Dutch semiconductor interests in Asia

The politicisation of the Asian semiconductor industry

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Jonas Lammertink
Tycho de Feijter
Dr. Chaitanya Giri
Alexandre Ferreira Gomes
Dr. Maaike Okano-Heijmans
Sense Hofstede

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For contact or orders: info@leidenasiacentre.nl

M. de Vrieshof 3, 2311 BZ Leiden, The Netherlands

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About the authors

Jonas Lammertink is a researcher at the LeidenAsiaCentre.

Tycho de Feijter is a researcher affilicated with the LeidenAsiaCentre.

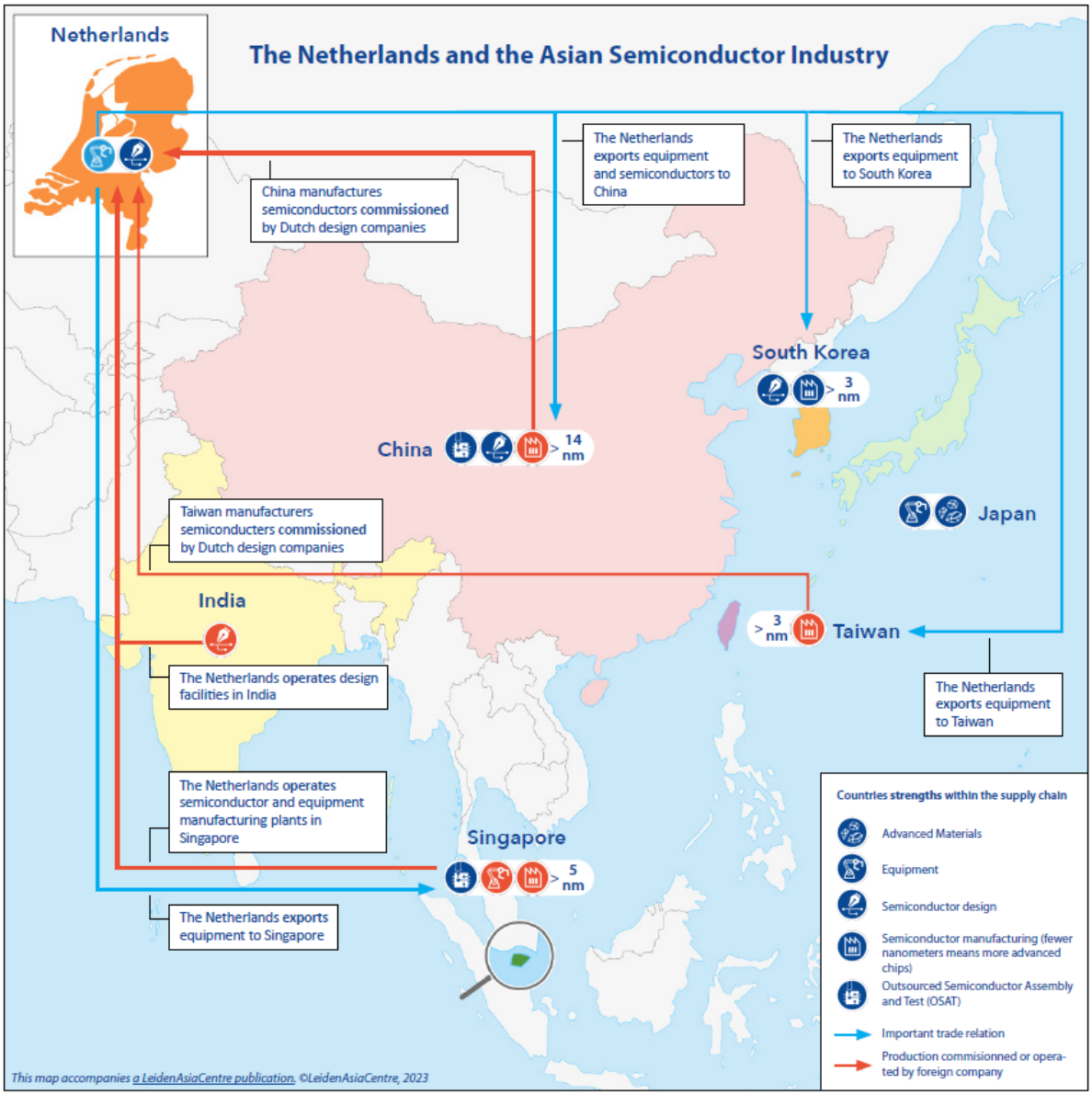
Dr. Chaitanya Giri is an Associate Professor at Flame University.

Alexandre F. Gomes is a Research Fellow at the Netherlands Institute for International Relations 'Clingendael' in The Hague, where he is part of the 'Geopolitics of Technology and Digitalisation' programme.

Maaike Okano-Heijmans is a Senior Research Fellow at the Netherlands Institute for International Relations 'Clingendael' in The Hague, where she leads the 'Geopolitics of Technology and Digitalisation' programme. She is also a Visiting Lecturer in the Master of Science in International Relations and Diplomacy (MIRD) of the University of Leiden.

Sense Hofstede is a researcher and University Lecturer at Leiden University.

Map of Dutch semiconductor interests in Asia



For an interactive version of this map, visit: https://leidenasiacentre.nl/map-of-dutch-semiconductor-interests-in-asia

1. Introduction

During a visit to the White House in 2019, Prime Minister of the Netherlands Mark Rutte was handed an intelligence report by one of President Trump's national security advisors. The security document laid out possible consequences of China acquiring the technology of ASML, an important Dutch semiconductor equipment manufacturer. The Trump administration hoped to convince the Dutch government to block shipment of one of ASML's most advanced chip-producing machines to China's Semiconductor Manufacturing International Corporation (SMIC). They got what they wanted: the Dutch government did not renew the export licence that ASML required for the shipment.[1] The event is illustrative of how the Dutch semiconductor industry has been drawn into the technological rivalry between the United States and China.

The United States' efforts to frustrate China's goal of becoming technologically highly advanced and self-reliant continue under President Biden. Not only is the Dutch semiconductor sector drawn into this endeavour, but so are many industries in Asia. For example, the Biden administration has proposed creating a 'Chips Alliance' to strengthen ties linking the industries of Japan, South Korea, Taiwan and the United States in the face of Chinese ambitions. Moreover, in October 2022 President Biden introduced export controls targeting semiconductor-related supplies to China, which also affect Asian companies.

However, the US–China rivalry is not the only political factor impacting Asia's semiconductor industries. So are domestic political agendas and regional relations. For example, trade disputes between Japan and South Korea are affecting the semiconductor industries in both countries, while India is looking to become a chip-manufacturing hub. Taiwanese semiconductor giant TSMC is considering building factories in other Asian countries amid political and military tensions over the island. Singapore's government is actively attracting foreign companies in the semiconductor industry to settle in the city state, while South Korean companies have built up large interests in China's semiconductor industry.

The Dutch semiconductor sector has many connections with companies, research institutes and official organisations in South and East Asian countries. These connections can be subject to any politicisation of the industry, creating both political and economic risks and opportunities for the Netherlands. Semiconductor devices (or microchips, integrated circuits or computer chips), to which the word 'semiconductor' refers in this study, are crucial for future technological and economic

[1] Alexandra Alper, Toby Sterling and Stephen Nellis, 'Trump administration pressed Dutch hard to cancel China chip-equipment sale: sources', *Reuters*, 6 January 2020, https://www.reuters.com/article/us-asml-holding-usa-china-insight-idUSKBN1Z50HN.

developments, as well as the transition to green technologies. Securing a sufficient supply of chips is therefore essential, while dependencies in the sector are used as political tools.

However, while the impact of US restrictions on Dutch companies as part of the US–China rivalry has been extensively analysed publicly, a clear overview of Dutch interests in the semiconductor industries in South and East Asia is lacking, as is analysis of how these interests are affected by general politicisation of the sector. This report therefore analyses the interests and connections of the Dutch semiconductor sector with companies, research institutes and government organisations in China, Taiwan, South Korea, Japan, Singapore and India. The report aims to answer the question: *What are the interests of the Dutch semiconductor industry in South and East Asia in light of the politicisation of the sector?*

Structure

In order to structure the analysis in a way that results in a clear answer to the research question, the report is designed as follows. The first chapter provides a brief overview of the Dutch semiconductor industry. The second chapter then lays out the most important European policies that shape Dutch interests in South and East Asia, as well as US policies that affect the global industry.

The main body of the report consists of country chapters that discuss the composition of the semiconductor industry in each country and their connections with the Dutch sector. These chapters are structured thus: (1) discussion is held of the government's policy plans for the sector and the relevant government agencies; (2) an overview is given of the semiconductor industry in the country, its characteristics, most important players and links with Dutch companies; (3) the relevant geopolitical positioning and regional economic and political relations of the country are mapped; and (4) the impact of the first three factors for the Dutch semiconductor industry's interests in the country under discussion are analysed.

Finally, the report's conclusions gather and compare the findings of the individual country chapters, and link these back to the research question and wider context. The conclusions will analyse how the Netherlands and Europe could position themselves regarding the politicisation of the semiconductor sector in South and East Asia.

Focus

Analysis focuses on those parts of the supply chain that are directly related to the manufacturing process of semiconductors. This considers the production of advanced materials, the production of wafers, the production of computer-chip equipment, the design of semiconductors, the 'printing' of the chips on wafers and finally the packaging process. Excluded from this research are the

manufacturers of electronic goods that place the completed chips in their products, such as computers, cars or phones. This report also does not focus on the sourcing of raw materials.[2]

The interests of the Dutch semiconductor industry in the following South and East Asian countries are included in this report: China, Taiwan, South Korea, Japan, Singapore and India. These countries have been selected because of their significance in the global semiconductor industry, their connections to the Dutch sector, or their potential to become important players, with implications for the industry in the Netherlands.

Methods

The information that informs the analysis was collected in various ways and from different sources:

(1) Policy documents from governments in the countries under discussion were studied in order to conceptualise how the qualities and interests of the Dutch sector match with the official national and international policies of each country;

(2) Company websites and documents were examined in order to learn how supply chains are structured and which connections Dutch companies have in each country;

(3) Academic literature on the design of semiconductor supply chains, the impact of geopolitics on these supply chains and the development of local industries was studied to deepen general understanding of the topic;

(4) News reports were considered to gain insights into recent policy plans and decisions, as well as international connections between local industries;

(5) Finally, a small number of interviews were conducted with representatives of the Dutch semiconductor sector and with industry experts from the Dutch government in the specific countries in order to gather information that is not accessible otherwise.

What are semiconductors?

Technically speaking, a semiconductor is a material that allows for a certain level of electrical conduction, but the term often refers to computer chips (also known as integrated circuits (IC) or microchips). These are typically small slices of silicium (a semiconductor material) with a large amount of microscopically small, interlinked switches (transistors) that can turn electric currents on or off, which correspond to the 1s and 0s on which the functions of electronic devices are based. Logic or

[2] The Hague Centre for Strategic Studies recently published an extensive report on this topic: Joris Teer and Mattia Bertolini, "Reaching breaking point. The semiconductor and critical raw material ecosystem at a time of great power rivalry", October 2022, https://hcss.nl/wp-content/uploads/2022/10/Reaching-breaking-point-The-semiconductor-and-critical-raw-material-ecosystem-at-a-time-of-great-power-rivalry-October-2022-Full-Version.pdf.pdf.

system chips are designed to process information to complete tasks, while memory chips store information.

Generally speaking, the more transistors one can fit on a small slice of silicium, the more advanced the chip will be. This is why in semiconductor manufacturing, chips are ranked based on their size, using the nanometre (nm) unit. The lower the number of nm, the more advanced the chip, and the more suitable it is for completing complex tasks. Today's most advanced mass-produced chips measure 5 nm. Chip makers are developing 3nm and 2nm chips. The most advanced chips can solely be manufactured with ASML's current extreme ultraviolet (EUV) machines. Such semiconductors can be found in smartphones, and are necessary for artificial intelligence (AI), autonomous driving and 5G applications. However, not all electronic devices require extremely advanced or small chips; there is also a large market for less advanced chips, for example in the automotive, healthcare or manufacturing industries.

The semiconductor supply chain

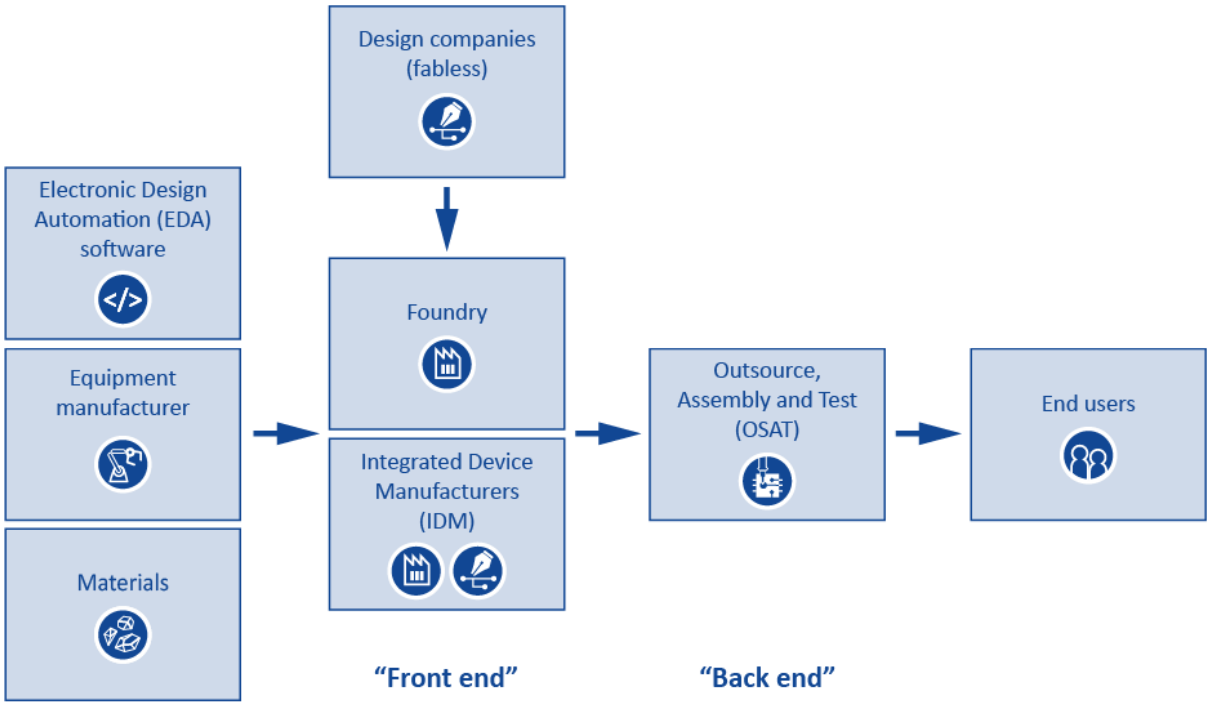
The production process for semiconductors consists of many different stages. Each step in the process takes place in a different part of the world, at companies that are specialised in that specific stage. In fact, according to a briefing report by the European Parliament, a chip crosses the border 70 times during the complete supply chain, including 50 choke points (when one region has more than 65 per cent of the worldwide market share). A large semiconductor producer makes use of up to 16,000 suppliers from all over the world.[3]

Before a chip can be produced, manufacturers need the right equipment (such as ASML's machines), materials for example, silicon wafers) and software (also known as electronic design automation (EDA) software). There are two types of manufacturers: 1) *foundries,* which produce chips based on the designs of companies that do not have their own fabrication plants (these design companies are therefore called 'fabless'); and 2) *integrated device manufacturers (IDMs)* which design and print chips based on their own intellectual property. These manufacturers 'print' the integrated circuits on slices (wafers) of semiconductor material, which is called the 'front end' of the production process. These wafers are then assembled, tested and packaged into semiconductors by outsource, assembly and test (OSAT) companies, which is called the 'back end' of the production process. The chips are then sold to companies that place semiconductors in their electronic products: the end users. See the figure below for a simplified illustration of the value chain. Certain steps, such as R&D processes (which take place at various stages in the value chain), component suppliers of equipment manufacturers and

[3] Kjeld van Wieringen, "Strengthening EU chip capabilities. How will the chips act reinforce Europe's semiconductor sector by 2030?", European Parliament, July 2022, https://www.europarl.europa.eu/RegData/etudes/BRIE/2022/733585/EPRS_BRI(2022)733585_EN.pdf.

equipment manufacturers for OSAT companies, are missing from this overview for the purpose of clarity.

Figure 1: The semiconductor value chain (source: author's compilation).



2. The Dutch semiconductor industry

The Netherlands has a relatively strong semiconductor sector. This is in part the result of the legacy of Philips, formerly one of the largest global electronic companies. Many of today's prominent Dutch semiconductor businesses derive their origins from Philips. It is difficult to establish how many companies are involved in the semiconductor industry in the Netherlands, because the industry does not have clear boundaries. However, the website of Dutch industry association Holland Semiconductors (formerly known as BCSEMI NL) lists 78 members. According to a report by this organisation, the Dutch semiconductor sector employed more than 15,000 people in 2019.[4] This number will grow rapidly, as ASML alone plans to expand the number of employees in the Netherlands to 35,000 in the coming years.[5] The total revenue of the semiconductor sector in the Netherlands is unknown, but the combined revenue of the three largest Dutch companies is already over 30 billion euros.[6]

Together with the United States and Japan, the Netherlands is one of only three countries to have a complete semiconductor value chain within its borders.[7] However, the strength of the Dutch industry lies predominantly in the manufacturing of semiconductor equipment, the machines that actually produce computer chips. Many of the most prominent Dutch companies are active in this sector. Surrounding these companies is a strong ecosystem of equipment component suppliers. Building such ecosystems is another strong point of the Dutch industry.

Other areas in which the semiconductor industry in the Netherlands excels are integrated photonics (chips based on light instead of electrons) and radio frequency (RF, chips based on radio waves, such as radar). Finally, the level of research at universities in the Netherlands is high and the links between academia and companies are relatively strong and often part of the earlier mentioned ecosystems. On the flip side, an analysis commissioned by the Dutch government found that the government's financial support for the sector is relatively small, while access to venture capital, technically trained personnel and funds that allow start-ups to expand is problematic.[8]

[4] Holland High Tech, "The whole Semicon value chain in one country", 2019, https://www.hightechnl.nl/wp-content/uploads/2019/11/Company-profiles-Semicon-Europa_2019.pdf.
[5] Nando Kasteleijn, "ASML heeft een groeispurt en dat merken de inwoners van Veldhoven", *NOS*, 14 September 2022, https://nos.nl/artikel/2444618-asml-heeft-een-groeispurt-en-dat-merken-de-inwoners-van-veldhoven.
[6] ASML, "2021 Annual Report Highlights", https://www.asml.com/en/investors/annual-report/2021/highlights#finance; https://www.nxp.com/docs/en/supporting-information/2021-IFRS-STATUTORY-ANNUAL-REPORT.pdf; ASM International, "Highlights Annual Report 2021", https://asmi-corporatereporting.com/2021/.
[7] Holland High Tech, "The whole Semicon value chain in one country", 2019, https://www.hightechnl.nl/wp-content/uploads/2019/11/Company-profiles-Semicon-Europa_2019.pdf.
[8] Reg Brennenraedts et al., "Het Nederlandse investeringsklimaat", https://www.dialogic.nl/wp-content/uploads/2021/06/Dialogic-2020.170-MinEZK-Het-Nederlandse-investeringsklimaat.pdf.

Policies by the Dutch government that target the semiconductor sector in the Netherlands are often part of, or in line with, EU policy plans. Such EU-level policies are discussed in the next chapter. However, the Dutch government has also developed national-level policies that target high-tech sectors, including semiconductors. For example, fiscal incentives are offered to promote R&D activities (for example, WBSO Tax Credit for Research and Development) or to attract skilled personnel (such as 30 Per Cent Facility for Knowledge Workers). Furthermore, as part of the National Growth Fund, the Dutch government invests 471 million euros in the Dutch integrated photonics industry and 450 million euros in high-tech machines and equipment (including in the semiconductor sector).[9] The government has also submitted a proposal to invest 230 million euros in six semiconductor projects by Dutch companies and knowledge institutions as part of the EU's Important Project of Common European Interest (IPCEI) programme on microelectronics.[10] In order to prevent the company Smart Photonics from falling into foreign hands, the Dutch government also provided a loan of 20 million euros to this integrated photonics company in 2020.[11]

Players in the Dutch industry

The most important and most internationally connected (and therefore most relevant for this study) players in the Dutch semiconductor industry are discussed below. This is only a very limited overview, so do consider perusing the website of Holland Semiconductors for a list of all members of this industry association.

Companies

- ASM International (ASMI) is one of the largest semiconductor companies in the Netherlands and manufactures equipment that is used by front-end companies (for example, foundries) to produce chips.
- ASML is by far the largest and most important Dutch semiconductor company. It manufactures the most high-tech semiconductor equipment: for example, ASML is the only company in the world with the capabilities to manufacture EUV machines, which are necessary to produce the most advanced chips (smaller than 5nm).
- BESI is also active in the equipment industry and is among the largest Dutch semiconductor companies. It produces equipment for the packaging segment of the value chain.
- NXP is the largest Dutch company that designs and produces semiconductors. The company does not focus on producing the smallest/most advanced chips, but specialises in chips with RF functionality.

[9] Rijksoverheid, "Overige projecten ronde 2", https://www.nationaalgroeifonds.nl/projecten-ronde-2.
[10] Rijksoverheid, "6 Nederlandse projecten aangemeld voor deelname IPCEI micro-elektronica", 20 April 2022, https://www.rijksoverheid.nl/ministeries/ministerie-van-economische-zaken-en-klimaat/nieuws/2022/04/20/zes-nederlandse-projecten-aangemeld-voor-deelname-ipcei-micro-elektronica.
[11] Mona Keijzer, "Financiering van het bedrijf Smart Photonics", 29 June 2020, https://open.overheid.nl/repository/ronl-25d65e67-a6d6-4efd-9fe5-91c610f68843/1/pdf/kamerbrief-over-financiering-van-het-bedrijf-smart-photonics.pdf.

- Some large semiconductor companies that are based in the Netherlands are in foreign hands. Noteworthy examples are Nexperia and Ampleon, which both produce RF chips and are Chinese owned.
- Smart Photonics is an important player in the integrated photonics sector and produces photonic chips.

Industry Associations

- Holland Semiconductors presents itself as a national network of semiconductor players in the Netherlands, the most important of which are all members of the association. The association represents the collective interests of the sector and focuses on supporting long-term innovation and international collaboration.
- PhotonDelta is an association that functions as a coordinator, spokesman and investor for the integrated photonics sector. The association is supported by the Dutch government, for example through investments.

