chain, Chinese companies have an overall share of 5.5%, compared with the USA with 43.2%. They are followed by Singapore (18.3%), Taiwan (9.7%), Japan (9.6%), and Europe (8.8%). However, the chips manufactured in China can also be produced worldwide, which means that the Chinese chip market does not play a role in high-end semiconductors (<10 nm).

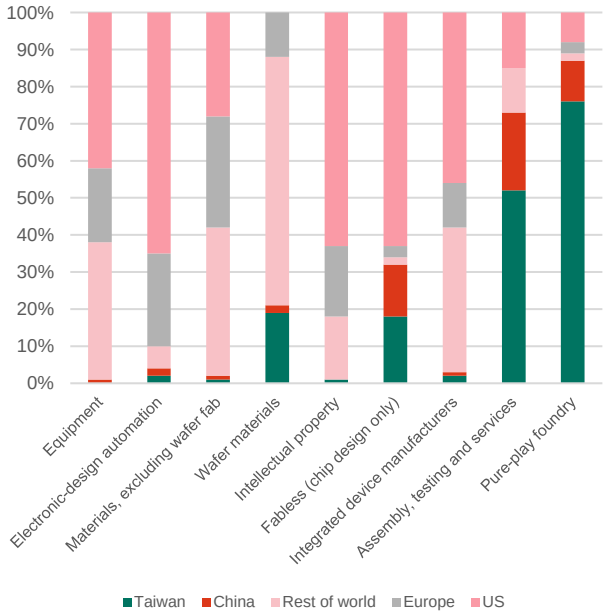
China's strategic mistake

China remains drastically dependent on

- US-based/m software and design,
- US, Dutch and Japanese machines as well as
- Taiwanese, South Korean, and Japanese manufacturing.

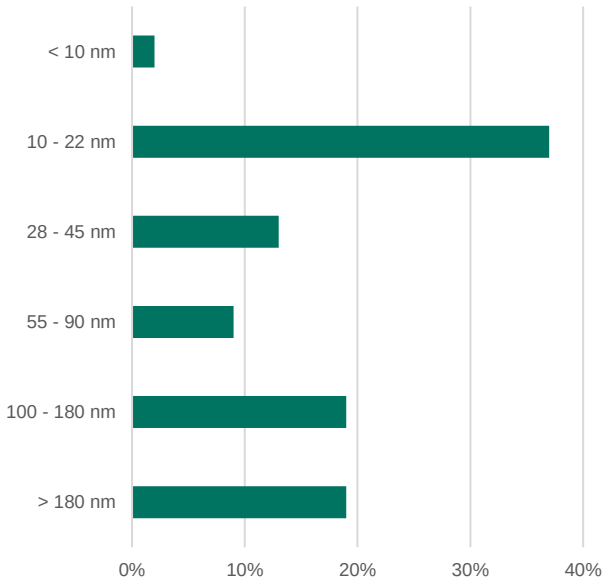
The fact that China is now heavily dependent on know-how, technology, and intermediate products from abroad and is not a "systemic player" in the semiconductor industry has to do with the fact that the Chinese leadership has avoided integration with Silicon Valley in the USA in its quest for autonomy across the entire value chain. Japan, South Korea, the Netherlands and Taiwan have pursued a more successful strategy and specifically sought symbiosis with the U.S. chip industry. As a result, these countries are dominant in various manufacturing stages in each case.

Semiconductor Sales Along the Value Chain, Share in % (2020)



Source: Gartner, Omdia, McKinsey Analysis

China's Production Broken Down Proportionally by Semiconductor Size



Source: SEMI Data, DB Research

Innovations in this industry are very application- and customer-oriented. Taiwan's TSMC has been able to advance in the manufacturing sector primarily because of U.S. software and design companies have outsourced their production to the East Asian island. The world market and technology leader among machine and tool manufacturers, the Dutch company ASML, produces in the high-end segment because the special light source required for this is manufactured in the U.S. in San Diego. If China had focused on certain manufacturing stages at the beginning of Xi's presidency in 2013, it is possible that today China would also be a major player in research-intensive manufacturing processes. Beijing, however, did not want an integral place in an ecosystem dominated by the United States and its allies. The ambitions of the world's second-largest economy were and are aimed at fundamentally changing the entire industry in its favor.