Knowledge and R&D

- The Netherlands has three technical universities with semiconductor research groups that have many connections with the business sector. These are Eindhoven University of Technology, the University of Twente and Delft University of Technology.
- Other noteworthy research and technology centres are TNO, the Holst Centre, the Chip Integration Technology Centre (CITC) and OnePlanet. These organisations provide applied R&D services for the sector. Many Dutch players also cooperate with IMEC, a research centre located in Belgium.

Government

- Regional development agencies support the development of Dutch companies, as well as foreign companies that are looking to collaborate with players from the Netherlands, including in the semiconductor sector. Noteworthy examples are OostNL, Brainport Development and the *Brabantse Ontwikkelings Maatschappij* (BOM).
- The Netherlands Enterprise Agency (RVO) supports innovative companies in the Netherlands.
- The Netherlands Foreign Investment Agency (NFIA) supports foreign companies investing in the Netherlands to link up with Dutch companies.

3. Relevant policies in the United States and the European Union

Some of the most important political developments that shape the worldwide interests of Dutch players in the semiconductor industry are recent policies by the United States and the European Union. Washington is not only looking to promote its domestic chips industry, but also to prevent China from acquiring advanced chips and semiconductor equipment. Meanwhile, Brussels feels compelled, as a result of recent developments that highlight the downsides of supply-chain dependencies, to invest in Europe's semiconductor production capacity. These policies are discussed here because they have the potential to affect Dutch semiconductor interests in the Asian countries under discussion. Whether and how they actually do affect these interests is discussed in the country chapters themselves.

The EU context

Currently, the EU accounts for about 9 per cent of global semiconductor production.[12] This manufacturing capacity can mainly be found in the area of less advanced chips (the most advanced chips made in Europe are from 22nm and above). Non-Dutch examples of companies in this area are ST Microelectronics, Infineon, ASM, S-Fab, Melexis and Bosch Semiconductors, which often specialise in supplying Europe's automotive, healthcare and industrial equipment sectors. Especially in supplying the automotive industry, the EU holds a strong position, with a global market share of 37 per cent. Outside of chip manufacturing, European strengths lie in its equipment manufacturing (such as ZEISS SMT) and advanced research (for example, Imec, CEA-Leti and Fraunhofer). There are also large European companies in the materials section of the value chain (including Siltronic, BASF and Merck KGaV).[13]

However, many European chip manufacturers outsource their testing, assembly and packaging processes to Asian companies. For advanced chip manufacturing, the EU is also highly dependent on East Asia, while European companies depend on intellectual property from the United States regarding chip design tools.[14] Importantly, the EU consumes twice as many semiconductors as it produces, and demand is expected to double by 2030.[15] The downsides of such reliance on external suppliers came to the fore during the recent chip shortage amid the global COVID-19 pandemic and

[12] European Commission, "European Chips Act", https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/europe-fit-digital-age/european-chips-act_en.
[13] Van Wieringen, "Strengthening EU chip capabilities".
[14] Ibidem.
[15] European Commission, "European Chips Act"; Jordan Bish et al., "A new dawn for European chips
Europe ramps up its semiconductor industry to become more self-sufficient", 03 November 2022, https://www2.deloitte.com/uk/en/insights/industry/technology/semiconductor-chip-shortage-supply-chain.html.

geopolitical tensions, which negatively affected European manufacturing industries and the EU's goals for digitalisation and sustainability.

For this reason, the European Commission proposed the European Chips Act in February 2022. The short-term goal of this act is to anticipate and avoid future supply-chain disruptions. In the longer term, the act intends to make the EU an industrial leader in semiconductors by strengthening European research and technology, reinforcing innovation capacity, addressing the shortage of talent and deepening understanding of global supply chains. Most concretely, the goal is to double the EU's market share of global chip production, from 9 per cent in 2020 to 20 per cent in 2030. This means quadrupling Europe's current production, as the global market is expected to double in the same time period.[16]

In order to realise these goals, the European Commission hopes to mobilise 43 billion euros in public and private investments by 2030. Many of these investments (about 30 billion euros) were actually already planned as part of national budgets and other EU funding schemes, such as for scientific research (Horizon Europe), the COVID-19 economic recovery package (Next Generation EU) and possibly the IPCEI on microelectronics mentioned in chapter 2 above.[17] The funds will be invested based on three pillars. First, the 'Chips for Europe Initiative' targets research, development and innovation. The second pillar focuses on ensuring the security of supply, by supporting start-ups and the development of chip-manufacturing facilities (both foundries and IDMs) at a level of innovation that is not yet present in the EU. Finally, the third pillar concerns an EU-wide coordination mechanism that monitors the supply chain.[18] At the same time, the European Commission emphasises that building international partnerships with 'like-minded countries' that share core values is required for secure supply chains and to find markets for European chips.[19]

The US context

Relevant US policies that target the semiconductor industry are aimed at both strengthening the US domestic sector and at slowing down China's technological progress. The US holds a strong position in the global semiconductor industry: in 2021, US-based firms had 46 per cent of the global semiconductor market share.[20] The United States is especially strong in the following sections of the

[16] European Commission, "Statement by President von der Leyen on the European Chips Act", 8 February 2022, https://ec.europa.eu/commission/presscorner/detail/en/statement_22_866; Van Wieringen, "Strengthening EU chip capabilities"; European Commission, "Commission Staff Working Document. A Chips Act for Europe", p.77, https://digital-strategy.ec.europa.eu/en/library/european-chips-act-staff-working-document.
[17] European Commission, "Statement by President von der Leyen on the European Chips Act"; Van Wieringen, "Strengthening EU chip capabilities".
[18] Van Wieringen, "Strengthening EU chip capabilities"; European Commission, "Commission Staff Working Document".
[19] Van Wieringen, "Strengthening EU chip capabilities", p. 4–5.
[20] Semiconductor Industry Association, "2022 Factbook", https://www.semiconductors.org/wp-content/uploads/2022/05/SIA-2022-Factbook_May-2022.pdf.

value chain: equipment (for example, Applied Materials, Lam Research and KLA), EDA (Synopsys and Cadence), design (Broadcom, Qualcomm, AMD and IBM) and IDM (Intel, Micron, Texas Instruments and Nvidia). The US also has a noteworthy foundry company (GlobalFoundries). It also has several significant academic/research centres, is generally strong in activities that require a high rate of R&D and it controls much of chip-design intellectual property (IP).[21]

However, the semiconductor industry in the United States has recently lost ground to other regions. For example, US chip-manufacturing capacity has dropped from 37 per cent of global production in the 1990s to 12 per cent today.[22] And while the United States continues to hold a leading position in chip design, it depends on Asia for the actual manufacturing of highly advanced chips.[23]

In response to these developments, the US government signed the CHIPS and Science Act into law in August 2022. This act allocates 52.7 billion USD in federal subsidies to support the US chip industry. The large majority of these funds (39 billion USD) supports the construction of domestic chip-manufacturing plants to increase production capacity. The other 11 billion USD is targeted at R&D. Moreover, the act establishes a tax credit for the construction of advanced semiconductor manufacturing facilities. However, countering China is also part of the act's goal: funding recipients are not allowed to expand advanced semiconductor manufacturing in certain countries, including China, for ten years.[24]

Furthermore, the United States is pursuing a forum for governments and companies from four 'like-minded' countries to coordinate their policies in the semiconductor industry, for example regarding subsidies, supply-chain security and R&D. The US has invited Japan, Taiwan and South Korea to join this initiative, dubbed the 'Chips 4 Alliance'. Industries in these countries cover most of the semiconductor value chain. According to reports by the *Financial Times* and *The Diplomat*, the alliance would not only serve to secure the supply of chips to the US, but would also slow down China's technological progress. China was not invited to join the grouping.[25] However, Japan and South Korea

[21] Semiconductor Industry Association, "The State of the U.S. Semiconductor Industry", https://www.semiconductors.org/wp-content/uploads/2021/09/2021-SIA-State-of-the-Industry-Report.pdf.
[22] Semiconductor Industry Association, "The State of the U.S. Semiconductor Industry".
[23] President's Council of Advisors on Science and Technology, "Revitalizing the U.S. Semiconductor Ecosystem", September 2022, https://www.whitehouse.gov/wp-content/uploads/2022/09/PCAST_Semiconductors-Report_Sep2022.pdf, p. 11.
[24] House Committee on Science, Space, and Technology, „The Chips and Science Act", https://science.house.gov/imo/media/doc/the_chips_and_science_act.pdf; Justin Badlam; „The CHIPS and Science Act: Here's what's in it", 4 October 2022, https://www.mckinsey.com/industries/public-and-social-sector/our-insights/the-chips-and-science-act-heres-whats-in-it; PWC, „The CHIPS Act: What it means for the semiconductor ecosystem", https://www.pwc.com/us/en/library/forward-now-accounting-business-news/chips-act.html.
[25] Financial Times, „US struggles to mobilise its East Asian 'Chip 4' alliance", 12 September 2022, https://www.ft.com/content/98f22615-ee7e-4431-ab98-fb6e3f9de032; Arjun Gargeyas, „
The Chip 4 Alliance Might Work on Paper, But Problems Will Persist", *The Diplomat,* 25 August 2022, https://thediplomat.com/2022/08/the-chip4-alliance-might-work-on-paper-but-problems-will-persist/.

have expressed concerns that engaging on a governmental level with Taiwan, or forming a block that excludes China, could jeopardise their relationship with Beijing. This is especially significant for South Korea, because of its proximity and strong economic links with China. Such considerations have slowed down formation of the alliance.[26]

Other US policies are specifically intended to slow China's technological progress and capabilities by blocking the international supply of advanced chips and advanced manufacturing equipment. In the words of Washington, this is necessary to prevent the Chinese military from being able to develop highly advanced systems that would threaten the security of the United States and could be used for human rights abuses.[27] The fact that this also helps the US to retain an economic edge over China and keeps Beijing dependent on foreign technology, thus giving the US certain political leverage, are other obvious benefits.

The above mentioned US pressure on the Dutch government to block the shipment of advanced semiconductor equipment to China is a clear example of such as policy. Recently, the governments of the Netherlands and Japan appear to also give in to demands from Washington to restrict the export to China of less advanced equipment by companies from their countries, though it is still unclear what the sides have agreed on exactly. Earlier, the US introduced several blacklists which restrict or control the interactions that companies can have with certain Chinese organisations (a notable example is Huawei), including in the area of semiconductors. [28]

Additional policies were unveiled in October 2022, when Washington introduced new semiconductor export restrictions targeting several countries, including China. The new restrictions are more extensive and serve a more far-reaching objective than earlier actions: Washington has indicated that the previous controls were aimed at helping the United States to maintain its relative technological advantage, but that the current environment requires the US to maintain 'as large of a lead as possible'.[29]

[26] Financial Times, „US struggles to mobilise its East Asian 'Chip 4' alliance".
[27] Bureau of Industry and Security, „Commerce Implements New Export Controls on Advanced Computing and Semiconductor Manufacturing Items to the People's Republic of China (PRC)", 7 October 2022, https://www.bis.doc.gov/index.php/documents/about-bis/newsroom/press-releases/3158-2022-10-07-bis-press-release-advanced-computing-and-semiconductor-manufacturing-controls-final/file.
[28] Michelle Toh, „US orders Nvidia and AMD to stop selling AI chips to China", *CNN*, 01 September 2022, http://edition.cnn.com/2022/09/01/tech/us-nvidia-amd-chips-china-sales-block-intl-hnk/index.html; The Guardian, „Chip war: Japan and Netherlands expected to join US in ban on tech exports to China", 1 February 2023, https://www.theguardian.com/technology/2023/feb/01/chip-war-japan-netherlands-us-tech-export-ban-china-microchips.
[29] The White House, „Remarks by National Security Advisor Jake Sullivan at the Special Competitive Studies Project Global Emerging Technologies Summit", 16 September 2022, https://www.whitehouse.gov/briefing-room/speeches-remarks/2022/09/16/remarks-by-national-security-advisor-jake-sullivan-at-the-special-competitive-studies-project-global-emerging-technologies-summit/.

The new restrictions amount to increased control by the United States over the export of advanced chips (e.g. logic chips of 16nm or below), chip design software (EDA) and chip manufacturing equipment. In the last two areas, the US has a leading global position.[30] When US companies want to export such products to China, they will have to obtain a licence (for which they will have to prove that the end-use of the technology is not military, which will be very difficult in many cases). The same also applies to foreign companies that use US technology (which is very often the case) in the semiconductor goods that they export to China. Moreover, the regulations also forbid US citizens, residents and Green Card holders from supporting the development or production of certain semiconductor products without a licence. Some non-US companies have received a general one-year licence in order for international supply chains to continue to function.[31] The United States has also attempted to convince other key players in the industry, such as Taiwan, Japan and South Korea, to follow its lead and adopt similar policies. However, Washington does not appear to have clearly succeeded in this.[32]

[30] Matthew Reynolds, „Assessing the New Semiconductor Export Controls", *CSIS*, 3 November 2022, https://www.csis.org/analysis/assessing-new-semiconductor-export-controls; Bureau of Industry and Security, „Commerce Implements New Export Controls".

[31] Michael Bluhm, „Biden's hugely consequential high-tech export ban on China, explained by an expert", 5 November 2022, https://www.vox.com/world/2022/11/5/23440525/biden-administration-semiconductor-export-ban-china; Bureau of Industry and Security, „Commerce Implements"; Industry and Security Bureau, „Implementation of Additional Export Controls: Certain Advanced Computing and Semiconductor Manufacturing Items; Supercomputer and Semiconductor End Use; Entity List Modification", *Federal Register,* 13 October 2022, https://www.federalregister.gov/documents/2022/10/13/2022-21658/implementation-of-additional-export-controls-certain-advanced-computing-and-semiconductor.

[32] Shannon Tiezzi, „Are US Allies Falling out of 'Alignment' on China?", *The Diplomat,* 19 December 2022, https://thediplomat.com/2022/12/are-us-allies-falling-out-of-alignment-on-china/.

China

Tycho de Feijter (LeidenAsiaCentre) & Jonas Lammertink (LeidenAsiaCentre)

The Chinese semiconductor sector has grown rapidly in recent years and the country has become a major player in the global semiconductor industry. China has the world's largest market for semiconductors, turned itself into a major chips producer and is home to many leading semiconductor companies. This is the result of large investments and efforts made by China's private sector, but also very much by the Chinese government through investments in R&D, favourable policies for domestic companies, tax incentives, and the establishment of technology parks and incubators. China is also a very significant market and partner for Dutch semiconductor players.

Despite its extensive domestic production, China is still heavily dependent on imports for many types of semiconductors, particularly high-end chips. It is exactly this sore spot of dependency where the US is applying pressure since Washington began to actively frustrate the development of China's technological capabilities. China finds itself in a geopolitical competition with the US, and increasingly with Washington's allies, and there are few areas as affected as the semiconductor industry.

This chapter discusses the policies and role of the Chinese government in China's semiconductor industry. It then examines the makeup of the sector in China, its connections with the Netherlands, China's geopolitical positioning and the relevant relations with other countries in the region. Finally, the implications of the geo- and regional political situation for the interests of the Dutch semiconductor sector are analysed.

1. The role of the Government

The Chinese government actively works to develop China's semiconductor industry and reduce its dependence on foreign companies. The government provides funding for R&D, encourages the formation of domestic semiconductor companies, attracts foreign investment, promotes foreign technology transfer, secures its supply chain, protects Chinese intellectual property, and implements regulations and policies to control the export of certain semiconductor products.

The government's long term plans for the semiconductor industry can be distilled from the country's many and often overlapping industry plans. These plans are mostly drafted at the central-government level, but implemented at local-government level, for which local authorities draft their own roadmaps. Local governments sometimes have surprising leeway with the implementation and

funding of these plans. The list below contains an overview of important government policies that directly or indirectly concern semiconductors. The most relevant are discussed in detail.

National Standardization Development Outline Action Plan[33] National Standardization Development Outline[34]	2021
14th Five-Year Plan for National Informatisation[35]	2021
14th Five Year Plan (2021-2025)[36]	2020
Notice of the State Council on Issuing Several Policies for Promoting the High-quality Development of the Integrated Circuit Industry and the Software Industry in the New Era[37]	2020
China Standards 2035[38]	2018
Made in China 2025[39]	2015
Guidelines to Promote National Integrated Circuit Industry Development[40]	2014

The **14th version of the five year plan** of China's Communist Party calls for the digital transformation of China's society, making everything, from classrooms to courts, "smart". This transformation

[33] Xinhua News Agency, „**中共中央 国务院印发《国家标准化发展纲要》**", 10 October 2021, https://gkml.samr.gov.cn/nsjg/bzjss/202207/t20220708_348515.html.

[34] Xinhua News Agency, „**中共中央 国务院印发《国家标准化发展纲要》**", 10 October 2021, http://www.gov.cn/zhengce/2021-10/10/content_5641727.htm.

[35] Rogier Creemers et al., "Translation: 14th Five-Year Plan for National Informatization – Dec. 2021", *DigiChina*, 24 January 2022, https://digichina.stanford.edu/work/translation-14th-five-year-plan-for-national-informatization-dec-2021/.

[36] Xinhua News Agency, "**中华人民共和国国民经济和社会发展第十四个五年规划和** 2035 **年远景目标纲要**", 13 March 2021, https://www.fujian.gov.cn/english/news/202108/t20210809_5665713.htm.

[37] State Council, "**国务院关于印发新时期促进集成电路产业和 软件产业高质量发展若干政策的通知**", 27 July 2020, http://www.gov.cn/zhengce/content/2020-08/04/content_5532370.htm.

[38] Chinanews.com, "国家标准委：正制定《中国标准 2035》", 10 January 2018, https://www.chinanews.com.cn/gn/2018/01-10/8420700.shtml.

[39] State Council, "国务院关于印发《中国制造 2025》的通知", 8 May 2015, http://www.gov.cn/zhengce/content/2015-05/19/content_9784.htm.

[40] Ministry of Industry and Information Technology, "**工信部正式公布《国家集成电路产业发展推进纲要》**", 26 June 2016, http://www.cac.gov.cn/2014-06/26/c_1111325916.htm.

requires key digital technologies, according to the plan, including high-end semiconductors.[41] The **14th Five-Year Plan for National Informatisation** provides a more detailed blueprint of this digitalisation. Regarding semiconductors, the plan calls for an acceleration of key technological breakthroughs, and the development of key materials such as design tools and equipment. The plan furthermore calls for the cultivation of an advanced dedicated chip ecosystem and the strengthening of chip research.[42]

The **Notice of the State Council on Issuing Several Policies for Promoting the High-quality Development of the Integrated Circuit Industry and the Software Industry in the New Era** stems from 2020. This policy promotes the development of chips and software and includes detailed tax benefit policies for different kinds of chip projects. For example, the notice stipulates that companies with chip-projects for 28 nm chips or smaller are exempted from corporate income taxes for 10 years, while companies producing and designing chips are exempt from import duties on the equipment they use. The notice also includes directions on how different government levels should support the industry through investments and other forms of financing. Furthermore, it calls for standardisation efforts in the industry and sets out policies that encourage the development of R&D, skilled personnel and international cooperation.[43]

Made in China 2025 is both a strategic- and an industrial policy plan launched in 2015 to develop China's industry sector towards more advanced manufacturing. It focuses on 10 Key Industries, including Information Technology, Robotics and Green Energy & Vehicles, for which semiconductors are indispensable. The plan sets up various new development funds. According to research by the US Congress, MIC 2025 was linked to 1800 funds with a valuation of 426 billion USD in 2018.[44] Semiconductors are also specifically mentioned, and the plan calls for improving design capabilities, enriching intellectual property, improving the capabilities of the packaging and testing industry, and the formation of key manufacturing equipment supply capabilities. The goal of the plain is to produce 40% of the Chinese semiconductor demand domestically by 2020, and 70% by 2025 (the latter goal was later changed to 80% by 2030).[45]

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[41] Xinhua News Agency, "中华人民共和国国民经济和社会发展第十四个五年规划和 2035 年远景目标纲要", 13 March 2021, https://www.fujian.gov.cn/english/news/202108/t20210809_5665713.htm.

[42] Rogier Creemers et al., "Translation: 14th Five-Year Plan for National Informatization – Dec. 2021", *DigiChina*, 24 January 2022, https://digichina.stanford.edu/work/translation-14th-five-year-plan-for-national-informatization-dec-2021/.

[43] State Council, "国务院关于印发新时期促进集成电路产业和 软件产业高质量发展若干政策的通知", 27 July 2020, http://www.gov.cn/zhengce/content/2020-08/04/content_5532370.htm.

[44] Jie Lu and Yann Morell y Alcover, "China: Navigating the push towards technology leadership", https://insuranceaum.com/wp-content/uploads/2021/10/China-navigating-the-push-towards-technology-leadership_ROBECO.pdf, see note 7 at page 7.

[45] State Council, "国务院关于印发《中国制造 2025》的通知", 8 May 2015, http://www.gov.cn/zhengce/content/2015-05/19/content_9784.htm.

The **Guidelines to Promote National Integrated Circuit Industry Development** launched in 2014 to support the chip sector. It includes provisions for chip design, research in equipment and materials and the development of the packaging and testing industry. The guidelines also encourage chip companies to go public, calls for preferential tax policies, a national investment fund (this became the Big Fund, see below), and to boost overseas cooperation. The guidelines also include chapters on training and attracting talented personnel, including from abroad. [46] It is important here to also mention the Thousand Talents Program, which was a scheme to attract foreign researchers to work for Chinese companies, universities, and other R&D institutions. After receiving negative attention outside of China, the plan was eventually renamed and moved away from the spotlights, but still exists.[47]

Also worth mentioning is that strengthening the capabilities and self-reliance of China's defence sector is one of the reasons why the Chinese government actively invests in developing the domestic semiconductor industry and in reducing the dependence on foreign companies. The sector is a key supplier of the country's defence industry, with semiconductors being used in a variety of defence applications, such as communication systems, radar systems, and guidance systems. One of the strategies to strengthen China's defence is the practice of "civil-military fusion". This refers to the integration of civilian and military resources and technologies in order to improve the military's capabilities. This can include things like using civilian technologies in military equipment, or having military personnel work in civilian research and development. China's "civil-military fusion" policy also applies to the semiconductor industry.

Government Funds

In order to realise the ambitious plans of the Chinese government for the semiconductor sector in the country, many funds have been founded to direct financial support to the industry. These do not just hand out cash, but actually invest and hold shares in many different companies. The funds are often overseen by a semi-private entity, like a government-backed investment company. For the semiconductor industry, two national funds stand out.

[46] Ministry of Industry and Information Technology, "工信部正式公布《国家集成电路产业发展推进纲要》", 26 June 2016, http://www.cac.gov.cn/2014-06/26/c_1111325916.htm.

[47] In 2019, the plan was renamed to: High-End Foreign Expert Recruitment Program, and merged with several other similar schemes. In 2022, the plan was renamed and reorganized once again. The current name is National Foreign Expert Project. Chinese R&D institutes are still recruiting, see for example this webpage of Wuxi University: "关于申报 2022 年度国家外国专家项目的通知", 18 March 2022, https://gjjy.cwxu.edu.cn/info/1124/1396.htm http://international.cumt.edu.cn/72/cb/c6289a619211/page.htm.

The **China Integrated Circuit Industry Investment Fund (CICF) Phase II** is also known as the "Big Fund II" and controls 204 billion CNY (31.8 billion USD).[48] As the name indicates, it is a successor to an earlier fund that contained about half that amount for the 2014-2019 period. The new fund is managed by a subsidiary of the China Development Bank (CDB).[49] Main investors are the Ministry of Finance and various central and local state-owned funds and companies. Its investment field covers the entire industrial chain of integrated circuit design, manufacturing, packaging and testing. The aim of the fund is to help leading enterprises to grow, to accelerate investments in core equipment such as lithography machines, to ensure the security of the industrial chain and to create a supply system for the integrated circuit industry chain with a focus on upstream equipment and materials.[50] Secondly, the **Advanced Manufacturing Industry Investment Fund** was established to support the development goals of Made in China 2025 with an initial capital of €2,7 billion, which later grew to €6,85 billion.[51] The scope of the fund is wide, but it also invests in semiconductor companies.

Besides the national funds, there are numerous funds backed by local governments. Similar to the national level, investors in these funds include a mix of (other) local government investment funds, local private investment funds, local banks, and companies. It appears that nobody keeps track of the combined amount of money that is supposed to sit in these funds.

The ownership structure of companies in which such funds invest is often very vague, as these companies undergo seemingly endless changes of shareholders. There is a lot of reporting in Chinese media about these dealings, so it is not exactly a secret, but it is still unclear to what extent the government funds are actually involved. There also have been numerous allegations of corruption concerning the funds. [52] One of the main problems is that directors of the funds are often also directors at other investment funds *and* hold positions at semiconductor companies. Another problem is that funds invest in companies that are themselves shareholders of the funds.

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[48] In Chinese, the Phase II fund is most often referred to by the same name as the first: 国家集成电路产业投资基金股份有限公司, but sometimes as 国家集成电路产业投资基金**二期**股份有限公司二期; Eudora Wang, "China Closes $29B 'Big Fund II' To Catch Up In Global Semiconductor Race – CSJ", *China Money Network*, 26 July 2019, https://www.chinamoneynetwork.com/2019/07/26/china-closes-29b-big-fund-ii-to-catch-up-in-global-semiconductor-race-csj.

[49] Shunsuke Tabeta, "China launches graft probe into another chip 'Big Fund' exec", *Nikkei Asia*, 21 September 2022, https://www.cbinsights.com/investor/sino-ic-capital.

[50] East Money, "国家集成电路产业投资基金二期成立，这两只股将笑傲市场", 29 October 2019, https://caifuhao.eastmoney.com/news/20191028100453943581980.

[51] SASAC, "国投参与出资设立的先进制造产业投资基金成立", 12 June 2016, http://www.sasac.gov.cn/n2588025/n2588124/c3822803/content.html.

[52] Eduardo Jaramillo, "After a year of corruption scandals, China's national chip fund forges ahead", *The China Project*, 4 January 2023, https://thechinaproject.com/2023/01/04/after-a-year-of-corruption-scandals-chinas-national-chip-fund-forges-ahead/; Barry van Wyk, "Mayhem in China's semiconductor industry as 'chips madmen' are arrested", *The China Project*, 1 August 2022, https://thechinaproject.com/2022/08/01/chinas-microchip-great-leap-forward-has-also-ended-in-chaos/.

Government organisations

In China, industry associations (such as the Chinese Semiconductor Industry Association (CSIA)) are not independent entities, but approved, regulated, controlled and largely funded by the government. In the case of semiconductors, the main regulator/funder is the Ministry of Industry and Information Technology (MIIT). Another noteworthy organisation is the Advanced Semiconductor Innovation Alliance (CASA). This is an alliance of government entities, research institutes, universities, and state-owned companies, which appears to be an important player in China's military-civil fusion strategy.[53] Finally, the China Center for Information Industry Development (CCID) is a research institute under MIIT that consists of 18 research institutes, more than 20 holding companies, and several fully- or partially state owned companies.[54]

2. Industry overview

China is the world's largest market for semiconductors. Estimates about the share of the Chinese market vary, some stating that sales in China represent more than half of worldwide sales, others put the number around one third. In both cases, total sales in China amount to hundreds of billions USD.[55] In fact, China is the largest export destination for the four other main semiconductor producers (South Korea, Taiwan, US, Japan).[56] This large Chinese consumption stems from the fact that many consumer goods, which use a large amount of chips, are produced in China.[57]

At the same time, China also has become an important producer of chips and is investing heavily, just like many other countries, to expand this capacity. One of its plans is to build 31 fabs between 2020 and 2021.[58] According to the US Semiconductor Industry Association (SIA), Chinese semiconductor companies captured 9% of the global market in 2020.[59] At the same time, China exports by far the most semiconductors.[60] However, different sources report different figures and numbers appear at odds with each other. This could be explained by the fact that many non-Chinese companies have

[53] Emily Weinstein, "Don't Underestimate China's Military-Civil Fusion Efforts", *Foreign Policy*, 5 February 2021, https://foreignpolicy.com/2021/02/05/dont-underestimate-chinas-military-civil-fusion-efforts/.
[54] CCID, "About us" (visited 8 February 2023), http://en.ccidgroup.com/ABOUT/About_Us.htm.
[55] Mark Lapedus, "China Accelerates Foundry, Power Semi Efforts", *Semiconductor Engineering*, 22 November 2021, https://semiengineering.com/china-accelerates-foundry-power-semi-efforts/.
[56] Gary Clyde Hufbauer and Megan Hogan, "Major semiconductor producing countries rely on each other for different types of chips", 31 October 2022, https://www.piie.com/research/piie-charts/major-semiconductor-producing-countries-rely-each-other-different-types-chips#:~:text=Each%20of%20the%20five%20major,also%20a%20large%20chip%20importer.
[57] Gary Clyde Hufbauer and Megan Hogan, "CHIPS Act Will Spur US Production but Not Foreclose China", https://www.piie.com/sites/default/files/2022-10/pb22-13.pdf.
[58] Gary Clyde Hufbauer and Megan Hogan, "CHIPS Act Will Spur US Production but Not Foreclose China".
[59] SIA, "China's Share of Global Chip Sales Now Surpasses Taiwan's, Closing in on Europe's and Japan's", 10 January 2022, https://www.semiconductors.org/chinas-share-of-global-chip-sales-now-surpasses-taiwan-closing-in-on-europe-and-japan/.
[60] Gary Clyde Hufbauer and Megan Hogan, "CHIPS Act Will Spur US Production but Not Foreclose China".

manufacturing facilities in China from where the chips are shipped (see section "international connections"), which some appear to consider to be Chinese chips or exports, and others do not.

Despite the large exports, China continues to import a large share of its semiconductors from abroad. According to figures by private-sector market research, only 16% of the semiconductors used by Chinese companies in 2020 were produced domestically. The number is even 6% when foreign-owned chip manufacturing facilities in China are excluded. The Chinese authorities themselves claim that the share of domestic supply was around 30%. Both fall short of the target of the Made in China plan to produce 40% of demand domestically by 2020.[61]

What's more, China is especially strong in producing relatively inexpensive and less advanced semiconductors. This can be illustrated by the fact that the average chip exported from China costs 0.19 USD (in 2021). Japanese chips are even cheaper (0.13 USD), but semiconductors from Taiwan (0.32 USD), South Korea (1.08 USD) and the US (2.16 USD) are considerably more expensive.[62] Furthermore, the price of the average chip that China buys from the US costs 70 times more than the ones it sells to that country (4.28 USD compared to 0.06 USD). China is thus still very dependent on overseas suppliers for advanced semiconductors. As discussed above, China invests heavily in its capabilities to produce more advanced semiconductors, and its technologies are progressing. It is exactly this progress that Washington is looking to slow down with its new export restrictions and by preventing the shipment of advanced equipment to China.

Another area in which China is especially strong is the Outsourced Semiconductor Assembly and Test (OSAT) segment the value chain. The three top Chinese companies in this segment together represent over 35% of the global market share.[63]

China has made significant investments in semiconductor R&D in recent years. The country has established several national labs and research institutes focused on semiconductor technology, and has also provided funding and support for private companies working on semiconductor R&D.

[61] Shunsuke Tabeta, "'Made in China' chip drive falls far short of 70% self-sufficiency", *Nikkei Asia,* https://asia.nikkei.com/Business/Tech/Semiconductors/Made-in-China-chip-drive-falls-far-short-of-70-self-sufficiency.
[62] Gary Clyde Hufbauer and Megan Hogan, "CHIPS Act Will Spur US Production but Not Foreclose China".
[63] SIA, "China's Share of Global Chip Sales Now Surpasses Taiwan's, Closing in on Europe's and Japan's".

Main Chinese semiconductor companies and research institutes[64]

There are an estimated 15,000 Chinese companies registered as semiconductor enterprises spread out across the complete value chain.[65] The fortunes of chip companies rise and fall fast, depending on market conditions, government policies and US sanctions. The sector is very dynamic, with a continuous stream of new companies, mergers and acquisitions, name-changes, etc. Discussed below are the major Chinese semiconductor companies as of early 2023.

In the foundry business, **Semiconductor Manufacturing International Corporation (SMIC)** stands out as the largest Chinese player, and one of the largest globally. It is partially state-owned and on the Chinese Military Companies and Entity List of the US.[66] It has been hit heavily by US sanctions. Although the company can still buy ASML DUV machines, at least for now, the EUV machine it bought from ASML in 2018 was never delivered.[67] This seriously limits its ability to expand to high-end chip manufacturing. That does not stop SMIC from expanding its current business, such as its recently announced investments in a foundry for the production of 28 nm to 180 nm chips.[68] **Hejian Technology Corporation (HJTC)** is the second largest Chinese foundry after SMIC and was fully acquired by Taiwan's United Microelectronics Corporation (UMC), making it one of the very few Chinese chip makers with 100% overseas ownership. HJCT makes relatively basic chips, the most advanced is 110 nm, that are mainly used in consumer electronics and automotive applications.[69] **Hua Hong Semiconductor** is another important foundry.

Regarding design (fabless) companies, **HiSilicon** is among the major Chinese players. It is a subsidiary of **Huawei Technologies** and mainly designs and manufactures semiconductors for use in Huawei's products. Huawei has been subject to US sanctions since 2019 and is on the Entity List, which restricts the company's access to US technology. This also has a significant impact on HiSilicon, which relies heavily on US technology and equipment for its semiconductor and electronic device production. **Unisoc** (formerly known as Spreadtrum Communications) is another Chinese fabless semiconductor design company. Its main shareholder was bailed out by a consortium including the same company that runs a joint venture with NXP in China and bought Nexperia from NXP. Furthermore, US based

[64] Will HuntSaif M. Khan Dahlia Peterson, "China's Progress in Semiconductor Manufacturing Equipment", March 2021, https://cset.georgetown.edu/publication/chinas-progress-in-semiconductor-manufacturing-equipment/.
[65] SIA, "China's Share of Global Chip Sales Now Surpasses Taiwan's, Closing in on Europe's and Japan's".
[66] U.S. Department of Denfese, "Entities Indentified as Chinese Military Companies Operating in the United States in Accordance with Section 1260H of the William M. ("Mac") Thornberry National Defense Authorization Act for the Fiscal Year 2021 (Public Law 116-238)", (visited 8 February 2023), https://media.defense.gov/2022/Oct/05/2003091659/-1/-1/0/1260H%20COMPANIES.PDF.
[67] Anton Shilov, "Chinese SMIC Tapes Out First N+1 '7 nm' Chip, But Mass Production Uncertain", 18 December 2020, https://www.tomshardware.com/news/chinese-smic-tapes-out-first-n-7-nm-chip-but-mass-production-uncertain.
[68] Channel News Asia, "Chinese chip foundry SMIC to invest $7.5 billion in new fab in Tianjin", 26 August 2022, https://www.channelnewsasia.com/business/chinese-chip-foundry-smic-invest-75-billion-new-fab-tianjin-2902211.
[69] Evertiq, "UMC's Hejian subsidiary resumes production", 24 February 2022, https://evertiq.com/news/51458.

Omnivision was bought by Will Semiconductors in 2018.[70] Will Semiconductor has since adopted 'Omnivision' as their English name. Finally, **GigaDevice** is also a major fabless design company and designs memory chips.

In the IDM segment, **Yangtze Memory Technologies Corporation (YMTC)** is an important player. In recent years, YMTC has made significant technological progress and has begun mass production of its 3D NAND memory semiconductors. YMTC is on the US Entity List, which meant Apple had to cancel its plans to source memory chips from the company.[71] YMTC's CEO, who had a US passport, stepped down in 2022 after becoming vulnerable to US sanction concerning US personnel working for Chips chip firms. [72] Other major IDMs are **ChangXin Memory Technologies (CXMT)** and **Silan Microelectronics**.

Chinese semiconductor manufacturing equipment makers are increasingly able to produce basic equipment for the chip production chain. **Shanghai Microelectronics Equipment (SMEE)** has long been working on the development of 28nm and 20 nm DUV machines.[73] In November 2022, the company announced that it plans to officially mass-produce and commercialise 28nm lithography machine before the end of that year. This pleased Chinese media, after ASML had reportedly stated earlier that "even if they gave Chinese companies drawings, they could not make lithography machines."[74] **Naura Technology Group** is another important player in this segment that produces etchers, deposition equipment, atomic layer deposition equipment (ALD), and cleaning equipment.[75] Other noteworthy equipment producers are **Advanced Micro-Fabrication Equipment Inc. (AMEC), Sai MicroElectronics (SMEI)**, whose purchase of a German chip company was blocked, and **Piotech**.

In the OSAT segment, **JCET** is China's largest company, and among the largest in the world.

[70] Peter Clarke, "OmniVision bought quietly by China's Will Semiconductor", 24 May 2019, https://www.eenewseurope.com/en/omnivision-bought-quietly-by-chinas-will-semiconductor/.
[71] Cheng Ting-Fang, Lauly Li and Yifan Yu, "Apple freezes plan to use China's YMTC chips amid political pressure", *Nikkei Asia,* 17 October 2022, https://asia.nikkei.com/Business/Tech/Semiconductors/Apple-freezes-plan-to-use-China-s-YMTC-chips-amid-political-pressure.
[72] Jiaxing Li, "China's top memory chip maker YMTC replaces CEO amid risks of US sanctions after rumoured Apple deal", *SCMP*, 1 October 2022, https://www.scmp.com/tech/big-tech/article/3194519/chinas-top-memory-chip-maker-ymtc-replaces-ceo-amid-risks-us.
[73] Anton Shilov, "China's 28nm-Capable Chip Fabbing Tool on Track Amid Trade War", 6 December 2020, https://www.tomshardware.com/news/chinas-28nm-capable-chip-fabbing-tool-on-track-amid-trade-war.
[74] iMedia, "A bigger crisis is coming!The domestic 28nm lithography machine just showed the light, ASML immediately "zoomed in"", 5 Febuary 2023, https://min.news/en/tech/08acbf8bdb4973e8b7b9dca55bc92134.html.
[75] Naura, "Semiconductor", visited 8 February 2023, https://www.naura.com/en/index.php/product/product_list/834.html.

R&D

China invests actively in the R&D of its semiconductor industry, with the goal of becoming self-sufficient in the production of semiconductor devices and reducing its dependence on foreign companies. China also works on developing and protecting its own intellectual property in the and promotes foreign technology transfers. Many universities in China have established research centres focused on semiconductor technology which are often supported by government funding. Universities often also have strong industry partnerships, and companies in the semiconductor industry often collaborate with universities on R&D projects. Some of the key areas of focus for Chinese semiconductor research include advanced manufacturing technology, advanced materials such as new types of transistors, artificial intelligence and machine learning technologies (in which China is world leader), and Internet of Things (with a focus on developing chips that enable connected devices).[76]

Two general trends are furthermore noticeable. First, mergers and name-changes of research institutes have been common, but in recent years this seems to intensify. This may be caused by the desire to combine expertise to get more results, and by the desire to avoid possible US sanctions. However, even after an official merger, the original institutes often appear to continue to go their own way. Secondly, there appears to be a shift of R&D activities away from the centre (Beijing and Shanghai) to the provinces. Many provincial capitals are setting up new semiconductor research institutes, often in cooperation with local-state owned companies and local universities.

There are many semiconductor R&D centres in China, some of which are especially worth mentioning. The **School of Integrated Circuits (SIC)** is a new semiconductor research institute at Tsinghua University in Beijing that offers relevant degree programs. There are also several relevant research institutes that are part of the Chinese Academy of Sciences (CAS), such as the **Institute of Computing Technology (ICT), Institute of Microelectronics (IME)** and the **Institute of Semiconductors (SEMI)** that do research on semiconductor related topics. Finally, the **Shanghai Industrial Technology Research Institute (SITRI)** focuses on applied research and development in the fields of advanced manufacturing, materials, and information technology.

[76] Arjun Kharpal, "In battle with U.S., China to focus on 7 'frontier' technologies from chips to brain-computer fusion", *CNBC*, 5 March 2021, https://www.cnbc.com/2021/03/05/china-to-focus-on-frontier-tech-from-chips-to-quantum-computing.html.

Connections with the Netherlands

The relationship between China and the Netherlands in the semiconductor industry is relatively extensive. Major Dutch companies have a strong presence in China and are looking to expand their activities. Below are the most prominent of these companies.

In 2021, **ASML**'s sales in China amounted to €2.74 billion, accounting for 14.7% of ASML's total net sales.[77] That makes China ASML's third largest market worldwide after Taiwan and South Korea. ASML expects business in China to grow, notwithstanding US sanctions. In June 2022, the company announced it would expand its China workforce with 14% or 200 employees.[78] 3% of ASML's R&D employees operate in China. This is comparable to Taiwan and more than in other Asian countries. ASML also sponsors five scholarships in China (compared to 54 in Netherlands, 24 in Taiwan, 7 in the US (and on par with South Korea).[79]

Starting from 2018, the Trump administration pressured the Dutch government to block the shipment of the company's most advanced EUV machine that can make chips of 7nm and smaller to China. Under president Biden, this policy has continued. Washing fears that if China acquires the EUV machine, it will be able to produce the most advanced chips that would strengthen the Chinese military capabilities.[80] At least until recently, ASML was able to export the less advanced DUV machines to the country. In March 2021, Chinese chip maker SMIC announced that it had placed an order of 1.2 billion USD with ASML for DUV machines.[81] There is also an active market for used ASML machines. ASML refurbishes and resells such machines, but Chinese companies are trying to purchase used machines on the international market themselves as well. This process may gain importance if ASML further reduces sales of machinery to China in the future. Chinese companies may buy chip machines in third-countries, either under their own name or by using intermediaries.

In 2021, 38% of **NXP**'s revenue was earned in China, which makes it by far the largest market for NXP. The net value of the company's assets (properties, plants and equipment) in China was 387 million,

[77] South China Morning Post, "Tech war: broader ban on ASML sales to China will hurt firm's revenue and set back Beijing's domestic chip-making drive, analysts say", 19 July 2022, https://www.yahoo.com/lifestyle/tech-war-broader-ban-asml-093000858.html.
[78] South China Morning Post, "Chip-making tools firm ASML to hire 200 staff in China as Covid restrictions ease, including sanctions compliance role", 8 June 2022, https://www.scmp.com/tech/big-tech/article/3180830/chip-making-tools-firm-asml-hire-200-staff-china-covid-restrictions.
[79] ASML, "Annual Report 2021" (visited 8 February 2023), https://www.asml.com/en/investors/annual-report/2021 p. 138, 240.
[80] Alexandra Alper, Toby Sterling, Stephen Nellis, "Trump administration pressed Dutch hard to cancel China chip-equipment sale: sources", *Reuters*, 6 January 2020, https://www.reuters.com/article/us-asml-holding-usa-china-insight-idUSKBN1Z50HN.
[81] Wency Chen, "Chinese chipmaker SMIC inks deal worth USD 1.2 billion with ASML", 4 March 2021, https://kr-asia.com/chinese-chipmaker-smic-inks-deal-worth-usd-1-2-billion-with-asml.

up from 257 in 2020, 15% of total NXP worldwide assets and ranking third after the US and Singapore.[82] NXP's facility in Tianjin is one of their most important back-end facilities worldwide.[83]

NXP runs several joint ventures and joint research programs in China. Datang NXP Semiconductors is such a joint venture between NXP and Datang Telecom Technology (DTT) with NXP controlling 49% of shares.[84] DTT is a subsidiary of state-owned enterprise Datang Telecom Technology & Industry Group, which owns another company that supplies communications network equipment to the Chinese military and conducts research with the military, according to US research.[85] Another joint venture is NXP Qiangxin (Tianjin) IC Design, with NXP having 75% of the shares.[86] This joint venture runs a training platform for local colleges and universities.[87] Furthermore, WeEn is a joint venture between NXP and Beijing JianGuang Asset Management Co. Ltd (JAC Capital).[88] In April 2019, NXP also entered into an agreement with the Chinese Hawkeye Technology which, according to a report, is affiliated with Southeast University (SEU) that is involved in various defence research with the Chinese military.[89]

For **ASM International,** 16% of total revenue is earned in China. Its most recent annual report states that "Notably, the China region has become a significant growth area for new fab investments .This includes both domestic Chinese companies and foreign companies building fabs there for the local market. To better serve this growing market, we are continuing to increase our investment in people and support infrastructure in China."[90] Revenue in China in 2020 had increased 10 times compared to 2017, and the number of employees three times. According to its general manager in China, AMS's Atomic Layer Deposition (ALD) machines are used by nearly every Chinese chipmaker.[91]

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[82] NXP Annual Report 2021, visited 8 February 2023, https://investors.nxp.com/static-files/4c564920-493f-4653-ab69-8ee1101152a4
[83] https://investors.nxp.com/static-files/4c564920-493f-4653-ab69-8ee1101152a4, p.9.
[84] Bits & Chips, "NXP in Chinese power-joint venture", 20 February 2015, https://bits-chips.nl/artikel/nxp-in-chinese-power-joint-venture/.
[85] Bryan Krekel, Patton Adams and George Bakos, "Occupying the Information High Ground: Chinese Capabilities for Computer Network Operations and Cyber Espionage", 7 March 2021, https://www.uscc.gov/sites/default/files/Research/USCC_Report_Chinese_Capabilities_for_Computer_Network_Operations_and_Cyber_%20Espionage.pdf.
[86] 权易汇, "「优质股权」天津强芯半导体芯片设计有限公司混改推介项目", 3 March 2020, https://www.toutiao.com/article/6799577946815201796/?wid=1668003672360.
[87] TEDA, "深耕经开区 20 年 校企合作开创"育才"新模式 恩智浦强芯为泰达引育高端芯片人才超 200 名", 25 April 2022, https://www.teda.gov.cn/tedazt/contents/8999/179205.html.
[88] NXP, "NXP and JAC Capital Complete Bipolar Power JV Following Regulatory Approvals", 9 November 2015, https://www.nxp.com/company/about-nxp/nxp-and-jac-capital-complete-bipolar-power-jv-following-regulatory-approvals:NW-JAC-BIPOLAR-POWER-JV.
[89] Rita Liao, "Dutch chipmaker NXP makes China push by backing radar company Hawkeye", 17 April 2019, https://techcrunch.com/2019/04/17/nxp-backs-hawkeye-china/; ASPI Unitracker, "Southeast University", 12 November 2019, https://unitracker.aspi.org.au/universities/southeast-university/.
[90] ASMI, "Growth through Innovation. Annual Report 2021" (visited 8 February 2023), https://www.asm.com/Downloads/2021_ASMI_Annual_Report.pdf, p. 24.
[91] EE World, "荷兰另一全球 top10 半导体设备厂商 ASMI 中国市场营收三年增 10 倍", 11 April 2021, http://news.eeworld.com.cn/xfdz/ic532486.html.