China can also produce 7-nanometer chips

From today's perspective, according to an estimate by the Boston Consulting Group (BCG), China would have to put up at least one trillion U.S. dollars (converted) to achieve self-sufficiency across the entire value chain. And even this estimate must be taken with a grain of salt, since many factors must come together, especially in the case of high-value semiconductors, to achieve research success - and sufficient money seems to be only one of them.

China's manageable shares of semiconductor production mainly relate to the area of technologically less advanced semiconductors. The most ambitious Chinese company, SMIC, generated over 75% of its sales in 2020 in the >40 nm range. In the mass market of <10 nm semiconductors, China plays no role at all. This is not to say that China cannot produce high-quality semiconductors: Some analysts have spotted evidence that SMIC has managed to produce 7-nanometer chips by using simpler DUV machines: Certain tools can be optimized. Scientists can find creative solutions. But whether Chinese companies can achieve relevant commercial volumes and revenues on their own? That can probably be ruled out for the time being. According to experts, China's equipment manufacturers are four to five years behind their foreign counterparts, making them unsuitable as direct replacements for equipment from global suppliers for the time being.

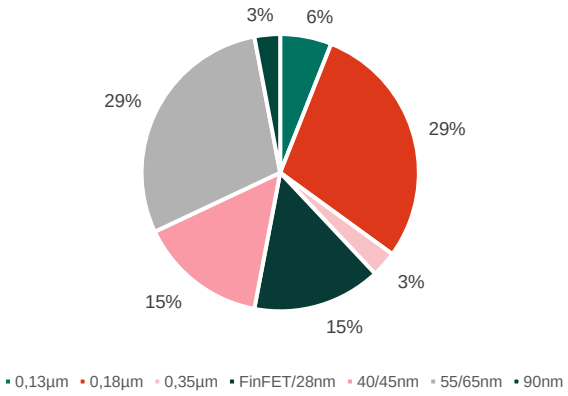
“Taiwan” as a possible shortcut to China's success?

Not far from China, about 160 km from the city of Fuzhou on the east coast, lies Taiwan. The country is not recognized as independent by most states under international law and is therefore not a member of the United Nations (UN). However, it has so far maintained its independence against China's resistance. And it has achieved what the Chinese leadership would like to have achieved for itself: to have created a state-subsidized "global champion" in chip production with TSMC. Currently, the most advanced chips with up to 3 nm are produced there. From 2024, it will probably even be possible to produce 2 nm chips. A few years ago, TSMC overtook Intel from the USA, which had been the undisputed market leader until then.

The Taiwanese succeeded in taking the lead in chip production by, on the one hand, directing national resources

towards this goal and, on the other, recognizing that this could only be achieved through deep integration into global semiconductor value chains. Since the road to an independent chip industry has become even stonier for China, Beijing seems willing to take shortcuts on the way to success. Given the geographic and cultural proximity to Taiwan, the Chinese leadership is therefore sparing no effort to poach skilled workers. The targeted theft of trade secrets is also used as an instrument.

SMIC's Revenue by Technology in 2021, in %.



Source: Annual Report SMIC 2022

China offers more

Chinese companies have deep pockets when it comes to poaching Taiwanese semiconductor industry talent. It's all about offering higher salaries. The most famous anecdote that circulates widely is that Chinese chip companies ask Taiwanese chip professionals how much they would get at their current position in Taiwanese dollars, and they would pay the same amount in Chinese yen. So that's about 4.5 times as much if the current exchange rate is used. Taiwanese authorities have since responded by drafting a law that prohibits virtually anyone working for Taiwanese semiconductor companies from traveling to China without government permission. China is also accused of "hacking" into the chip semiconductor industry's electronic resources to steal trade secrets to gain an advantage in the industry. Chinese computer hackers have reportedly targeted companies in the U.S. as well as other countries, using a variety of tactics such as phishing emails and malware to gain access to sensitive information.

Another common strategy for acquiring the sought-after technology is the participation of Chinese companies in foreign companies or their complete takeover. In this way, Chinese producers gain access to advanced technologies and corresponding patents. This applies not only to companies in the semiconductor sector but also to companies in the fields of artificial intelligence, biotechnology, and other high-tech sectors. In the U.S., Chinese companies have been particularly active in the technology sector with mergers and acquisitions: some notable examples are Tsinghua Unigroup's $23 billion bid to acquire Micron Technology in 2015 (this transaction was blocked by U.S. authorities) and Canyon Bridge Capital Partners' $1.3 billion acquisition of Lattice Semiconductor in 2017.