BE Semiconductor Industries N.V. (Besi) revenue in China in 2021 was €282 million, nearly 38% of Besi's 2021 total revenue. To put that into perspective: China earns Besi almost the same revenue as the next six countries combined. Revenue growth in China was 86.7% in 2021.[92] BESI runs several factories that produce semiconductor equipment in China. Its plant in Leshan is its second-largest worldwide, producing 25% of its global production.[93] China is thus not only a very important market for BESI, but also a crucial location for production.

There are also several connections in other areas. For example, TU Delft opened a Beijing Research Center in cooperation with the Institute of Semiconductors in 2011.[94] There also have been Sino-Dutch semiconductor summer schools, such as between TU Delft and Tsinghua University from 2016-2019.[95] In 2015, TU Delft and the Beijing Shunyi Government (a district in Beijing) signed a "Strategic Cooperation" to set up a semiconductor joint innovation and entrepreneurship incubation centre.[96] The Chinese industry association CSIA has cooperated with Dutch counterpart Holland Semiconductors in the China-Netherlands Semiconductor Industry Cooperation Forum of 2018, during which the latter said it would invest 1 million USD to found a 'Sino-Dutch innovation centre'.[97] There are also certain noteworthy Dutch semiconductor companies that were acquired by Chinese parties, such as Nexperia and Ampleon (former divisions of NXP), Nowi (a company that develops energy-harvesting semiconductors) and Anteryon (a supplier for the semiconductor manufacturing industry).

3. International positioning and connections

Geopolitical positioning

The technological rivalry between the US and China is the major international political issue affecting the Chinese semiconductor industry. The conflict turned *geo*political when the US persuaded other countries to join its efforts to slow down China's development, specifically in the area of semiconductors. Washington has expressed concern that if China becomes technologically highly advanced and self-reliant in the area of semiconductors, it will use these capabilities to upgrade its

[92] Besi, "Annual Report 2021, visited 8 February 2023, https://view.publitas.com/cfreport/besi-annual-report-2021/page/155.
[93] Besi, "Investor Presentation", October 2022, https://www.besi.com/fileadmin/data/Investor_Relations/Investor_Presentations/Investor_Presentation_October_2022.pdf.
[94] Netherlands Innovation Network, "Opening ceremony TU Delft Beijing Research Center", 10 December 2011, https://netherlandsinnovation.nl/uncategorized/opening-ceremony-tu-delft-beijing-research-center/.
[95] TU Delft, "Sino-Dutch Summer School", visited 8 February 2023, https://www.tudelft.nl/en/eemcs/the-faculty/departments/quantum-computer-engineering/sino-dutch-summer-school.
[96] Ministry of Science and Technology, "荷兰代尔夫特理工大学中国研究院落户顺义第三代半导体联合创新基", 28 November 2016, https://www.most.gov.cn/dfkj/bj/zxdt/201611/t20161125_129192.html.
[97] Yuqing Ni, "荷兰半导体协会在华投资百万美元 建中荷创新中心", 12 March 2018, https://m.21jingji.com/article/20180312/herald/7b553eb50e62aa6a06203817ba759424.html, 1 million euro would make more sense, but the source-article clearly mentions USD.

military to a level that challenges the security interests of the US and its allies. Such concerns are fuelled by the Chinese government policies discussed above, which promote the self-sufficiency of China's semiconductor sector and civil-military fusion.

In response, the US has taken several steps, as also mentioned in chapter 3. Chinese companies and research centres which could threaten US security interests or undermine human rights, for example because Washington believes they have ties with China's security apparatus or military, are added to several US blacklists, such as the Entity List or the Military End User List.[98] This restricts or adds control mechanisms for the interactions that US companies can have with these Chinese actors.

The US also introduced stringent export restrictions regarding certain, often advanced, semiconductors and related goods in October 2022. In addition, Washington pressures its allies, notably the Dutch and Japanese government, to prevent the shipment of advanced semiconductor equipment to China, so that Chinese companies are not able to manufacture advanced semiconductors or acquire the necessary technology. After preventing ASML from shipping its most advanced semiconductor manufacturing equipment to China, the Dutch government, along with the government of Japan, appear to have given in to US demands to also restrict the export of less advanced machinery to China.[99] The US furthermore attempts to convince South Korea, Taiwan and Japan to join the so-called Chips 4 Alliance to coordinate on semiconductors and to counter China's development in the sector. See chapter 3 for more details on all of these policies.

Obviously, Beijing condemns these actions by the US and has initiated a dispute settlement case at the WTO over the measures.[100] Chinese state media state that the case demonstrates that China upholds multilateralism, while the US is disrupting global supply chains.[101]

Many Chinese actors, such as the Chinese industry association CSIA, try to put a positive spin on the restriction, stating they spur the founding of more Chinese semiconductor companies and lead to a wider use of Chinese-designed chips.[102] State-media in China also contend that the restriction only motivates Chinese companies to increase their technological capabilities.[103]

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[98] Other lists include: Unverified List (UVL), *the Commerce Control List (CCL), and the list of Chinese military companies.*
[99] Dee-Ann Durbin and Aamer Madhani, "Source: Dutch, Japanese join US limits on chip tech to China", *AP News*, 30 January 2023, *https://apnews.com/article/technology-district-of-columbia-netherlands-china-business-6801d6c5f65b0bc1df6186e2e89a6f7d.*
[100] WTO, "China initiates WTO dispute complaint targeting US semiconductor chip measures", 15 December 2022, https://www.wto.org/english/news_e/news22_e/ds615rfc_15dec22_e.htm.
[101] Si Ma and Zhihua Liu, "Chip suit aims to safeguard supply chains", *ChinaDaily*, 14 December 2022, https://global.chinadaily.com.cn/a/202212/14/WS639902eba31057c47eba43ad.html.
[102] Si Ma and Zhihua Liu, "Chip suit aims to safeguard supply chains".
[103] Si Ma, "US chip tech ban threatens supply chain", 7 October 2022, https://www.chinadaily.com.cn/a/202210/07/WS633f6176a310fd2b29e7b293.html.

Chinese companies are also trying to deal with the restrictions by, for example, setting up "Non-A lines", which are semiconductor manufacturing plants without any American equipment.[104] Some research centres and companies are also looking to develop technologies to manufacture advanced semiconductors (7nm generation and beyond) that do not require the restricted equipment.[105]

In the meantime, semiconductor imports have declined due to the US restrictions and slowing demand. Over the first 10 months of 2022, China imported 13.2% less semiconductors compared to the same period in 2021 (though higher prices meant the value of the imports went up 1.3%).[106] The value of Chinese semiconductor equipment imports in November 2022 was 40% less compared to a year earlier and the lowest number since May 2020.[107]

Finally, the tensions over Taiwan are another important (geo)political factor shaping the semiconductor industry. The potential consequences of a reunification of Taiwan with China by military force are considerable for the industry, considering that some of the world's largest foundries are Taiwanese and operate major manufacturing plants in both Taiwan and China. Concerns over these consequences have motivated governments and semiconductor industries around the world to strengthen their domestic capacities and diversify their international supply chains to rely less on Taiwan.[108]

China's relations with other countries in the region

Despite the problematic political relationship between **Taiwan** and China, the two are highly connected in the economic sphere and in the semiconductor industry specifically. Taiwan's TSMC, the largest foundry in the world, has production facilities in China and many of its customers are Chinese. Other major Taiwanese foundries, such as UMC and PSMC also have facilities, customers or joint ventures in China. However, the efforts of the Chinese government to develop its own semiconductor industry and reduce its dependence on foreign companies has resulted in more competition for these Taiwanese companies from Chinese businesses. Increased scrutiny of foreign companies by the

[104] David Manners, "Huawei leading China chip dream revival", *Electronics Weekly,* 7 December 2022, https://www.electronicsweekly.com/blogs/mannerisms/manufacturing-mannerisms/huawei-leading-china-revival-of-chip-aspirations-2022-12/.
[105] Anton Shilov, "SMIC Details Its N+1 Process Technology: 7nm Performance in China, March 23 2020, https://www.anandtech.com/show/15649/smic-details-its-n1-process-technology-7nm-performance-in-china.
[106] Ann Cao, "China's chip imports see biggest drop in 2022 with accelerated decline in October amid US restrictions and weak demand", *SCMP,* 7 November 2022, https://www.scmp.com/tech/tech-war/article/3198726/chinas-chip-imports-see-biggest-drop-2022-accelerated-decline-october-amid-us-restrictions-and-weak.
[107] Ailing Tan and James Mayger, "China's Imports of Chip-Making Gear Drop to Lowest Since Mid-2020", *Bloomberg,* 22 December 2022, https://www.bloomberg.com/news/articles/2022-12-22/china-s-imports-of-chip-making-gear-drop-to-lowest-since-mid-2020.
[108] Gregory Arcuri and Samantha Lu, "Taiwan's Semiconductor Dominance: Implications for Cross-Strait Relations and the Prospect of Forceful Unification", 22 March 2022, https://www.csis.org/blogs/perspectives-innovation/taiwans-semiconductor-dominance-implications-cross-strait-relations.

Chinese authorities also led to concerns about the business environment for Taiwanese enterprises in China. Recent US sanctions make it furthermore increasingly difficult for TSMC to operate in China, as it is unsure if the company can ship manufacturing equipment to its facilities in the country (for which it currently received a one-year waiver from the US).[109] TSMC may also be forced to cancel contracts with Chinese customers that are blacklisted by the US.

China and **South Korea** have a close economic relationship in the area of semiconductors. The Chinese market is very important to Korean semiconductor companies: almost 60% of their chips are sold to China or Hong Kong.[110] China also houses significant manufacturing plants operated by Samsung and SK Hynix which produce 40% of Samsung's NAND flash memory chips (10% of global output) and 50% of SK Hynix's DRAM chips (15% of global output).[111] Chinese companies also operate facilities in South Korea, such as OSAT company JCET.[112] South Korean and Chinese semiconductor manufacturers are also competing with one another in the production of memory semiconductors.

Political disputes between Seoul and Beijing are challenging the strong economic ties in the semiconductor sector. Most importantly, South Korea appears to align itself more closely with the US and its allies in opposition to China. Militarily, the adoption of a US defence system and closer coordination with Tokyo angered Beijing.[113] In the area of semiconductors, South Korea's expected participation in the US-initiated Chips 4 Alliance further aggravates China.[114] SK Hynix was also blocked by Washington from shipping an ASML EUV machine to China in order to upgrade one of its Chinese manufacturing plants.[115]

Singapore is trying to position itself as a non-aligned country in the US-China tech war and to serve as a meeting point between China and the rest of the world. However, its semiconductor sector is much more integrated with that of the US and its allies than with that of China. There are only two major Chinese presences in Singapore: Chinese OSAT company JCET and private equity fund Wise Road

[109] Che Pan, "TSMC gets one-year equipment waiver for mainland China chip plant, easing the blow from new US restrictions", *SCMP*, 13 October 2022, https://www.scmp.com/tech/tech-war/article/3195870/tsmc-gets-one-year-equipment-waiver-mainland-china-chip-plant-easing.
[110] He-rim Jo, "Minister confirms South Korea's participation in US-led chip alliance", *The Korea Herald*, 18 December 2022, https://www.koreaherald.com/view.php?ud=20221218000120.

[111] Che Pan, "Tech war: SK Hynix executive says Korean chip maker may sell China fab under 'extreme' US pressure", 26 October 2022, https://www.scmp.com/tech/tech-war/article/3197331/tech-war-sk-hynix-executive-says-korean-chip-maker-may-sell-china-fab-under-extreme-us-pressure.
[112] JCET, "Company Information", visited 8 February 2023, https://www.jcetglobal.com/en/site/about.
[113] The New York Times, "'Yankees, Go Home!': Seoul Gets Squeezed Between the U.S. and China", *19 October 2022,* https://www.nytimes.com/2022/10/19/world/asia/korea-china-us-thaad-missiles.html
[114] He-rim Jo, "Minister confirms South Korea's participation in US-led chip alliance", *The Korea Herald*, 18 December 2022, https://www.koreaherald.com/view.php?ud=20221218000120.
[115] Jan Fred van Wijnen en Stijn van Gils, "Koreaanse chipmaker SK Hynix mag zijn ASML-machines niet in China zetten", *FD*, 18 November 2021, https://fd.nl/tech-en-innovatie/1419763/koreaanse-chipmaker-sk-hynix-mag-zijn-asml-machines-niet-in-china-zetten.

Capital each acquired a Singaporean OSAT business.[116] Nonetheless, China is a very important export market for Singapore's semiconductor industry.[117]

Political relations with **Japan** have obviously historically been difficult, but the two countries are highly connected economically, including in the semiconductor industry. China is Japan's most important trade partner in terms of value and Japan depends on China for about 60% of the rare earth materials it uses (which are significant for the semiconductor sector).[118] China, at the same time, relies on Japan for advanced semiconductor materials and semiconductor equipment, two areas in which the latter country is relatively strong. China is also the most important export market for Japanese semiconductors.[119]

Despite these close economic connections, Beijing and Tokyo appear to drift away further apart politically, which is in part due to tensions in the semiconductor sector. Japan takes a relatively confrontational position among semiconductor countries in the Asian region and labels China "the greatest strategic challenge in ensuring peace and security".[120] The country also appears relatively willing to work with the US on preventing China from acquiring the most advanced semiconductors and equipment.[121]

4. Implications for the Netherlands

The Dutch semiconductor sector is highly connected with that of China. For most of the large semiconductor companies in the Netherlands, China is among their largest (if not the largest) export markets. What's more, some companies run joint ventures with Chinese parties, conduct R&D activities in China or operate manufacturing facilities in the country. Dutch universities and the industry association of the Netherlands also have connections with Chinese counterparts. Many of

[116] 'UTAC Completes Sale to Wise Road Capital', UTAC Group, August 12, 2020, https://www.utacgroup.com/wp-content/uploads/2020/08/WR-Yransaction-announcement.pdf; Business Wire, 'KLA-Tencor's New Singapore Facility Will Provide Base for Regional Expansion', *KLA Corporation*, May 16, 2008, https://ir.kla.com/news-events/press-releases/detail/327/kla-tencors-new-singapore-facility-will-provide-base-for.
[117] Nile Bowie, 'Singapore's Chip Revival Hinges on a Wobbly China', *Asia Times*, January 14, 2022, https://asiatimes.com/2022/01/singapores-chip-revival-hinges-on-a-wobbly-china/.
[118] Ministry of Economy of Trade and Innovation, "Japan's new international resource strategy to secure rare metals", 31 July 2020, last accessed 30 January 2023, https://www.enecho.meti.go.jp/en/category/special/article/detail_158.html
[119] Gary Clyde Hufbauer and Megan Hogan, "CHIPS Act Will Spur US Production but Not Foreclose China", https://www.piie.com/sites/default/files/2022-10/pb22-13.pdf, p12.
[120] The Government of Japan, "National Security Strategy of Japan (Provisional Translation)", December 2022, last accessed 30 January 2023, https://www.cas.go.jp/jp/siryou/221216anzenhoshou/nss-e.pdf
[121] Orange Wang, "Japanese official signals that Tokyo will join US in chip ban against China", *SCMP*, 6 January 2023, https://www.scmp.com/news/china/article/3205769/japanese-official-signals-tokyo-will-join-us-chip-ban-against-china.

these relations are, or can be, affected by the political developments surrounding the Chinese semiconductor industry.

First of all, the actions by the US government that prevent companies in other countries from supplying advanced semiconductors and equipment to China have negative consequences for the Dutch industry. ASML is blocked from shipping its most advanced EUV machines to its Chinese customers, and it seems the same will apply to some of its less advanced equipment. Non-Chinese companies, such as South Korean company SK Hynix, are also not allowed to ship ASML's EUV machines to their Chinese facilities. This means that ASML loses an important market for its advanced equipment. The new US export restrictions introduced in October 2022 also impacts Dutch companies. For example, ASM International expects that 40% of its sales in China will be affected by the new restrictions.[122] The number of companies or organisations with whom Dutch semiconductor players can trade, start joint ventures or collaborate on R&D is also affected by the several blacklists drafted by the US.

China is motivated to invest extra funds and efforts to overcome the challenges of being cut-off from access to advanced semiconductors and semiconductor related goods. The need to develop alternative technologies is especially strong in the equipment sector. This could eventually result in Chinese competition for Dutch equipment companies. Within the Chinese market, the impact of this competition is relatively limited, considering that Dutch equipment companies are not able to export advanced goods to China. However, in the long run, if Chinese companies manage to develop alternatives, they could challenge Dutch equipment enterprises in the global market. China will be slowed-down, however, by the fact that international collaboration for many Chinese research centres and companies is complicated by US restrictions. What's more, Dutch equipment companies will contend that they will work hard to maintain their technological lead.

[122] Reuters, "ASMI expects Chinese sales to drop 40% on U.S. chip sanctions", 25 October 2022, https://www.reuters.com/technology/semiconductor-supplier-asmi-beats-its-q3-revenue-guidance-2022-10-25/.

India

Dr. Chaitanya Giri (Associate Professor, Flame University)

India's commercial semiconductor industry is currently on a growth catapult.[123] It is expected to grow from 119 billion USD in 2021 to 300 billion USD by 2026, with a compound annual growth rate of 19 per cent. This positioning on an upward trajectory has been possible because of numerous systemic policy decisions taken by the Indian government in the past decade (from 2012–2022). The semiconductor industry is not new to India. India's semiconductor design industry, over the years, has carved a worldwide niche and the Indian semiconductor ecosystem is now preparing to expand from design-only to design and large-scale assembly, testing, manufacturing and packaging capabilities.

India's semiconductor design competencies have long existed. These were operated directly by the Department of Electronics (now branched into the Ministry of Communications and Ministry of Electronics and Information Technology), government-owned companies and strategic agencies, the Defence Research Development Organisation and Indian Space Research Organisation. Until 2010, the Indian government and its strategic agencies had their designed semiconductor chips contract manufactured abroad.[124] India had no policy architecture that would allow semiconductor or higher-order, full-spectrum electronics manufacturing to become competitive and grow in the commercial realm. Indian semiconductor design engineers account for approximately 20 per cent of the global semiconductor design workforce.[125] They are deeply involved in numerous pre-silicon processes – specifications, architecture, design, physical implementation and manufacturing support. This tremendous workforce is also engaged in post-silicon (post-manufacturing) processes like testing and qualification. India's massive talent pool made it a preferred destination for global original equipment manufacturers (OEM) to set up offshore semiconductor design facilities.[126]

[221] 'Semiconductor component market to grow at CAGR 19%', *Trade Promotion Council of India*, 17 August 2022, https://www.tpci.in/indiabusinesstrade/news_buzz/semiconductor-component-market-to-grow-at-cagr-19/#:~:text=The%20semiconductor%20component%20market%20of,Market%20Report%2C%202019%2D2026.
[222] Kamaljeet Singh and S.V. Sharma, 'Semi-Conductor Ambience for Building Self-Reliance in the Country', *ICTAT Journal on Microelectronics* 03:04, 2018, pp. 488–493, https://ictactjournals.in/paper/IJME_Vol_3_Iss_4_Paper_7_488_493.pdf.
[223] Ministry of Electronics and Information Technology – Press Information Bureau, 'Semiconductor Chip Designing and Manufacturing', Government of India, 6 April 2022, accessed 10 December 2022, https://www.pib.gov.in/PressReleasePage.aspx?PRID=1814029.
[224] Chitra Giridhar, 'India's niche: semiconductor design services', *EDN*, 24 October 2006, last accessed on 10 December 2022, https://www.edn.com/indias-niche-semiconductor-design-services/.

Since the announcement of the Indian government's 'Make in India, Make for World' flagship policy in 2014 and the national India Semiconductor Mission (ISM) in 2021, India has taken steps in a short period to graduate into a pivotal global electronics and semiconductor manufacturing hub. This aspiration was strengthened by intense domestic and regional international demands forecasted for the region. India's consumer electronics and appliances manufacturing is estimated to contribute as much as one-fifth of national gross domestic product by 2025.[127]

Besides these national targets, India's economic growth, as forecasted by global credit rating agencies and multilateral financing institutions, its robust domestic governance instruments and the strong confidence expressed by global investors have collectively convinced global semiconductor companies to set up manufacturing units in India.[128] In the coming decade of the 2020s, a few large (giga) fabs and numerous outsourced semiconductor assembly and test (OSAT), as well as assembly, testing, marking and packaging (ATMP) units, will appear in India. These will serve India's massive domestic and, of course, global markets.

1. Government

The Indian government has laid an extensive and continuously maturing policy framework for establishing a large semiconductor and electronic hardware ecosystem in India as a high priority. The broadest of the policy frameworks are the pan-Indian government 'Make in India', 'Digital India', 'Start-up India' and 'Skill India' campaigns. In recent years, the Indian government has carried out numerous systemic reforms that were earlier inhibiting the gestation of high-technology manufacturing in India.

The 'Make in India' campaign works towards enhancing India's 'Ease of Doing Business' (EODB) rankings, which are maintained by the World Bank. India's consistent efforts have resulted in India's EODB ranking rising from 142nd globally in 2014 to 63rd globally in 2020.[129] India's rankings are further expected to move up the charts, owing to sector-specific production-linked incentive (PLI) schemes,

[127] Ishita Guha, 'Electronics manufacturing will contribute $1 trillion by 2025', *The Mint*, 18 December 2020, last accessed 15 December 2022, https://www.livemint.com/news/india/govt-sees-electronics-manufacturing-contributing-one-fifth-to-economy-by-2025-11608288599559.html.
[128] Chris Anstey, 'India's Economic Ascendance May Happen This Time', *Bloomberg*, 26 November 2022, last accessed 15 December 2022, https://www.bloomberg.com/news/newsletters/2022-11-26/india-s-economic-ascendance-might-just-happen-this-time-new-economy-saturday.
[129] Make in India, 'Ease of Doing Business', Government of India, accessed 15 December 2022, https://www.makeinindia.com/eodb.

which were started in March 2020 and are explained later in this chapter. The EODB-driven reforms stimulated by the 'Make in India' campaign have helped the Indian government repeal nearly 2,000 antiquated laws from the British colonial era that would inhibit the smooth setting up and accomplishment of mundane business activities.[130]

The second framework – of importance for the semiconductor and electronics design and manufacturing industries – has been the pan-government 'Digital India' campaign. Within the ambits of the 'Digital India' campaign, the Indian government established a not-for-profit company, the Digital India Corporation, in September 2017.[131] The Digital India Corporation is mandated to assist the Indian government in policy and implementation related to the 'Digital India' campaign, to promote public–private partnerships, to offer a skilled workforce from the digital sector to various governmental ministries and agencies, and to promote innovation. In December 2021, the India Semiconductor Mission was launched as an independent division within the Digital India Corporation, with an incentive outlay of approximately 9 billion USD to attract investments in the semiconductor sector. The ISM is working on the following four schemes:[132]

- Fiscal support for setting up semiconductor fabs in India: with up to 50 per cent of project cost for fabs making 28nm or lower nodes; up to 40 per cent of the project cost for fabs manufacturing 28–45 nm; and up to 30 per cent for those manufacturing 45–65 nm.
- Fiscal support of 30 per cent of the total capital expenditure to eligible applicants for establishing silicon photonics, compound semiconductor, sensor (including MEMS) fabs and semiconductor ATMP or OSAT facilities in India.
- Fiscal support of up to 50 per cent of project costs (condition to a ceiling of approximately 1.4 billion USD per fab) for establishing thin-film-transistor liquid-crystal display or active-matrix organic light-emitting diode display fabrication units in India.

[130] 'British-era laws scrapped, ease of doing business rank escalated: PM Modi lists achievements', *The Mint*, 11 October 2022, accessed 15 December 2022, https://www.livemint.com/news/india/britishera-laws-scrapped-ease-of-doing-business-rank-escalated-pm-modi-lists-achievements-11665424421886.html.
[131] Digital India Corporation, 'About DIC', Government of India, https://dic.gov.in/.
[132] Ministry of Electronics and Information Technology – Press Information Bureau, 'MoS Shri Rajeev Chandrasekhar to visit Gandhinagar tomorrow to flag off the first SemiconIndia Future Design Roadshow', Government of India, 16 October 2022, last accessed 15 December 2022, https://pib.gov.in/PressReleseDetailm.aspx?PRID=1868283#:~:text=The%20Government%20of%20India%2C%20in,in%20the%20strategic%20Semiconductor%20sector.

- A Design-Linked Incentive Scheme that offers various financial incentives, design infrastructure support at various stages of design (up to 50 per cent to a ceiling of approximately 1.8 million USD per application) and deployment (6–4 per cent of net sales over five years) of integrated circuits, chipsets, system on chips, systems and IP cores.

The Indian government's production-linked incentive scheme known as the Scheme for Promotion of Manufacturing of Electronic Components and Semiconductors (SPECS), which was announced on 1 April 2020, offers a financial incentive on 25 per cent of capital expenditure for various semiconductor-related goods.[133]

Another scheme executed by India's Ministry of Electronics and Information Technology is the Modified Electronics Manufacturing Clusters (EMC 2.0) Scheme. [134] This scheme involves governmental assistance with establishing new and greenfield electronic manufacturing clusters and assists electronics system design and manufacturing (ESDM) entities in establishing their bases in these clusters with shared facilities and amenities. The EMC 2.0 will also upgrade infrastructure in existing and brownfield industrial estates and industrial parks by developing common facilities and amenities for ESDM entities. Of the benefiting ESDM entities, EMC 2.0 intends to support one anchor entity that would purchase 20 per cent of the saleable or leasable real estate and make an investment higher than approximately 37 million USD for establishing a new electronics or semiconductor manufacturing entity. For smoother execution of the EMC 2.0, India's central and state governments have collaboratively formed a governing council, project review committees and project implementation agencies for every state, as well as a singular project management agency operating as an autonomous body of India's Ministry of Electronics and Information Technology (MEITY).

On the skilling front, numerous industry associations – partnering with the Electronic Sector Skills Council of India, a not-for-profit body – have been skilling and training the workforce required for the ESDM sector, at all levels of qualification, in association with the National Skill Development

[133] Ministry of Electronics and Information Technology – The Gazette of India, 'Notification – Scheme for Promotion of manufacturing of Electronic Components and Semiconductors (SPECS)', Government of India, 1 April 2020, last accessed 19 December 2022, https://www.meity.gov.in/writereaddata/files/scheme_for_promotion_of_manufacturing_of_electronic_components_and_semiconductors.pdf.
[134] Ministry of Electronics and Information Technology – The Gazette of India, 'Notification – Modified Electronics Manufacturing Clusters (EMC 2.0) Scheme', Government of India, 1 April 2020, last accessed 19 December 2022, https://www.meity.gov.in/writereaddata/files/modified_electronics_manufacturing_clusters_scheme.pdf.

Corporation, a not-for-profit company operated by India's Ministry of Finance.[135] Another important initiative of the MEITY is the Chips to Startup (C2S) programme.[136] The C2S aims to train human resources for the semiconductor industry in India in designing application-specific integrated circuits, field-programmable gated arrays, systems, and creating an academia–industry interface with universities, national laboratories, start-ups, and small and medium-scale enterprises. The India Chip Centre at the Centre for Development of Advanced Computing, an autonomous scientific society under the MEITY, has been identified as a nodal entity to gather chip designs from academia and industry participating in the C2S. The India Chip Centre sends the gathered chips to the Semiconductor Laboratory (another MEITY laboratory) for fabrication under the multi-project wafer mode.

On the start-up front, and under the 'Start-up India' campaign, financing and incubation of semiconductor start-ups have already begun. The Karnataka Innovation Society of the Government of Karnataka, along with the India Electronics and Semiconductor Association, has established the Semiconductor Fabless Accelerator Lab, which currently involves eleven portfolio companies and more than 80 ecosystem companies.[137] In October 2022, the Atal Innovation Mission of Niti Aayog (the Indian government's foremost policy think tank) and T-Hub, a renowned start-up incubator supported by the Government of Telangana, based in Hyderabad, selected ten start-ups for their AIC–T-Hub Semiconductor Program.[138]

India's central government does not carry out all the semiconductor-related policies in India. Of course, the Karnataka and Telangana state governments are both rearing semiconductor start-ups. However, some other industrious state governments in India have also had their own ESDM and semiconductor policies.[139] These policies commonly have the respective state government's subsidies and incentives on land procurement, water availability, electricity duty and power tariffs, as well as exemption on stamp duties. Among the non-fiscal support given, the state governments commonly offer uninterrupted power and water supplies, assistance with effluent and hazardous waste management,

[135] Electronics Sector Skills Council of India, 'A Study to Assess Employment Potential and Skilling Requirement', Ministry of Skill Development and Entrepreneurship, Government of India, 2019, last accessed 15 December 2022, https://www.essc-india.org/wp-content/uploads/ESSCI_Market%20Research-PCB_SC.pdf.
[136] Ministry of Electronics and Information Technology, 'Chips to Startup', Government of India, accessed 15 December 2022, https://www.c2s.gov.in/.
[137] K-Tech Center of Excellence for Fabless, 'Semiconductor Fabless Accelerator Laboratory', https://www.sfalcoe.com/.
[138] NITI Aayog – Atal Innovation Mission, 'AIC T-Hub Foundation', https://old.t-hub.co/aic-semiconductor-program/.
[139] These include the Karnataka Semiconductor Policy 2010, the Maharashtra Electronics Policy 2016, the 2nd Telangana Information Communication Technology Policy 2021-26, the Tamil Nadu Electronics Hardware Manufacturing Policy 2020, the Andhra Pradesh Electronics Policy 2021-24, the Madhya Pradesh Analog Semiconductor Fab Policy, the Uttar Pradesh Electronics Manufacturing Policy 2020, the Rajasthan Electronics Manufacturing Policy 2021, and the Gujarat Semiconductor Policy 2022.

single-window clearance during the initial stages of business establishment and ease of doing business self-certifications.

To summarise, India's semiconductor policies and execution plans span various ministries, agencies, and departments of the state and central governments. They interlink within the national campaigns, yet it is the India Semiconductor Mission that assumes the flagship role for developing the semiconductor ecosystem in India. The Indian government comprehends the necessity to offer fiscal incentives, infrastructural support, and smooth project implementation and execution as non-fiscal support.

2. Overview of the local industry

India's semiconductor market size is growing steadily because of the various PLIs, including those for electronics, mobile phones, displays and semiconductors. Although the pre-silicon era did not see India become an influential player in the global semiconductor industry, concerted efforts taken by the Indian government since 2014 have swung the scenario constructively in India's favour.
The fiscal support offered under the India Semiconductor Mission, around 9 billion USD, is substantial. In US dollar terms, globally, the Indian semiconductor market stood at 15 billion USD in 2020. By 2026, this market is expected to reach 63 billion USD.[140] Owing to the incentives of the India Semiconductor Mission, in the last quarter of 2022 the Taiwanese semiconductor company Foxconn (Hon Hai in China and Taiwan) entered into a joint venture with Indian conglomerate Vedanta to set up a 20 billion USD semiconductor fabrication unit constructing 28nm semiconductor nodes in India.[141] In the coming years, India may have an even more significant share in semiconductor design, could have several sector-specific OSAT and ATMP units, as well as a sizeable domestic market that is well connected with markets in Asia, Oceania and Africa.

The Indian electronics hardware manufacturing landscape had many impediments earlier. India was afflicted by a high cost of manufacturing, of up to 8–10 per cent, across various ESDM value chain stages *vis-à-vis* competing economies like China. The share of the domestic value chain in the ESDM

[140] Ministry of Electronics and Information Technology, 'Semicon India takes a step forward with Acceptance of Applications for Semiconductor and Display Fabs', *Government of India*, 19 February 2022, last accessed 19 December 2022, https://pib.gov.in/PressReleasePage.aspx?PRID=1799621.
[141] Vedanta Limited, 'Vedanta signs MoUs with Government of Gujarat to set up semiconductors and display fab units', https://www.vedantalimited.com/img/media_mentions/press_release/2022/Vedanta%20signs%20MoUs%20with%20Govt%20of%20Guj%20to%20set%20up%20semiconductors%20and%20display%20fab%20units.pdf.

segment has been merely between 10 and 30 per cent, primarily because of the absence of a semiconductor and display manufacturing ecosystem. This deficient domestic value chain was not gaining from the bill of material, which constitutes a sizeable portion of any electronic product. Another major impediment to attracting investments in domestic semiconductor and electronic hardware manufacturing was the nil basic customs duty on electronic components and semiconductors under the Information Technology Agreement-1 (ITA-1) of the World Trade Organisation (WTO). India has opted out of any further ITA expansion negotiations. It has chosen to promote manufacturing that was severely affected by ITA-1.

The semiconductor and electronics industries demand world-class public infrastructure, which has been in the works in India through a whole-of-government approach. India is currently working on the National Infrastructure Pipeline, which will witness investments of around 1.3 trillion USD. The investments will extend over five industrial corridors under the National Industrial Corridor programme, six freight corridors under the Dedicated Freight Corridor programme, 100 smart cities (including greenfield and brownfield) under the Smart City Mission, and economic corridors, logistics parks and numerous expressways under the Bharatmala project. The National Infrastructure Pipeline is a force multiplier for the proliferation of electronics and semiconductor manufacturing across India.[142]

One inherent advantage of manufacturing semiconductors in India is the enormous domestic and regional market volume, including mobile phones, industrial electronics, consumer electronics, strategic electronics, computer hardware and electronic components. Domestic production across these categories had already seen a measurable rise, even during the pre-PLI and pre-ISM years. The post-PLI and post-ISM years, when ESDM policies have matured and investments have poured in, are likely to show a steep rise in production.

[142] Department of Economic Affairs – Ministry of Finance, 'National Infrastructure Pipeline – Report of the Task Force', *Government of India*, accessed 21 December 2022, https://dea.gov.in/sites/default/files/Report%20of%20the%20Task%20Force%20National%20Infrastructure%20Pipeline%20%28NIP%29%20-%20volume-i_1.pdf.

Table 2: Overview of semiconductor businesses, industry bodies and R&D laboratories in India

Noteworthy semiconductor companies in India	**Country of origin**
Tata Elxsi	India
ASM Technologies	India
Polymatech	India
Dixon Technologies	India
SignalChip	India
Solex Energy	India
Vedanta	India
HCL Technologies – Sankalp Semiconductors	India
MIC Electronics	India
RIR Electronics	India
Tessolve	India
Moschip Technologies	India
SPEL Semiconductors	India
Saankhya Labs	India
Chiplogic Technologies	India
Continental Device India	India
Cirel Systems	India
Manjeera Digital Systems	India
Semtronics Micro Systems	India
Terminus Circuit	India
Bharat Electronics Limited	India
Wipro Engineering/NXT	India
Samsung Semiconductors	South Korea
TSMC	Taiwan
Micron Technology	US
Applied Materials	US
Broadcom Technologies	US
Lam Research	US

GlobalFoundries	US
eInfochips – an Arrow Company	US
NXP India	Netherlands
ASM Pacific Technology	Netherlands
Millux	Netherlands

Semiconductor and related ESDM industry bodies in India	**Year of establishment**
Electronics Industry Association of India	1967
VLSI Society of India	1990
Indian Cellular and Electronics Association	2002
India Electronics and Semiconductor Association	2004

Semiconductor R&D laboratories in India	**City located**
Microelectronics & MEMS Laboratory, Indian Institute of Technology (IIT) Madras	Chennai
Nanoelectronics Devices and Circuits Laboratory, IIT Gandhinagar	Gandhinagar
Wide Bandgap Semiconductor Laboratory, IIT Roorkee	Roorkee
Device Research Laboratory, IIT Roorkee	Roorkee
Semiconductor Device Fabrication Laboratory, IIT Kanpur	Kanpur
Nanofabrication Facility, IIT Bombay	Mumbai
Semiconductor Thin Film and Plasma Processing Laboratory, IIT Bombay	Mumbai
Nanophotonics Laboratory, IIT Hyderabad	Hyderabad
Department of Electronic Systems Engineering, Indian Institute of Science	Bengaluru
Department of Condensed Matter Physics & Material Science, Tata Institute of Fundamental Research	Mumbai
Centre for Materials for Electronics Technology	Hyderabad
Centre for Development of Advanced Computing	Bengaluru

Central Electronics Engineering Research Institute	Pilani
Central Scientific Instruments Organisation	Chandigarh
Semi-Conductor Laboratory	Chandigarh
Semiconductor Technology & Applied Research Centre	Bengaluru
Gallium Arsenide Enabling Technology Centre	Hyderabad
Solid State Physics Laboratory	New Delhi

As shown in Table 2 above, Dutch ESDM companies, especially those from the semiconductor sector, have minimal presence in India. This minimal presence has primarily been a sign of the absent semiconductor sector enabling policies and partnerships that would have enabled it. Regardless, some major Dutch ESDM companies have long been present in India and are vital contributors to the Indian semiconductor ecosystem.

NXP Semiconductors (formerly Philips Semiconductors), Europe's second-largest semiconductor company, has a significant presence in India's semiconductor design ecosystem.[143] Recently, NXP Semiconductors was among the sponsors of the 2022 'SemiconIndia' conference organised by the India Semiconductor Mission.[144] Philips has had a long presence in India through its domestic appliances business, since 1930, and it understands the Indian market well.[145] Some of this ground knowledge could be passed on to NXP Semiconductors. In 2021, the Dutch company NXP Semiconductors (India), along with MEITY's Startup Hub and the Fabless Chip Design Incubator at the IIT Hyderabad, initiated the Semiconductor Startup Incubation and Acceleration Program.[146] NXP Semiconductors, through this programme, will provide EDA tools to start-ups, give start-ups access to the ecosystem, mentor them, enable them with post-silicon laboratory access, and offer them their industry-experienced and ecosystem-exposed experts.

[143] Sanjay Gupta, 'We are NXP | NXP India Celebrates Its 'Tiny Scientists', *NXP*, 3 February 2021, accessed 21 December 2022, https://www.nxp.com/company/blog/we-are-nxp-nxp-india-celebrates-its-tiny-scientists:BL-NXP-INDIA-TINY-SCIENTISTS.
[144] Ministry of Electronics and Information Technology, 'SemiconIndia 2022', accessed 24 December 2022, https://www.semiconindia.org/.
[145] Elcoma India, 'History – Philips India Limited', accessed 24 December 2022, https://www.elcomaindia.com/?page_id=2406.
[146] Indian Institute of Technology Hyderabad, 'Fabless Chip Design Incubator', accessed 24 December 2022, http://fabci.iith.ac.in/fabci-nxp-sips-program.html#:~:text=Semiconductor%20Startup%20Incubation%20and%20Acceleration,IP%20design%20startups%20across%20India.

ASM Pacific Technology (ASMPT), a sister company of ASM International, has sales representation in India extending to neighbouring Bangladesh and Sri Lanka.[147] ASMPT will be a vital vendor in establishing fabs, OSAT and ATMP units.

Millux, a Dutch high-precision laser technology company that supplies its lasers to the semiconductor fabrication industry, is part of the Muon Group, based in Eerbeek.[148] The group also consists of India-based Atul Sugar Screens, Asia's largest manufacturer of nickel screens for the sugar-processing industry.[149] The Millux–Atul relationship through the Muon Group is one example of how high-precision ESDM components can serve diverse industries. This Millux–Atul exemplar also indicates Indian Prime Minister Narendra Modi's views on the health–agriculture–water trinity as the bedrock of India–Netherlands close mutual collaborations.[150]

India's MEITY and the Netherlands Organisation for Scientific Research (NWO) have supported collaborative R&D in convergence communications and broadband technologies on government-to-government bilateral research initiatives. Inopportunely, none of these projects are directly involved in semiconductor capacity-building, but some of these bilateral projects include:[151]

i. Digital Twin for Pipeline TRANSport Network;
ii. Personal Health Train for Radiation Oncology in India and the Netherlands;
iii. Data-Driven E-Commerce Order Fulfilment;
iv. Collaborative R&D Projects in Pervasive Communications & Computing.

Since 2018, India's Department for Promotion of Industry and Internal Trade, Invest India and Start-up India have created the #StartUpLink initiative with the Embassy of the Netherlands in India. Here, both India and the Netherlands have also identified medical technologies, agriculture technologies and cybersecurity as priority sectors for collaborations between their respective start-ups.[152]

[147] ASM Pacific Technology, 'Who we are', accessed 24 December 2022, https://www.asmpt.com/.
[148] Millux, 'Applications', accessed 24 December 2022, https://www.millux.nl/millux-applications/#semicon.
[149] Atul Sugar Screens, 'About', accessed 24 December 2022, https://atulscreens.com/.
[150] Ministry of External Affairs – Embassy of India, The Hague, Netherlands, 'India-Netherlands Bilateral Relations', *Government of India*, accessed 24 December 2022, https://indianembassynetherlands.gov.in/page/india-netherlands-relations/.
[151] Ministry of Electronics and Information Technology, 'International R&D Collaboration – Indo Dutch R&D Collaboration', accessed 24 December 2022, https://www.meity.gov.in/international-rd-collaboration.
[152] Startup India, 'Creating opportunities to navigate the Indian and Dutch startup ecosystems', Government of India, accessed 25 December 2022, https://www.startupindia.gov.in/content/sih/en/international/indo-dutch.html.

Semiconductor manufacturing capabilities are crucial for India's self-reliance (*Aatmanirbhar Bharat*) goals for its comprehensive national security, regional technological leadership, digital sovereignty, industrial growth and for ensuring skilling and employment for its large and skilled young population.

3. International positioning and connections

India is taking multifarious steps to incentivise ESDM companies operating in both pre-silicon and post-silicon domains. At present, India can be considered to be expediently positioned in pre-silicon domains, with numerous top-notch US, European, Asian and even home-grown fab-less and integrated device manufacturers (IDM) companies having large presence in the domestic ecosystem. Yet even the domestic IDMs are engaged largely in design and are deficient on the manufacturing side. India's semiconductor fabs have largely been run by the central government and have thus been working primarily in space, aerospace and defence domains. Nonetheless, India in the past few years had realised the limitations of its ESDM capabilities.

Although India has a formidable share in global semiconductor design capacities, many Asian countries have substantial pre-silicon ecosystems, nearly similar in strength with that of India. New Delhi understands that it has been heavily dependent on Asian countries for assembly, testing and manufacturing. Precisely because of this dependence, India intends to evolve its own manufacturing/ATMP/OSAT ecosystem, which will in turn also strengthen India's semiconductor design competencies.

With PLIs for mobile phones, large-scale (consumer) electronics, IT hardware and electronic manufacturing clusters, the Indian government has attracted numerous original design manufacturers (ODMs) and OEMs from China, Japan, Taiwan, Europe and North America, to establish manufacturing facilities in India under the 'Make in India, Make for World' campaign. This electronics assembly ecosystem would naturally become a bedrock market for fabs and semiconductor OSAT/ATMP units, especially with overseas investments for the massive market in the Indo-Pacific. To this end, India has begun to identify strategic semiconductor partners.