This strategy must be seen as a way for Chinese companies to quickly acquire the technological capabilities they need to compete globally, but also to strengthen Chinese self-sufficiency in the sector. Some experts argue that these acquisitions also help Chinese companies circumvent the challenges of developing certain technologies in-house and avoid the high costs and risks associated with research and development. The problem: The U.S., the EU, and many other countries are making it increasingly difficult for China to implement this strategy.

US export controls on higher-value semiconductors to China

In recent years, the United States government has repeatedly imposed bans on the sale of certain types of advanced chips to Chinese companies, citing national security concerns. These bans were aimed at preventing the transfer of sensitive technologies to certain Chinese companies that could be used for military or espionage purposes. Previously, the ban applied specifically to companies deemed a risk to U.S. national security, such as those with close ties to the Chinese military or those that have been implicated in human rights abuses. Huawei was one of the first major Chinese tech companies to be affected by such bans. The company was placed on the so-called U.S. Entity List in 2019, prohibiting American companies from selling chips or other components to Huawei without U.S. government approval. In addition, the government has subsequently imposed similar restrictions on other Chinese companies such as ZTE (Zhongxing Telecommunication Equipment Corporation) and SMIC.

In October 2022, the U.S. government introduced the most extensive export controls on chips to slow China's progress in artificial intelligence and supercomputers and make it harder for the country to manufacture advanced semiconductors. More specifically, the regulations prohibit the sale of advanced chips with high performance (at least 300 trillion operations per second) and high interconnect speeds (generally at least 600 gigabytes per second) to Chinese customers. In addition, the regulations restrict the sale of equipment if it is knowingly used to manufacture certain classes of advanced logic or memory chips. These include logic chips manufactured at nodes of 16 nm or less (which Intel, Samsung, and TSMC have been doing since the early 2010s), NAND long-term memory integrated circuits with at least 128 layers (the current state of the art), or DRAM short-term memory integrated circuits manufactured at 18 nm or less (produced by Samsung since 2016).

Effective U.S. Sanctions Regime

In addition, the new rule restricts the ability of "U.S. persons" - including U.S. citizens or green card holders - to support the "development or production" of chips at certain manufacturing facilities in China. Executives working for Chinese companies may now have to decide whether to keep their jobs or act as legal U.S. citizens. More than a dozen chip companies in China have senior executives with U.S. citizenship or green cards.

To prevent possible circumvention, the controls also apply to non-U.S. companies that rely on U.S.-made equipment or software. For example, Taiwanese or South Korean chipmakers cannot sell their Chinese customers advanced chips produced with U.S.-made technology.
Exemptions from some restrictions can indeed be requested from the U.S. Department of Commerce. The bottom line, however, is that China remains largely cut off from technology transfer from abroad, which presumably quite effectively impedes China's progress toward independence from foreign producers.

China's subdued development prospects

We can assume that China is striving for a similar development path as South Korea, Japan, or Taiwan. Demographics, education level of the population, political stability - and also semiconductors in their function as key technology play a decisive role. While from the outside one can make a checkmark on the factor "political stability" and regard it as achieved, the demographic development seems to be rather critical and the educational level of the employable population is comparatively low and supports the thesis that China is in the so-called middle-income trap.

In Taiwan, for example, around 70% of the working-age population had a high school diploma when the country reached a similar level of development to China today in the 1970s. China's high school rate, by contrast, is currently only 29%. Against this backdrop, it may not be a coincidence that China lags so far behind its international competitors in the key industry of semiconductor development and manufacturing. This industry relies on a very well-educated workforce. This weakness is compounded by China's strategic mistake of trying to achieve self-sufficiency in this industrial sector across all value chains virtually from scratch.

This, in turn, has meant that U.S. bans on exporting high-value semiconductors and technologies that could be used to produce high-value semiconductors to China effectively impede progress in China and set high-tech companies back on their development path.
We, therefore, see ourselves supported in our thesis that China will only grow at a rate of 2% to 4% in the longer term and will not be able to catch up with, let alone overtake, the USA in terms of either technology or economic strength in the foreseeable future.