Through the Foxconn–Vedanta partnership, India and Taiwan are investing in a multi-billion dollar 28nm node giga fab. This fab's output is bound to reduce India's imports and create new jobs and a massive exports market, especially in West, South, South-East and Central Asia, Africa and Oceania. Furthermore, the 28nm node caters to applications from consumer electronics, smart phones, computing, automotive, the Internet of Things, graphic processing and high-speed networking chips. Therefore, the approximately 8 billion USD investment will seemingly give a reasonable internal rate of return. Furthermore, Foxconn–Vedanta's success with the 28nm node will encourage subsequent international investments on other nodes, especially those with 24nm and lower nodes. For Taiwan, such investments will moreover reduce its overdependence on China, from the globally strategic semiconductor industry standpoint.

Furthermore, it is well acknowledged that the global semiconductor industry is siloed in a few countries, and any geopolitically crucial conflict may disrupt the global semiconductor supply chain. The world is looking forward to diversifying global semiconductor supplies, and especially to building manufacturing capacities in politically and economically stable countries. India suits this requirement.

Taiwan's TSMC is one of the three large pure-play semiconductor companies, along with Intel and Samsung. These are the only three companies likely to set up giga fabs in India, but Intel and Samsung have yet to make a decision. This leads to a scenario where India is actually *less* likely to house several multi-billion dollar giga fabs through foreign partnerships, regardless of the incentives offered. For the same reason, India may look into establishing numerous ATMP and OSAT plants, which are fiscally prudent options and each plant could cater to one or more applications. For example, the Tata Group, India's leading automobile manufacturer, and Renesas (Japan) have entered a strategic partnership and could soon set up an OSAT plant, worth less than 500 million USD, catering exclusively to automotive semiconductors.[153]

India's geopolitical positioning is not only limited to being a high-tech manufacturing hub, but an exporter of high-tech goods along the International North–South Transport Corridor, the Asia–Africa Growth Corridor and the India–Israel–United States–United Arab Emirates trade routes.

[153] 'Renesas Partners with Tata to accelerate progress in advanced electronics for India and Emerging Markets', *Renesas*, 29 June 2022, accessed 25 December 2022, https://www.renesas.com/tw/en/about/press-room/renesas-partners-tata-accelerate-progress-advanced-electronics-india-and-emerging-markets-0.

India may not demarcate its alignment in the ongoing US–China Chip War but may instead simply leverage its inherent strengths. India's robust national and regional security architecture, forthcoming diplomatic outreach and strategic location along trade corridors make it a suitable base for global ESDM companies. India is consciously framing policies around its 2070 net zero commitments from COP26 in November 2021. This has begun attracting environmental, social and governance (ESG)-conscious sovereign wealth funds.

India's PLI schemes and the India Semiconductor Mission will together become a cornerstone of the strong economic indicators that are forecasted for India in the foreseeable future.

4. Implications for the Dutch sector

The role of the Dutch semiconductor industry in the India Semiconductor Mission will be essential. The Vedanta–Foxconn Giga fab and other smaller pure-play mega fabs, ATMP and OSAT units will likely become a new market opportunity for the global photolithography giant, ASML Holdings.

India's semiconductor ecosystem has a strong US imprint, primarily through the design and R&D units of big fabless firms located in India. There is therefore less likelihood of the US imposing sanctions concerning sales of ASML lithography units to India-based companies, just as the US attempts to do with China through the CHIPS and Science Act.[154] India is a cost-conscious market and manufacturers may avail themselves of the services of any other lithography instrument manufacturer that offers their technology at competitive prices. ASML Holdings may therefore find competition if its competitors pursue an aggressive pricing strategy in India.

India's and the Netherlands' semiconductor ecosystems are distant, with minimal business happening between them. Very few Indian and Dutch small and medium enterprises from the semiconductor ecosystem deal with each other. There are thus numerous opportunities to acquire stakes in each other's entities and grow in each other's ecosystems.

[154] 'Fact Sheet: CHIPS and Science Act will lower costs, create jobs, strengthen supply chains, and counter China', *The White House*, 9 August 2022, accessed 25 December 2022, https://www.whitehouse.gov/briefing-room/statements-releases/2022/08/09/fact-sheet-chips-and-science-act-will-lower-costs-create-jobs-strengthen-supply-chains-and-counter-china/.

India's largest employment sector exists among its micro, small and medium-scale enterprises (MSMEs). South Korea, the United States, Japan and Taiwan have made strong bilateral connections with India's lucrative MSME sector. In waiting for large Dutch businesses to do impactful business in India, and vice versa, the Dutch and Indian governments might be losing out on numerous opportunities that could be quickly realised if Indian and Dutch MSMEs engaged more with each other. These possibilities also include Dutch companies partnering in small, Indian pure-play fabs, OSAT and ATMP units and utilising India's various incentives.

NXP Semiconductors was present at the 2022 'SemiconIndia' conference. Nevertheless, the Dutch Embassy in India and Indian Embassy in the Netherlands must ponder why the Netherlands' foremost semiconductor industry organisation, Holland Semiconductors,[155] or any of its partner industry bodies, participate in this conference or even in other activities of the India Semiconductor Mission. Thoroughly knowing the Dutch semiconductor ecosystem's strengths, the Indian ecosystem's potential and the strong India–Netherlands bilateral trade, the #StartUpLink has also not initiated a dedicated programme for nurturing semiconductor start-ups. Overall, there is tremendous untapped potential in the India–Netherlands semiconductor partnership, which is going unused because of limited interactions between their start-ups and MSMEs.

Protectionist tendencies in the European Union and the United States impede the Dutch industry's expansion into new and strengthening semiconductor manufacturing markets such as India. A low degree of business relations in India will likely make protectionist tendencies effective. On the other hand, more comprehensive bilateral semiconductor businesses and stakes in each other's MSMEs and start-ups are likely to deter such tendencies. Indian and Dutch semiconductor ecosystems must explore newer business opportunities, build new and resilient supply chains, and create a solid bilateral niche within the global semiconductor industry. The already strong Indo-Dutch trading relations should be leveraged further.

[155] Holland Semiconductors, 'Internationalisation', accessed 25 December 2022, https://hollandsemiconductors.nl/.

Japan

Alexandre F. Gomes (Institute for International Relations 'Clingendael') and Maaike Okano-Heijmans (Institute for International Relations 'Clingendael')

Since its creation in the 1960s to today, the Japanese semiconductor industry has gone from a gradually rising industry to global leadership, into decline and – most recently – towards renewed growth. The Japanese government has played a significant role in each of these phases, both through domestic industrial policies for growth and through concessions to the United States that led to the sector's decline. Today, Japanese government involvement is largely driven by economic security concerns and, more specifically, by a desire to ensure the secure and stable supply of semiconductors and the materials needed for their production. The Japanese government has labelled semiconductors as a critical component for the development of new leading-edge technologies.

This chapter presents the state of play and latest trends of the Japanese semiconductor industry, as well as key government policies. It reflects on implications for the Dutch semiconductor sector and government, and highlights opportunities and challenges for collaboration. The analysis suggests that the Netherlands and Europe can learn from Japan's clarity about strategic objectives, which serves as a powerful driver for Japanese stakeholders in the semiconductor sector and beyond to act proactively and jointly.

A brief history

In the late 1980s, Japan was the world leader in the semiconductor industry, transcending American firms in both the quality of chips and size of its industry. This was the result of almost three decades of gradual rise of the sector, facilitated by the Japanese government's effort and money, as well as considerable investments by major industry players at the beginning of the 1970s. In 1980, the general manager of one of the United States' biggest information technology companies Hewlett-Packard, Richard W. Anderson, shook the American industry by saying that the best American chips had a failure rate more than ten times higher than that of Japanese firms. By 1986, Japan surpassed the United States as the biggest semiconductor supplier in the world, to reach its peak in 1988, with over 50 per cent of the global market share.[156]

[156] William Sposato, 'Japan Bets Big on Bringing Semiconductor Manufacturing Home', *Foreign Policy*, 9 January 2023, last accessed 30/01/2023, https://foreignpolicy.com/2023/01/09/japan-semiconductor-chip-manufacturing-china/.

The US and Japan Semiconductor Agreement of 1986 heralded the fall of the Japanese semiconductor sector. The agreement followed years of US–Japan trade friction, which had erupted as US policymakers and industry players came to see Japan as an unfair competitor, claiming that Tokyo subsidised exports of chips and consumer electronics and based its growth on unfair trade practices. US policymakers thus acted upon the threat of having its own semiconductor industry disappear. Afraid of losing access to the important US market, Japanese government officials succumbed to the agreement, which would ultimately be responsible for the decline of its semiconductor industry. Furthermore, the Japanese industry failed to move from vertical integration to horizontal firms, specialised in particular aspects of the supply chain. In the years that followed, Japan's market share gradually declined to a global market share of below 10 per cent today,[157] with a market worth of approximately 595 billion USD in 2021.[158]

Semiconductors are of vital importance for Japan's manufacturing, automotive and electronics industries, and for achieving the government's vision of a green and digital Society 5.0 more broadly.[159] This also explains why the Japanese government labelled semiconductors as a 'critical component for the development of new leading-edge technologies'.[160]

Facing this reality, and with the growing geopolitical and supply chain challenges that have emerged over recent years, the Japanese government has tried to reinvest and relaunch the industry since the 2000s, without success. Recently, it placed semiconductors back at the core of its industrial policy, with a dedicated national strategy to revamp the industry being presented in June 2021. The Japanese government now considers the semiconductor industry to be within the realm of economic and national security.

1. The role of government

Economic security as a driver of government involvement

Japan's industrial policies in the initial growth period of the semiconductor industry revolved mainly around funding for R&D. This fostered public–private technology research cooperation and information-sharing between rival companies that nurtured innovation. A key initiative was the

[157] US International Trade Administration, 'Japan - Country Commercial Guide', last accessed 30 January 2023, https://www.trade.gov/country-commercial-guides/japan-semiconductors.
[158] Gartner Press Release, 'Gartner Says Worldwide Semiconductor Revenue Grew 26% in 2021', *Gartner*, last accessed 30 January 2023, https://www.gartner.com/en/newsroom/press-releases/2022-04-14-gartner-says-worldwide-semiconductor-revenue-grew-26-percent-in-2021.
[159] Society 5.0 is an aspirational model for a human-centred Japanese society, which 'balances economic advancement with the resolution of social problems by a system that highly integrates cyberspace and physical space'. See: https://www8.cao.go.jp/cstp/english/society5_0/index.html.
[160] Tim Kelly and Elaine Lies, 'Japan to invest $500 million to manufacture advanced chips', *Euronews*, last accessed 30 January 2023, https://www.euronews.com/next/2022/11/11/japan-semiconductors.

establishment of the Very Large-Scale Integrated (VLSI) project, a research consortium that ran from 1976 until 1980.[161] Fujitsu, Hitachi, Mitsubishi Electric, NEC and Toshiba were the associated companies that had a playground to cooperate in R&D projects, with about half of the funds coming from the Japanese government. Perhaps the most notable result was the creation of the electron beam lithography (EBL) technique, which fundamentally changed the ability to manufacture chips at scale.

As Japanese enterprises failed to move from vertical integration to horizontal business models in the 1990s and early 2000s, the Japanese government sought to push the industry in that direction in several ways. Among its initiatives was the replication of the VLSI model to convince companies to work together on specialised products, such as the creation of smaller and more advanced semiconductors. These initiatives ultimately failed, in part because of the lack of private capital to invest in R&D.

Government involvement was revamped only in the early 2020s. Japan's Ministry of Economy, Trade and Industry (METI) released a new National Strategy for Semiconductors and the Digital Industry[162] in 2021. This strategy considers the semiconductor industry to be a matter of economic and national security, alongside energy and food. The new government of Prime Minister Fumio Kishida that took office in October 2021 put economic security at the centre of its agenda. As evidenced also by the 2022 Economic Security Promotion Bill, Japan is committed to supporting and investing in the semiconductor sector in order to revive and strengthen it.[163]

Towards strategic autonomy and strategic indispensability

Japan's semiconductor strategy acknowledges the ongoing conflict between the United States and China for 'technological hegemony'. Set against that backdrop, the Japanese government established the goals of achieving: (1) strategic autonomy; and (2) strategic indispensability.[164] Strategic autonomy relates to the ability to reduce vulnerabilities in key infrastructures and supply chains, while strategic indispensability is about improving technology and industrial competitiveness by strengthening R&D, as well as preventing technology leaks. The combination of the two goals cements the importance given by the Japanese government to playing a greater role in the global supply chain.

[161] Hideki Uno, 'Japan's Semiconductor Industrial Policy from the 1970s to Today', *Center for Strategic & International* Studies, last accessed 30 January 2023, https://www.csis.org/blogs/perspectives-innovation/japans-semiconductor-industrial-policy-1970s-today.
[162] Ministry of Economy of Trade and Innovation, 'The Strategy for Semiconductors and the Digital Industry (Summary)', 4 June 2021, last accessed 30 January 2023, https://www.meti.go.jp/english/press/2021/pdf/0604_005a.pdf.
[163] Minister Yasutoshi Nishimura, 'Press Conference by Minister Nishimura (Excerpt)', last accessed 30 January 2023, https://www.meti.go.jp/english/speeches/press_conferences/2022/1014001.html.
[164] Amari Akira and Tanaka Akihiko, 'The Urgent Need to Establish 'Strategic Autonomy' and 'Strategic Indispensability': economic security strategy for a digital transformation society', last accessed 30 January 2023, https://www.japanpolicyforum.jp/diplomacy/pt20211013080925116 42.html. The official translation of the strategy refers to being 'strategically independent' and 'strategically essential'. In this chapter, for clarity of all readers, we use respectively 'strategic autonomy' and 'strategic indispensability', which is the most commonly used terminology in literature.

The pillar of strategic autonomy includes two key elements. First, to bring more production onshore, since Japan currently imports more than 60 per cent of its semiconductors.[165] The path to meet that goal includes 'establishing joint-venture factories with overseas foundries'. As elaborated below, Taiwan's TSMC plays a key role herein. Furthermore, the Japanese government is also looking for chances to collaborate with trusted foreign partners to strengthen its supply chain of rare-earth materials. Key objectives are to find innovative solutions to diversify this supply chain, and to invest in R&D to develop new materials in laboratories, which could help to reduce dependency on the outside. Japan currently depends on China for about 60 per cent of the rare-earth materials it uses.[166]

The second pillar of Japan's semiconductor strategy is that of strategic indispensability. This includes the 'identification of targets and leaders' in different areas of semiconductor specialisation, with the aim to enable further focus and differentiation within the overall supply chain, namely in the fields of memory, sensors, power and microcomputers.[167] The Japanese government also prioritises the ability to produce more high-end chips, since the production of chips smaller than 40nm is currently very limited. This move will require extensive investments in upgrading domestic foundries, as well as working with international trusted partners to work on next-generation microchips.[168]

Japan's vision for Society 5.0

The 2021 Japanese National Strategy for Semiconductors not only has a national security outlook. Overarching it is the fact that the Japanese government wants the semiconductor industry to support, design and develop more and more solutions tailored for the twin transitions of digital and green. These, in turn, are logical major levers to realise Society 5.0, a blueprint released by the Japanese government in December 2015 that presents an aspirational model for society that Japan should pursue. It ought to be a human-centered 'super-smart society', beyond the information age, where the innovations of the fourth industrial revolution are fully integrated and used in favour of the people and industry, in a sustainable manner.[169] The government wants Japan to be relatively independent when it comes to supporting businesses to develop the technologies and applications that 5G, AI and quantum computing are expected to bring about, or green-related technologies and products like electric

[165] Takashi Tsuji, Tomohiro Ebuchi and Kosuke Takeuch, 'Japan puts all chips on the table to lure semiconductor makers', *Nikkei*, 3 June 2021, last accessed 30 January 2023, https://asia.nikkei.com/Business/Tech/Semiconductors/Japan-puts-all-chips-on-the-table-to-lure-semiconductor-makers.
[166] Ministry of Economy of Trade and Innovation, 'Japan's new international resource strategy to secure rare metals', 31 July 2020, last accessed 30 January 2023, https://www.enecho.meti.go.jp/en/category/special/article/detail_158.html.
[167] Ministry of Economy of Trade and Innovation, 'The Strategy for Semiconductors and the Digital Industry (Summary)', 4 June 2021, last accessed 30 January 2023, https://www.meti.go.jp/english/press/2021/pdf/0604_005a.pdf.
[168] Mariko Togashi, 'Japan prioritises semiconductor industry in bid to enhance economic security', 30 March 2022, last accessed 30 January 2023, https://www.iiss.org/blogs/analysis/2022/03/japan-prioritises-semiconductor-industry-in-bid-to-enhance-economic-security.
[169] The Government of Japan, 'Realising Society 5.0', last update June 2020, last accessed 30 January 2023, https://www.japan.go.jp/abenomics/_userdata/abenomics/pdf/society_5.0.pdf.

vehicles or clean sources of energy. Having a clean supply chain of chips, free of disruptions and external threats, is regarded as central for achieving this.

METI has several funds and mechanisms to support the implementation of this strategy, including funds from the annual budget of the New Energy and Industrial Technology Development Organisation (NEDO), which were 1.3 billion USD in 2022, and from the 16.3 billion USD Green Innovation fund, among others.[170] The Japanese government's political commitment is clear, for it has gone as far as to state that it is available for 'establishing a system for special measures to treat them [strategic digital industry sectors] beyond normal industrial policy'.[171]

Rapidus

A major step in Japan's semiconductor industrial policy came with the launch in November 2022 of the Rapidus Corporation. Supported by roughly 485 million USD in subsidies, Rapidus (Latin for 'speed') brings together a group of companies to drive Japan's revival into semiconductor supremacy – and to strengthen the country's strategic autonomy as well as strategic indispensability. The new semiconductor producer includes eight major Japanese players: Toyota; Sony; Kioxia; NEC; Tokyo Electron; Denso; NTT; and SoftBank. The US giant IBM, whose research on 2-nanometre (nm) technology will be used by the consortium, will also be part of the project.[172] Strikingly, the consortium thus includes both players in the semiconductor industry itself, as well as key buyers of the chips: Japan's key manufacturers of automotive, electronics and telecommunications equipment.

This venture aims to produce 2nm chips domestically by 2027. This is an ambitious objective, since the market leaders TSMC and Samsung are aiming to produce chips of the same range only by 2025.[173] Table 1 below shows the scope of the players involved.

[170] Ministry of Economy of Trade and Innovation, 'Basic Policies for Green Innovation Fund (Summary)', 12 March 2021, last accessed 30 January 2023, https://www.meti.go.jp/english/press/2021/pdf/0312_002a.pdf.
[171] Ministry of Economy of Trade and Innovation, 'The Strategy for Semiconductors and the Digital Industry (Summary)', 4 June 2021, last accessed 30 January 2023, https://www.meti.go.jp/english/press/2021/pdf/0604_005a.pdf.
[172] IBM Newsroom, 'IBM and Rapidus Form Strategic Partnership to Build Advanced Semiconductor Technology and Ecosystem in Japan', 12 December 2022, last accessed 30 January 2023, https://newsroom.ibm.com/2022-12-12-IBM-and-Rapidus-Form-Strategic-Partnership-to-Build-Advanced-Semiconductor-Technology-and-Ecosystem-in-Japan.
[173] Marco Vlot, 'Japan zet vol in op ontwikkeling geavanceerde halfgeleiders', *Het Financieele Dagblad*, 11 November 2022, last accessed 30 January 2023, https://fd.nl/bedrijfsleven/1457656/japanse-zet-vol-in-op-ontwikkeling-geavanceerde-halfgeleiders-onk2ca8sg0yw.

Table 1: Companies that are part of Rapidus

Automotive	Telecommunications	Technology and Electronics	Others
Toyota	NTT	Sony	Kioxia (memory)
Denso	SoftBank	NEC	MUFG (banking)

One key difference with earlier efforts by the Japanese government to boost the semiconductor sector is the engagement also with foreign companies. Whereas earlier efforts were 'Japan-only', Rapidus partners with foreign companies. Besides IBM, the Belgian R&D organisation Imec has set up a strategic partnership to research beyond 2nm technologies in Japan.[174] Ties with Dutch semiconductor giant ASML are likely to be informal, although the Dutch company is expected to be engaged as Rapidus' supplier.

Promoting technological development and stimulating innovation

While Japan's METI is in charge of guiding, making policy and monitoring the progress of Japan's semiconductor industry strategy, two national agencies stand out in helping the industry to implement that strategy. First, the New Energy and Industrial Technology Development Organisation (NEDO) is a national agency responsible for promoting technological development and stimulating innovation. NEDO bridges the gap between Japan's national government, including METI, and the private sector, universities and public research institutes. It allocates funding and supports with project management and planning, and informs the government about progress made in the industry, allowing for well-informed policymaking by the METI.

Another agency that is relevant to Japan's semiconductor industry is the National Institute of Advanced Industrial Science and Technology (AIST). Since its creation in 2001, the AIST seeks to support the creation and development of technologies that may be useful to society at large, and to close the gap between research and industrialisation by creating consortiums around specific themes. In 2021, the AIST set up a consortium with Tokyo Electron, SCREEN and Canon to develop semiconductor equipment. Several other companies, including Intel and TSMC, as well as universities, are sponsoring or have access to the results of the pilot project. Also sponsored by the AIST is the Japan 3D IC R&D Centre,[175]

[174] Imec Press Release, 'Imec and Rapidus sign Memorandum of Cooperation to collaborate on advanced semiconductor technology', *Imec*, 6 December 2022, last accessed 30 January 2023, https://www.imec-int.com/en/press/imec-and-rapidus-sign-memorandum-cooperation-collaborate-advanced-semiconductor-technologies.

[175] TSMC, 'TSMC Japan 3DIC R&D Center Completes Clean Room Construction in AIST Tsukuba Center', 24 June 2022, last accessed 30 January 2023, https://pr.tsmc.com/system/files/newspdf/attachment/43c4fd19dc5cdd233b76395ad558ee56950651b6/0624_TSMC%20Japan%203DIC%20RD%20Center%20Completes%20Clean%20Room_%28E%29_final_wmn.pdf.

where TSMC will work with local companies and partners to develop new packaging techniques. Launched in March 2021 and opened in June 2022, in the Tsukuba Centre of the AIST, it will be used to explore three-dimensional packaging of integrated circuits (composed by semiconductors and peripheral circuits).

2. Overview of the industry in Japan

Today's competitive disadvantage of Japan's semiconductor industry *vis-à-vis* Taiwanese, Korean, Chinese or US firms triggered not only the recent push in terms of public and private investment, but also in strategic partnerships within Japan and abroad. Factories and plants need to be revamped to meet state-of-the-art standards, knowledge needs to be updated and captured from abroad, and funds need to be channelled to achieve a broad improvement.

The fact that the semiconductor industry has been placed at the heart of the Japanese economic security agenda pressures Japan's industry to perform and deliver quick results. At the same time, it means that public funds and, eventually, a more beneficial legislative framework may be made available for the industry to achieve progress that would otherwise be impossible to accomplish. Japan's funding seems small, however, in comparison to that of other countries. The US Chips Act provisions about 280 billion USD over the coming ten years, while South Korea's figure is about 260 billion USD, and the European Chips Act allocates 43 billion euros to the semiconductor industry until 2030. So far, the numbers put forward by the Japanese government in concrete projects have not surpassed 10 billion USD.

To summarise, the Japanese semiconductor industry benefits from three favourable conditions. First, the political and economic support offered by the Japanese government makes it easier for industry players to apply for funds that can help to achieve their goals. Second, the openness of both Japanese government and industry leaders to learn from and build meaningful relationships with companies from other countries may work as an accelerator of knowledge transfer. Third, Japan can draw inspiration from the VLSI project, which helped the country climb the industry's ladder 40 years ago.

Key players in the industry

The segment of the semiconductor industry that is of particular interest to the Netherlands in relation to Japan is lithography, where the Dutch firm ASML is a world leader thanks to its monopoly on extreme ultraviolet (EUV) machines. By the mid-1990s, Japan's Canon and Nikon together had almost three-quarters of global market share, 45 per cent and 25 per cent, respectively. However, these Japanese companies would be overtaken by ASML, which was founded in 1984 but by 1995 had a global market

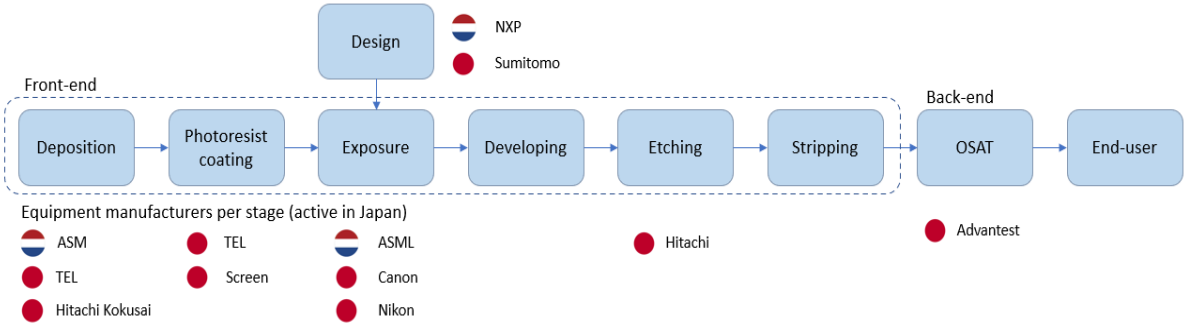
share of 25 per cent. By 2002, that number had risen already to 50 per cent of global market share.[176] ASML has made huge leaps forward with TwinScan and immersion lithography since then, and in 2010 it started selling EUV machines – which are by far the most advanced in the market and solely sold by ASML. In Japan, ASML has seven offices with more than 250 employees focused on customer service and support, responsible for delivering, installing and maintaining the lithography machines for more than ten clients.

Canon is trying to leapfrog with a new technology called nano-imprinting lithography, which could, at least in theory, compete with ASML's EUV machines. Canon is now building a 345 million USD lithography equipment plant in Tochigi prefecture, Japan, to start operating in 2025.[177] This will be the first such plant built in Japan in over 20 years and, with it, Canon is aiming to double its current production capacity with deep ultraviolet (DUV) machines and to research nano-imprinting lithography. Kioxia and Dai Nippon Printing are supporting Canon in this development. Importantly also for Japan's green ambitions, with this new imprinting technology, Canon expects to reduce manufacturing costs by 40 per cent and power consumption by about 90 per cent in comparison to EUV technology. If successful, Canon may be able to reduce ASML's current strategic advantage of possessing EUV machines.

In addition to ASML, two other big Dutch companies have customer support offices in Japan: ASM International (ASMI); and NXP. ASMI works in wafer-processing technology, including single-wafer epitaxy and atomic layer deposition (ALD), and is among the market leaders in the latter. It has five offices in Japan to support its clients. In Japan, ASMI faces competition from Tokyo Electron (also known as TEL) and Hitachi Kokusai, besides the US firms Applied Materials and LAM Research. The other big Dutch company, NXP, operates in the global radiofrequency market, especially focused on the automotive industry, as well as in defence and communications applications and near-field communication (NFC) chips. NXP's main competitors are the Japanese firm Sumitomo Electric Devices Innovations and the US company Advanced Materials. Meanwhile, BESI, another important Dutch player, operates at the other end of the supply chain, namely on assembly and packaging technology. Its main competitors are ASM Pacific Technology (Hong Kong) and Kulicke & Soffa (a US company based in Singapore), but BESI has no presence in Japan yet. Figure 2 below presents the main Dutch and Japanese players in the industry.

[176] ASML Press Release, 'ASML named world leader in stepper market', 1 May 2003, last accessed 30 January 2023, https://www.asml.com/en/news/press-releases/2003/asml-named-world-leader-in-stepper-market.
[177] Nikkei, 'Canon to build $345m plant for chipmaking equipment in Japan', *Nikkei*, 4 October 2022, last accessed 30 January 2023, https://asia.nikkei.com/Business/Tech/Semiconductors/Canon-to-build-345m-plant-for-chipmaking-equipment-in-Japan.

Figure 2: Biggest Dutch companies operating in Japan and their main competitors



Source: authors' compilation

The presence of ASML, ASMI and NXP is well-recognised in Japan, and places the Netherlands as a reference point for the Japanese industry. Furthermore, there is an ecosystem of Dutch companies working with Japanese counterparts, both on their own and via the three aforementioned big companies. While these bigger companies have been well established in Japan for several years and are comfortable with the business environment, small and medium-sized enterprises normally need support from the local Dutch Embassy and from the Dutch Innovation Attachés' network, in order to have a smoother entry in the Japanese market.

As well as industry connections, research collaboration exists between Japanese and Dutch organisations. For example, the Dutch independent research organisation of applied science, TNO, has links with its Japanese counterpart, AIST. Moreover, several Dutch and Japanese universities cooperate with each other, including the Tokyo Institute of Technology and the Universities of Kyoto, Osaka and Nagoya in Japan, as well as the Dutch Technical University of Delft and Leiden University.

3. Japan's international positioning and connections

Japan's 2022 National Security Strategy labels China as the 'the greatest strategic challenge in ensuring the peace and security' of Japan and of the international community.[178] Clearly, Japan aligns much more with many of the United States' and European Union's values and the United States and Taiwan are highest on the list of foreign partners with which Japan wants to cooperate.[179]

[178] The Government of Japan, 'National Security Strategy of Japan (Provisional Translation)', December 2022, last accessed 30 January 2023, https://www.cas.go.jp/jp/siryou/221216anzenhoshou/nss-e.pdf.
[179] Ko Fujioka And Ryuto Imao, 'Japan to spend $2.4bn on joint chip research hub with U.S'., *Nikkei*, 6 November 2022, last accessed 30 January 2022, https://asia.nikkei.com/Business/Electronics/Japan-to-spend-2.4bn-on-joint-chip-research-hub-with-U.S.

Japan and the Netherlands have been caught in the great-power competition between the United States and China. American officials have placed pressure on both Japan and the Netherlands to limit sectorial exports to China, both in terms of material and knowledge.[180] The position both countries hold by leading the global market in lithography machines, which ultimately hold the key to unlocking the potential to manufacture chips at even greater scale, with lower costs and higher precision, has made US Presidents and high officials intervene regularly over the past few years. In 2018, the Trump administration began a campaign with ASML and the Dutch government to limit exports of lithography machines to China.[181] More recently, since new export controls were put in place in the United States in October 2022, US representatives have repeatedly asked their allies to follow suit.[182]

Relations with countries in the region

Japan cooperates with partners and allies in several multilateral and bilateral fora. Within the Quadrilateral Security Dialogue (also known as the Quad), Japan engages with the United States, India and Australia. Primarily driven by military cooperation, this forum – initiated in 2007 by then Japanese Prime Minister Shinzo Abe – shows Japan's eagerness to cooperate with these countries. India and Australia, in particular, share a common understanding with Japan of the position of China in the Indo-Pacific and the threats and opportunities associated therein. This common view is further put in practice by another forum proposed by Japan and including the three countries: the Supply Chain Resilience Initiative (SCRI). Launched in April 2021, the SCRI seeks to enhance their collaboration in face of the geopolitical tensions growing in the region and the need to balance Chinese power, a concern that grew in the face of overdependency on China during the COVID-19 pandemic. Japan has also held 2+2 Ministerial Dialogues with the three other members of the Quad.

Led by the United States, the Indo-Pacific Economic Framework (IPEF) was launched in May 2022 in Tokyo, to further engage the United States with countries in the region. Japanese Prime Minister Kishida's in-person attendance signalled the Japanese government's political support for the initiative. Among the key themes to be addressed in this forum are supply-chain security and clean energy, decarbonisation and infrastructure, intrinsically linked to the availability of semiconductors.[183] Besides

[180] Rintaro Tobita, 'US calls out Japan and Netherlands over China chip curbs', *Nikkei*, 6 November 2022, last accessed 30 January 2023, https://asia.nikkei.com/Business/Electronics/U.S.-calls-out-Japan-and-Netherlands-over-China-chip-curbs.
[181] Alexandra Alper, Toby Sterling and Stephen Nellis, 'Trump administration pressed Dutch hard to cancel China chip-equipment sale', *Reuters*, 6 January 2020, last accessed 30 January 2023, https://www.reuters.com/article/us-asml-holding-usa-china-insight-idUSKBN1Z50HN.
[182] Reuters, 'US consults with Japan, Netherlands on chip restrictions as China pushes back', *Reuters,* 13 December 2022, last accessed 30 January 2023, https://www.reuters.com/technology/japan-netherlands-join-us-china-chip-curbs-bloomberg-news-2022-12-12/.
[183] Office of the United States Trade Representative, 'Indo-Pacific Economic Framework for Prosperity (IPEF)', last accessed 30 January 2023, https://ustr.gov/trade-agreements/agreements-under-negotiation/indo-pacific-economic-framework-prosperity-ipef.

the Quad members, other countries in the region, such as Malaysia, New Zealand, Vietnam and South Korea, are also involved.

Historically, Japan's relationship with South Korea has not been particularly smooth. South Korea benefited greatly from the 1986 US–Japan Semiconductors Agreement, which allowed it to surpass Japan in the production of, among others, DRAM components, in which it currently holds a global market share above 70 per cent.[184] In July 2019, Japan's export controls on three chemicals used to manufacture semiconductors and display screens shook the relationship between the two countries further. This decision was a response to a South Korean court's decision to request reparations from Japanese companies that had used South Korean forced labour during the Second World War.[185] Nonetheless, the geopolitical context may create the conditions to enhance cooperation between the two countries, namely in the face of the security concerns that both countries share in relation to China and North Korea. A South Korean government that is more open to cooperating with Japan, particularly in the fields of economic security, including semiconductors, took office in May 2022, which may help to improve the bilateral relationship.[186]

Another related thematic forum, which was proposed by the United States in March 2022, is the Chip 4 Alliance that also includes Japan, South Korea and Taiwan. Its goal is to increase self-sufficient semiconductor supply chains among these four countries. The selection of countries has strategic reasoning: together, they cover all the major areas of the semiconductor value chain, from design to chip production, testing, assembly and packaging. However, it is still unclear whether this forum will succeed in its objectives, because of the three Asian countries' reluctance to collaborate. First, for historical reasons Japan and South Korea may not wish to enter into this cooperation. Furthermore, both countries are reluctant to be included in the same alliance as Taiwan, as they fear China may interpret the partnership as a challenge to its 'One China' policy and regional tensions arise as a consequence. Finally, since China is the three Asian countries' leading trading partner, it is still unclear whether they are willing to risk their commercial relationships.[187]

[184] Invest Korea, 'No. 1 Memory Semiconductor Industry in the World, Second Largest Semiconductor Producing Country', last accessed 30 January 2023, https://www.investkorea.org/ik-en/cntnts/i-312/web.do#:~:text=Korea's%20global%20semiconductor%20market%20share,%25%20and%20NAND%20at%2044.9%25.
[185] CNBC, 'South Korea downgrades Japan trade status as dispute deepens', *CNBC*, last accessed 30 January 2023, https://www.cnbc.com/2019/09/18/south-korea-downgrades-japan-trade-status-as-dispute-deepens.html.
[186] Gyu-Pan Kim, 'Japan's Semiconductor Strategy and Implications for Korea', *Korea Institute for International Economic Policy*, 1 September 2022, last accessed 30 January 2023, https://www.kiep.go.kr/gallery.es?mid=a20308000000&bid=0008&list_no=10310&act=view.
[187] *Financial Times*, 'US struggles to mobilise its East Asian "Chip 4" alliance', *Financial* Times, last accessed 30 January 2023, https://www.ft.com/content/98f22615-ee7e-4431-ab98-fb6e3f9de032.

Regarding Taiwan, one of the legacies of Shinzo Abe was the transformation of Japanese ties with the island.[188] Japan is currently dedicated to improving its relationship further, including by capturing foreign direct investment from TSMC to achieve its aim of strategic autonomy. In 2022, TSMC was invited to build a semiconductor plant in Kumamoto, Japan. Japan's METI will subsidise this undertaking with an estimated sum of 3.5 billion USD, corresponding to about 40 per cent of the total estimated cost of 8.5 billion USD.[189] A joint venture called Japan Advanced Semiconductor Manufacturing (JASM), led by the Taiwanese company in which Sony and Denso also participate, has been formed to carry out the project.[190] In line with its strategy to have valuable international partnerships, Japan is wanting to learn from Taiwanese companies.

The only country in the region where collaboration with Japan is not to be expected is China. Although reluctantly, the Japanese government aligned in January 2023 with the export controls mechanism imposed by the United States on China in October 2022.[191] Although the relationship between Japan and China has been troublesome, also because of geopolitical disagreements and territorial disputes in the East China Sea, both countries do have a strong mutual economic dependency. China is both the biggest importer from and exporter to Japan, and Japan largely relies on China for rare-earth materials, which are vital for the semiconductor industry. In 2010, Japan imported more than 80 per cent of its rare-earth materials from China, a figure reduced to about 60 per cent in 2019 and targeted to decrease to below 50 per cent in 2025.[192]

Japan's biggest strengths in the semiconductor supply chain reside in the production of silicon wafers, manufacturing equipment and advanced material fields. First, Shin-Etsu Chemical and Sumco lead in the global market of silicon wafer production, where Japan holds more than 50 per cent of global market share. Second, Japan has about 75 per cent of global market share in producing equipment for wafers, handling and marking, above 40 per cent in etching and cleaning, and about 50 per cent in testing. When it comes to advanced materials, Japanese companies hold up to 90 per cent market share in both photoresist and special chemicals, about 70 per cent in etching gasses and above 50 per cent in photomask. Japan stands out, therefore, as a key player in the global semiconductor supply

[188] David Sacks, 'Shinzo Abe Transformed Japan's Relationship With Taiwan to Counter Threats from China', 13 July 2022, last accessed 30 January 2023, https://www.cfr.org/blog/shinzo-abe-transformed-japans-relationship-taiwan-counter-threats-china.
[189] Nikkei, 'Japan to subsidise TSMC's Kumamoto plant by up to $3.5bn', *Nikkei,* 17 June 2022, last accessed 30 January 2023, https://asia.nikkei.com/Business/Tech/Semiconductors/Japan-to-subsidise-TSMC-s-Kumamoto-plant-by-up-to-3.5bn.
[190] Nikkei, 'Japan to subsidise TSMC's Kumamoto plant by up to $3.5bn', *Nikkei,* 17 June 2022, last accessed 30 January 2023, https://asia.nikkei.com/Business/Tech/Semiconductors/TSMC-lifts-Japan-chip-plant-investment-with-Denso-following-Sony.
[191] Nikkei, 'US secures deal with Netherlands, Japan on China chip export limit: Bloomberg', *Nikkei,* 28 January 2023, last accessed 30 January 2023, https://asia.nikkei.com/Business/Tech/Semiconductors/U.S.-secures-deal-with-Netherlands-Japan-on-China-chip-export-limit-Bloomberg.
[192] Ryosuke Hanafusa, 'Japan to pour investment into non-China rare-earth projects', *Nikkei*, 15 February 2020, last accessed 30 January 2023, https://asia.nikkei.com/Politics/International-relations/Japan-to-pour-investment-into-non-China-rare-earth-projects.

chain. As such, Japanese exports in the sector are mostly consumed by the four greatest powerhouses on semiconductor development and end-user and commercial devices production: the United States; Taiwan; China; and South Korea.

4. Implications for the Netherlands

In the Netherlands, innovation and business have been left to the market, in a typical bottom–up approach where the government does not interfere. Japan, on the other hand, is known for its strategic partnerships between public and private sectors, including between competitors in specific sectors, to meet specific national goals. The current times are pushing all governments into new territories, and perceptions on trade and industrial policy are changing. In Europe, the Netherlands induced a paradigm shift from free markets to more closed-economy thinking.[193] European Union (EU) member states aim for so-called open strategic autonomy and aim to identify and reduce one-sided strategic dependencies *vis-à-vis* unreliable partners, especially those outside the European framework of values.

Japan and the EU and its member states seem to be on the same page in their approach to China. This assessment is based on both their analysis of geopolitical risks, as well as the pressure imposed by the United States upon their governments to slow down China's progress on technology. In this context, the Netherlands can exchange best practices with Japan on how to promote Europe's own capabilities and competitiveness, namely by promoting R&D and innovation, building strong relationships between the public and private sectors, and creating consortia tailored to specific themes. As the Rapidus project shows, Japan is thinking strategically about how these consortia could be set up. Both the Japanese government and its private-sector actors see the urgency of acting together, also because they are closer to the heart of the US–China competition, and they are focusing on themes where they are strongest, such as automotive and electronics – thus including the partners that they think can best work together. In fact, one potential medium- or long-term consequence of the current focus in the semiconductor industry in Japan is the risk, even if very small, that the Japanese lithography industry may reduce its gap with the Dutch. The strategic investments made by the Japanese government may be the last opportunity for Nikon and Canon to catch up with ASML.

When it comes to collaboration between the Dutch and Japanese semiconductor industries, a characteristic to keep in mind is the lack of complementarity between them. The major Dutch semiconductor companies have offices in Japan to serve clients, as well as counterparts with which

[193] Maaike Okano-Heijmans, 'Open strategic autonomy: the digital dimension', *Clingendael*, 23 December 2023, last accesses 30 January 2023, https://www.clingendael.org/publication/open-strategic-autonomy-digital-dimension.

they compete, even if at different scales. The Netherlands should also work on finding new opportunities for its small and medium-sized enterprises working in the sector and wanting to invest in Japan. Furthermore, it is worth mentioning that the broad strategic goals are similar in both countries: the twin transitions of green and digital are background themes for both governments; and their allies and trusted partners are essentially the same. Another common theme with Japan – and if not in the Netherlands specifically, then at least in Europe at large – is demography. Japan has the oldest population in the world and needs quickly to step up digitalisation of the country, with which the Netherlands might help Japan.

Moreover, a broader presence of Dutch companies in the Japanese market might be a means for them to establish meaningful business relationships and to learn more in technology fields led by Japan, such as photonics, sensors and power chips (used for industrial equipment and in the automotive sector). Furthermore, Japan can help the Netherlands with technology transfer, and in valorising research – that is, turning research into products that can be commercialised, something that the Dutch often fail to do. Finally, and most importantly, in order to push all these agendas, more bilateral involvement between both governments is required, since both countries are already well connected at the business level. The December 2022 SEMICON conference in Tokyo is a good example of this business-level connection: the Netherlands was represented by twelve companies – compared to three from Germany and one from the Czech Republic – three times as many as at the 2021 conference.

The Japanese government is investing heavily in semiconductors, because they are considered of paramount importance to Japan's economic security. Japan's actions are the logical outcome of a vision of what the government wants future society to look like: so-called 'Society 5.0'. By coherently placing its main industries – such as automotive, robotics and electronics – at the centre of this approach, Japan is seeking to achieve a diversity of policy objectives: securing earning potential; contributing to the digital and green transitions; and responding to its social and demographic challenges. In short, Japan is actively pursuing its goal to live in the Society 5.0 to which it aspires. This clarity about strategic objectives is the primary driver for Japanese stakeholders to act proactively and jointly. The EU and the Netherlands should also invest in such strategic clarity, which can deliver better policies at home and jointly with partners, including Japan.

Singapore

Sense Hofstede (University Lecturer, Leiden University)

Singapore's government has stressed the importance of light manufacturing with a strong electronics component ever since the current ruling party came to power shortly before the city-state's independence in 1965. The development plans of the legendary minister Goh Keng Swee and United Nations (UN) advisor Albert Winsemius already laid the groundwork for the further development of Singapore's manufacturing industry. The first semiconductor firms began offshoring production from the United States right from the start of the industry. Singapore was already one of their destinations in the 1960s.

Dutch presence has also always been there. Just as Philips featured in Winsemius's early plans, so the company played a role in expanding semiconductor manufacturing in Singapore. Today, the list of semiconductor industry companies with a presence in Singapore is a fairly comprehensive overview of the global industry. This is the result of conscious efforts by the city-state's government to attract foreign business. Goh and Winsemius's Economic Development Board (EDB) – itself originally inspired by Winsemius's directorate-general for industrialisation at the post-war Dutch Ministry of Economic Affairs – plays a central role in everything that occurs. [194]

Singapore maintains a foreign policy of neutrality that seeks balance by involving as many players as possible in the city-state. It is a member of the Non-Aligned Movement (NAM) and still claims developing-country status. This positions Singapore as a meeting place between different worlds as the technology war heats up, something that already busies the finance industry.[195] At the same time, Singapore has always maintained close security cooperation with the United States and the main semiconductor manufacturers in the city-state are American too. In the great-power technology struggle, Singapore serves as an interface to the OECD semiconductor chain for Chinese customers, more than as a base for Chinese manufacturers.

1. Government

Singapore's political system is a modified Westminster parliamentary system with regular elections that have no chance of changing the government. The press is expected to assume a constructive rather than a critical role. The current ruling People's Action Party (PAP) has been in power since 1959

[194] Frans Stoelinga, *Albert Winsemius: De man die Nederland en Singapore rijk maakte* (Amsterdam: Boom, 2021), p. 176.
[195] Leo Lewis, 'Singapore Is Well-Positioned to Play Both Sides of Decoupling', *Financial Times*, 24 November 2022, https://www.ft.com/content/269b1a53-dd66-4446-8da8-f54d39403bfc.

and the country attained independence in 1965. Economic policy is shaped by various long-term plans. Thanks to low tariffs and welcoming government agencies, Singapore has always been attractive to foreign companies.