Tariq Kamal Chaudhry
Economist
Phone: +49 171 9159096

Literature

- Alloway, T., and Weisenthal J., **"This is What the US Just Did to China Semiconductors,"** Bloomberg Podcast: Odd Lots, October 2022.https://open.spotify.com/episode/7ntZZ5w2yCItmNO83uwwPf?si=f673b8f4f62f41f3&nd=1
- Chang, J. et al, **"Special Topic: US-China trade Chipping away,"** Barclays Global Macro Research, November 2022.
- FT Reporters, **"How the US chip export controls have turned the screws on China,"** Financial Times, October 2022. https://www.ft.com/content/bbbdc7dc-0566-4a05-a7b3-27afd82580f3
- Garcia-Herrero, A**., "China's Industrial Policy for Semiconductors: Lessons for the World**," HKUST Institute for Emerging Market Studies and Ernest & Young, 2022. https://iems.ust.hk/events/talk/2022/garcia-herrero-china-industrial-policy-for-semiconductors-lessons-for-the-world
- Iyengar, R., **"Biden Short-Circuits China**," Foreign Policy, October 2022. https://foreignpolicy.com/2022/10/28/biden-china-semiconductors-chips/
- Kynge, J., **"US-China Tech Race: Chips with Everything"** FT Podcast: Tech Tonic, April 2022. https://www.ft.com/content/cf4aa80e-3d44-4290-b9ff-5aff74c06187
- Lee J. and Kleinhans J.-P., **"Mapping China's Semiconductor Ecosystem in Global Context**," Stiftung Neue Verantwortung and MERICS, June 2021. https://merics.org/en/report/mapping-chinas-semiconductor-ecosystem-global-context-strategic-dimensions-and-conclusions
- Lee J. and Kleinhans J.-P., **"China's rise in semiconductors and Europe,"** Stiftung Neue Verantwortung and MERICS, December 2021. https://www.stiftung-nv.de/sites/default/files/chinas_rise_in_semiconductors_and_europe.pdf
- Neuhoff, J. et al, **"Industry Outlook 2030+ | The Semiconductor Industry"**, Oxford Economics and Stiftung Arbeit und Umwelt der IGBCE, 2022. https://tinyurl.com/yh2u5vwm
- Lepcha, M., **"Semiconductor shortage guide: Winners and losers of crisis**," Capital.com, February 2022. https://capital.com/semiconductor-shortage-guide
- Miller, C.; **"Chip War: The Fight for the World's Most Critical Technology."** Simon and Schuster, 2022.
- Rapp, H. and Möbert J. **"Extraordinary semiconductor cycle triggered by one-time events, cyclical and geopolitical effects"** Deutsche Bank (DB) Research, May 2022. https://tinyurl.com/2ycnt2rd
- Schneider, J., **"US-China Chips War"** ChinaTalk Podcast, October 2022. https://open.spotify.com/episode/30Ng4BxDaxPmczEP9OPMWh?si=91c600854ce14c4b
- Semiconductor Industry Association (SIA) **Factbook 2022.** https://www.semiconductors.org/wp-content/uploads/2022/05/SIA-2022-Factbook_May-2022.pdf
- Ting-Fang, C., **"U.S. chip curbs start to bite and India explores an e-rupee,"** Nikkei Asia, October 2022. https://asia.nikkei.com/techAsia/U.S.-chip-curbs-start-to-bite-and-India-explores-an-e-rupee
- Varas A. et al, **"Strengthening the Global Semiconductor Supply Chain in Uncertain Era**," Boston Consulting Group and Semiconductor Industry Association (SIA), April 2021. https://www.bcg.com/publications/2021/strengthening-the-global-semiconductor-supply-chain

IMPRINT

Hamburg Commercial Bank

Hamburg
Gerhart-Hauptmann-Platz 50
20095 Hamburg
Phone 040 3333-0
Fax 040 3333-34001

Editing & Shipping

Dr. Cyrus de la Rubia
Chief Economist
Tel.: +49 160 90180792

Christian Eggers
Senior FX Trader
Tel.: +49 171 8493460

Jonas Feldhusen
Junior Economist
Tel.: +49 151 22942945

Norman Liebke
Trainee Economics
Tel.: +49 171 5466753

Tariq Chaudhry
Economist
Tel.: +49 171 9159096

Further contact persons

Institutional & Liability Sales
Thomas Benthien
Tel.: +49 151 14833046

Corporate Treasury Sales
Fritz Bedbur
Tel.: +49 151 14651131
Boris Gettkowski
Tel.: +49 175 2281619

Syndicate & Credit Solutions
Tim Boltzen
Tel.: +49 151 15244845

Editorial deadline for this issue: 24. März 2023
The glossary of our publications can be found on the Hamburg Commercial Bank homepage at http://www.hcob-bank.de/publikationen_glossar.

Disclaimer