The city-state's foreign policy aims to get as many countries and thus companies as possible to develop a stake in Singapore's welfare and continued independence. Domestically, Singapore's economy is dominated by government-linked companies (GLCs), many controlled by Temasek Holdings under Singapore's Ministry of Finance. The sovereign wealth fund GIC manages and invests the country's substantial reserves. Singapore's Ministry of Trade and Industry (MTI) and its Economic Development Board (EDB) play major roles in assisting and steering the development of industry.

Singapore's population of 5.5 million consists of only 3.5 million citizens. There are another 500,000 so-called 'permanent residents', foreign passport holders who have many rights and duties similar to those of citizens. The remaining 1.5 million residents are made up of foreign workers, students, dependents and 'talents'. The government's immigration policy aims to protect its own middle class through quotas, local hiring requirements, and by dividing immigrant labour into the two categories.

The foreign workers – sometimes referred to as guest workers – are heavily regulated and lowly paid labourers and domestic workers, who often stay in large dormitories on the edge of town. They help to keep Singapore's construction and manufacturing prices competitive.

At the higher end of the wage spectrum are the large numbers of 'foreign talents' or expatriates, who work in the increasingly hard-to-fill roles for technical and creative talent, as well as many of the managerial positions. It is the foreign talents who are the most vulnerable to middle-class unhappiness, which became clearest around the 2011 General Election.

Policy plans for the industry

Despite the large number of expatriates in management and the presence of many multinationals, the government ensures that they serve Singapore's goals through their reliance on government cooperation and subsidies, as well as the frequent need to work together with some of the many Temasek-owned GLCs that dominate the domestic economy.

Besides cheap foreign labour and the absence of a universal minimum wage, other ways in which Singapore's government keeps manufacturing affordable is through robotic automation to reduce

labour intensity, as well as cooperation between government, industry and vocational education to increase the productivity of workers.[196]

The JTC Corporation, a statutory board under Singapore's Ministry of Trade and Industry that was originally founded in 1968 to develop the Jurong industrial estate, is now used as one of the tools for Singapore's government to steer industry. JTC has four wafer fab parks, totalling 391 hectares. These are home to fourteen global semiconductor companies, but also serve smaller players.[197]

The EDB is the main driver behind industrial plans. The 'Semiconductor Vision 2020' taskforce was a cooperation between the EDB and various companies from the industry to coordinate efforts for next generation manufacturing.[198] The EDB's 'Manufacturing 2030' plan aims to grow Singapore's manufacturing sector by 50 per cent of its 2021 value of 106 billion Singapore dollars (SGD) (or 80 billion USD) by 2030, while remaining approximately 20 per cent of gross domestic product (GDP).[199]

The aim is 'to anchor frontier investments from global companies with specialised capabilities to support [Singapore's] local manufacturing ecosystem'.[200] This includes the semiconductor industry.

One part of the recently launched Refreshed Industry Transformation Maps concerns advanced manufacturing. The Singapore government's plans project that by 2025 there will be 70,700 jobs in electronics manufacturing, while reducing the industry's carbon footprint.[201]

Singapore is an example of a country that not just supports research and development and innovation (R&D&I), but also provides investment incentives in the form of tax concessions.[202] The EDB's plans for the semiconductor industry focus on providing grants and placing 'bigger bets' on improving five areas:[203]

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[196] James Lambert, 'Robots Have Made Singapore a Modern Manufacturing Success', *Nikkei Asia*, 24 October 2022, https://asia.nikkei.com/Opinion/Robots-have-made-Singapore-a-modern-manufacturing-success.
[197] Choo Yun Ting, 'How Has Singapore Been Cashing in on Semiconductor Chips', *The Straits Times*, 2 October 2022, https://www.straitstimes.com/tech/tech-news/how-has-singapore-been-cashing-in-on-semiconductor-chips.
[198] Alvin Tan, 'Speech by MOS Alvin Tan at SSIA Semiconductor Business Connect 2021', *Ministry of Trade and Industry, Singapore*, https://www.mti.gov.sg/Newsroom/Speeches/2021/07/Speech-by-MOS-Alvin-Tan-at-SSIA-Semiconductor-Business-Connect-2021.
[199] Singapore Economic Development Board, 'Singapore Seeking Frontier Firms for 'Manufacturing 2030'', Economic Development Board, Singapore, 2 February 2021, https://www.edb.gov.sg/en/business-insights/insights/singapore-seeking-frontier-firms-for-manufacturing-2030.html.
[200] Alvin Tan, 'Speech by MOS Alvin Tan at the SSIA Semiconductor Business Connect 2022', *Ministry of Trade and Industry, Singapore*, https://www.mti.gov.sg/Newsroom/Speeches/2022/05/Speech-by-MOS-Alvin-Tan-at-the-SSIA-Semiconductor-Business-Connect-2022.
[201] Elysia Tan, 'Investments into Semiconductor Centre, Industry Tie-Ups to Power Manufacturing Transformation', *The Business Times*, 18 October 2022, https://www.businesstimes.com.sg/government-economy/investments-into-semiconductor-centre-industry-tie-ups-to-power-manufacturing.
[202] OECD, 'Measuring Distortions in International Markets: The Semiconductor Value Chain', OECD Trade Policy Papers no. 234 (Paris: OECD Publishing, 12 December 2019), https://doi.org/10.1787/8fe4491d-en, p. 9.
[203] Singapore Economic Development Board, 'The Growth and Advancement of Singapore's Semiconductor Industry' (Singapore: SEMI, October 2021), https://www.semi.org/sites/semi.org/files/2021-10/The-Growth-and-Advancement-of-Singapores-Semiconductor-Industry.pdf.

1. Heterogenous integration;
2. Millimetre wave and beyond;
3. Novel architectures for edge AI;
4. Wide bandgap semiconductors;
5. Piezoelectric microelectromechanical systems (MEMS).

These plans are now being implemented. One example is the recent Singaporean government announcement of an initial investment of 85 million USD to set up a National Gallium Nitride Technology Centre over the next five years. This 'boutique foundry' will serve as 'a shared resource and translation centre'.[204] Research is an important part of the Singapore government's approach and is mostly organised under the Institute of Microelectronics, founded in 1991, which is part of the Agency for Science, Technology and Research (A*STAR).

In education, efforts are made by stakeholders both to educate the workforce and to upgrade their skills for the future. The Singapore Institute of Technology has signed a memorandum of understanding with American semiconductor supplier Applied Materials for continuing education and training. Coordination with industry associations, as well as vocational schools (known as Institutes of Technical Education or ITEs) and polytechnics, is meant to ensure training before and during careers.[205]

Singapore is not only important as a manufacturing location, but also sits at the critical transportation choke point of the Strait of Malacca, where raw materials[206] and finished goods pass through. The Singapore Armed Forces (SAF) are active in multilateral anti-piracy missions in the region, which help to ensure the safety of maritime traffic. The SAF's new fourth service – the Digital and Intelligence Service – is worth following. Singapore's Army has long-standing ties with Israel and all men are obliged to serve two years of National Service. Singapore might take inspiration from Israel's success in harnessing tech talent for its conscripted soldiers, who often begin start-ups once discharged.

Singapore is not a member of the export control regime the Wassenaar Arrangement. As a rule, it only joins sanctions mandated by the UN Security Council. Singapore's measures taken against Russia

[204] Elysia Tan, 'Investments into Semiconductor Centre, Industry Tie-Ups to Power Manufacturing Transformation', *The Business Times*, 18 October 2022, https://www.businesstimes.com.sg/government-economy/investments-into-semiconductor-centre-industry-tie-ups-to-power-manufacturing.
[205] Alvin Tan, 'Speech by MOS Alvin Tan at the SSIA Semiconductor Business Connect 2022', *Ministry of Trade and Industry, Singapore*, https://www.mti.gov.sg/Newsroom/Speeches/2022/05/Speech-by-MOS-Alvin-Tan-at-the-SSIA-Semiconductor-Business-Connect-2022.
[206] Joris Teer and Mattia Bertolini, *Threats to the Supply of Critical Raw Materials for Semiconductors* (The Hague: The Hague Centre for Strategic Studies, 2022).

following Russia's invasion of Ukraine in February 2022 are an exception. They include export controls on weapons and tools for offensive cyber operations.[207]

2. Overview of Singapore's local industry

Singapore was involved in overseas manufacturing right from the start,[208] although the situation has changed radically since then. It began with Singapore's first Prime Minister Lee Kuan Yew telling US President Richard Nixon that he needed exports to 'sop up unemployment' to prevent unrest as Singaporean government support brought in US firms Texas Instruments and National Semiconductors.[209] Now, the government's Refreshed Industry Transformation Maps call for robotisation as automation complements the use of highly productive locals and affordable foreign workers.

In 2021, manufacturing as a whole provided for 450,400 jobs in Singapore and produced 22 per cent of GDP.[210] Thanks to the above-mentioned robotisation plans, by now 60 per cent of the people working in manufacturing are highly skilled.[211] A substantial part of this is made up by the semiconductor industry. Semiconductors constituted 17 per cent of Singapore's exports in 2017.[212] In 2021, the semiconductor industry provided roughly 7 per cent of Singapore's GDP, making up 11 per cent of the global semiconductor market.[213]

Singapore is especially strong in semiconductor equipment manufacturing, of which it constitutes 20 per cent globally, and wafer capacity, of which it is 5 per cent.[214] The industry's focus in Singapore is assembly and testing, and non-edge manufacturing, with Singapore's proximity to Malaysia allowing companies to locate services and support for manufacturing there, nearby the easily accessible city-state.

Care must be taken, however, when interpreting the statistics. Beyond its small size and dependence on foreign trade causing big swings, Singapore's attractiveness as a welcoming and relatively neutral

[207] 'Sanctions and Restrictions against Russia in Response to Its Invasion of Ukraine', Ministry of Foreign Affairs of Singapore, 5 March 2022, https://www.mfa.gov.sg/Newsroom/Press-Statements-Transcripts-and-Photos/2022/03/20220305-sanctions.
[208] Chris Miller, *Chip War: The Fight for the World's Most Critical Technology* (London: Simon and Schuster, 2022), p. 54.
[209] Chris Miller, *Chip War: The Fight for the World's Most Critical Technology* (London: Simon and Schuster, 2022), p. 65.
[210] Ovais Subhani, 'S'pore Updates Industry Transformation Plans to Boost Production, Add 13,400 Jobs by 2025', *The Straits Times*, 18 October 2022, https://www.straitstimes.com/business/s-pore-updates-industry-transformation-plans-to-boost-production-add-13400-jobs-by-2025.
[211] James Lambert, 'Robots Have Made Singapore a Modern Manufacturing Success', *Nikkei Asia*, 24 October 2022, https://asia.nikkei.com/Opinion/Robots-have-made-Singapore-a-modern-manufacturing-success.
[212] Chris Miller, *Chip War: The Fight for the World's Most Critical Technology* (London: Simon and Schuster, 2022), p. 253.
[213] Choo Yun Ting, 'How Has Singapore Been Cashing in on Semiconductor Chips', *The Straits Times*, 2 October 2022, https://www.straitstimes.com/tech/tech-news/how-has-singapore-been-cashing-in-on-semiconductor-chips.
[214] Choo Yun Ting, 'How Has Singapore Been Cashing in on Semiconductor Chips', *The Straits Times*, 2 October 2022, https://www.straitstimes.com/tech/tech-news/how-has-singapore-been-cashing-in-on-semiconductor-chips.

place to headquarter companies can also lead to confusion in the data, as illustrated by the noise resulting from the fact that US company Broadcom was domiciled there until 2018.[215]

Singapore does not have any major semiconductor firms of its own. Singapore's attempt to create its own foundry, called Chartered Semiconductor and modelled after Taiwan's TSMC,[216] ended with its takeover by US firm GlobalFoundries in 2010.[217] Instead, Singapore is home to players from all around the world. The two big manufacturing firms active in Singapore are Micron and GlobalFoundries. Singapore's semiconductor manufacturing equipment (SME) exports are largely attributable to Applied Materials, ASM International and KLA Corporation.[218]

Manufacturers

Government subsidies help **Micron** maintain and expand its fabs in Singapore.[219] Singapore state support for Micron and **Qualcomm** is important.[220] Singapore is home to Micron's non-US operational headquarters and three factories, as well as a test and assembly facility, critical for producing its NAND flash memory chips.[221]

GlobalFoundries announced in 2021 that it would invest 4 billion USD [3.8 billion euros] to expand its Tuas factory from 750,000 wafers a year to 1.2 million wafers by Q1 2023 and 1.5 million wafers in 2024. Its Singapore fab produces about one-third of GlobalFoundries' global revenue. EDB partners with GlobalFoundries to support the investment[222] and Qualcomm is an important customer.

When it was still a division of Philips, Dutch manufacturer **NXP Semiconductors** entered a joint venture with **TSMC** and EDB Investments in 1998 to create the **Systems on Silicon Manufacturing Company** (SSMC), which was expanded in 2007 with an R&D centre to work on NXP's specialised chips with automotive, near-field communication (NFC) and RF functions, and their manufacturing processes.[223] NXP and TSMC are now the only shareholders, in a roughly 61:39 per cent split. In 2018, SSMC

[215] OECD, 'Measuring Distortions in International Markets: The Semiconductor Value Chain', OECD Trade Policy Papers no. 234 (Paris: OECD Publishing, 12 December 2019), https://doi.org/10.1787/8fe4491d-en, p. 20.
[216] Chris Miller, *Chip War: The Fight for the World's Most Critical Technology* (London: Simon and Schuster, 2022), p. 178.
[217] Chris Miller, *Chip War: The Fight for the World's Most Critical Technology* (London: Simon and Schuster, 2022), p. 233.
[218] Andre Barbe and Will Hunt, 'Preserving the Chokepoints: Reducing the Risks of Offshoring among US Semiconductor Manufacturing Equipment Firms' (Washington, DC: Center for Security and Emerging Technology, May 2022), https://cset.georgetown.edu/publication/preserving-the-chokepoints/, p. 6.
[219] Chris Miller, *Chip War: The Fight for the World's Most Critical Technology* (London: Simon and Schuster, 2022), p. 207.
[220] OECD, 'Measuring Distortions in International Markets: The Semiconductor Value Chain', OECD Trade Policy Papers no. 234 (Paris: OECD Publishing, 12 December 2019), https://doi.org/10.1787/8fe4491d-en, p. 61.
[221] Choo Yun Ting, 'Semiconductor Giant Micron Aims to Invest over US$150b Globally over next Decade', *The Straits Times*, 20 October 2021, https://www.straitstimes.com/business/companies-markets/semiconductor-giant-micron-aims-to-invest-over-us150b-globally-over-next.
[222] Dylan Loh, 'GlobalFoundries Puts $4bn into Singapore Expansion', *Nikkei Asia*, 22 June 2021, https://asia.nikkei.com/Business/Tech/Semiconductors/GlobalFoundries-puts-4bn-into-Singapore-expansion.
[223] 'NXP in Singapore', NXP Semiconductors, accessed 27 December 2022, https://www.nxp.com/company/about-nxp/worldwide-locations/singapore:CAREERS_SINGAPORE_HOME.

expanded with a new 4,400 square metre facility, increasing its automotive and speciality chip manufacturing space by 34 per cent. With a total capital expenditure of 3 billion SGD since its founding, it is the largest 200mm plant in the region.[224]

NXP's Singapore office supports sales and technical support teams for South-East Asia and Australia, a global distribution centre and engineering support for Singapore.[225] *The Wall Steet Journal* reported in May 2022 that TSMC was in talks with the EDB over a possible plant in Singapore.[226]

Taiwanese foundry **Vanguard International Semiconductor (VIS)** purchased GlobalFoundries' 200mm MEMS fab with a capacity of 35,000 wafer starts per month in Tampines in eastern Singapore in 2019.[227] It is also considering a 300mm fab in Singapore, according to Taiwanese business press.[228] Meanwhile, Taiwan's **UMC** is to spend 5 billion USD [4.7 billion euros] on a new factory in Singapore for 22nm and 28nm chips, next to its existing Pasir Ris factory, producing 30,000 wafers per month.[229]

Germany's Siemens spin-off **Infineon** in 2020 announced a 27 million SGD investment over three years, with the aim of making Singapore its AI hub.[230] Its country office hosts its Development Centre Singapore, as well as its headquarters for the countries of the Association of South-East Asian Nations (ASEAN), India, South Korea and Oceania.[231]

Outsourced semiconductor assembly and test (OSAT)

The US firm **KLA Corporation** opened its Advanced Packaging Development Centre in Singapore in 2015.[232] This follows upon the opening of its 17,400 square metre manufacturing site in 2008.[233]

[224] Janice Heng, 'Semiconductor Firm SSMC Opens New S$300m Facility', *The Business Times*, 27 November 2018, https://www.businesstimes.com.sg/startups-tech/technology/semiconductor-firm-ssmc-opens-new-s300m-facility.
[225] 'NXP in Singapore', NXP Semiconductors, accessed 27 December 2022, https://www.nxp.com/company/about-nxp/worldwide-locations/singapore:CAREERS_SINGAPORE_HOME.
[226] Yang Jie and Keith Zhai, 'TSMC Looks to Build Multibillion-Dollar Chip Plant in Singapore', *The Wall Street Journal*, 20 May 2022, https://www.wsj.com/articles/tsmc-looks-to-build-multibillion-dollar-chip-plant-in-singapore-11652958840.
[227] Peter Clarke, 'GloFo Sells MEMS Business, Fab to Taiwan's Vanguard', *eeNews Europe*, 31 January 2019, https://www.eenewseurope.com/en/glofo-sells-mems-business-fab-to-taiwans-vanguard/.
[228] Yin Hui-chung 尹慧中, '世界先進續考慮台灣、新加坡建 12 吋廠 但暫時沒有時間表' [VIS considers building 12-inch fab in Taiwan and Singapore, but for now has no time schedule], United Daily News, 6 January 2023, https://udn.com/news/story/7240/6891577.
[229] Sharon See, 'Global Chipmakers' Investments in Singapore', *The Business Times*, 22 July 2022, https://www.businesstimes.com.sg/government-economy/global-chipmakers-investments-in-singapore.
[230] Sharon See, 'Global Chipmakers' Investments in Singapore', *The Business Times*, 22 July 2022, https://www.businesstimes.com.sg/government-economy/global-chipmakers-investments-in-singapore.
[231] 'Infineon Singapore', Infineon Technologies, accessed 27 December 2022, https://www.infineon.com/cms/singapore/en/.
[232] Amit Roy Choudhury, 'KLA-Tencor Opens New Facility in Singapore', *The Business Times*, 18 November 2015, https://www.businesstimes.com.sg/startups-tech/technology/kla-tencor-opens-new-facility-singapore.
[233] Business Wire, 'KLA-Tencor's New Singapore Facility Will Provide Base for Regional Expansion', *KLA Corporation*, 16 May 2008, https://ir.kla.com/news-events/press-releases/detail/327/kla-tencors-new-singapore-facility-will-provide-base-for.

Singapore's packaging and test services company STATS ChipPAC was taken over by **JCET** in 2015, an acquisition funded by China's National IC Fund, [234] a subsidiary of China's Semiconductor Manufacturing International Corporation (SMIC), and Bank of China loans.[235] This demonstrates the close involvement of Chinese state mechanisms. According to electronic component distributor Utmel, JCET had an OSAT market share of almost 11.96 per cent in 2020.[236]

Singapore-headquartered **UTAC** had a market share of 2.15 per cent in 2020, declining to tenth place,[237] down from seventh with 3 per cent market share in 2018.[238] UTAC had manufacturing locations in Singapore, China and Taiwan. In 2020 it was bought by Beijing-based private equity fund Wise Road Capital, except for its Taiwanese operations.[239] Taiwanese OSAT market leader **ASE** also has operations in Singapore.

The OSAT market dominance by Taiwanese and Chinese companies and the decline of Singapore during the 2009–2019 period[240] can perhaps be explained by the above takeovers, obscuring the importance of these companies' Singapore location in the statistics.

Wafer processing

Dutch multinational **ASM International** assembles and tests advanced deposition tools in Singapore. It moved most of its production to Singapore in 2007, with one big reason being Singaporean government support. It also considered the practical and geopolitical advantages of Singapore.[241] Its new manufacturing floor opened in 2020 and a second is planned to be ready at the start of 2023. This will quadruple its Singapore yield and triple its global yield. Headcount has more than doubled to 850 people since late 2021.[242]

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[234] OECD, 'Measuring Distortions in International Markets: The Semiconductor Value Chain', OECD Trade Policy Papers no. 234 (Paris: OECD Publishing, 12 December 2019), https://doi.org/10.1787/8fe4491d-en, p. 44.
[235] OECD, 'Measuring Distortions in International Markets: The Semiconductor Value Chain', OECD Trade Policy Papers no. 234 (Paris: OECD Publishing, 12 December 2019), https://doi.org/10.1787/8fe4491d-en, p. 54.
[236] 'Top 10 OSAT (Outsourced Semiconductor Assembly and Test) Companies', *Utmel*, 10 January 2022, https://www.utmel.com/blog/categories/semiconductor/top-10-osat-outsourced-semiconductor-assembly-and-test-companies.
[237] 'Top 10 OSAT (Outsourced Semiconductor Assembly and Test) Companies', *Utmel*, 10 January 2022, https://www.utmel.com/blog/categories/semiconductor/top-10-osat-outsourced-semiconductor-assembly-and-test-companies.
[238] OECD, 'Measuring Distortions in International Markets: The Semiconductor Value Chain', OECD Trade Policy Papers no. 234 (Paris: OECD Publishing, 12 December 2019), https://doi.org/10.1787/8fe4491d-en, p. 22.
[239] 'UTAC Completes Sale to Wise Road Capital', UTAC Group, 12 August 2020, https://www.utacgroup.com/wp-content/uploads/2020/08/WR-Yransaction-announcement.pdf.
[240] Jan-Peter Kleinhans and Nurzat Baisakova, 'The Semiconductor Value Chain: A Technology Primer for Policy Makers' (Berlin: Stiftung Neue Verantwortung, October 2020), p. 20.
[241] Interview with a representative of ASMI.
[242] 'ASM International Unveils Expansion in Singapore to Meet Global Customer Demand for Advanced Semiconductors', *Yole Group*, 29 March 2022, https://www.yolegroup.com/industry-news/asm-international-unveils-expansion-in-singapore-to-meet-global-customer-demand-for-advanced-semiconductors/.

German publicly traded company **Siltronic** has entered a joint venture with **Samsung** for a new 2 billion euro 300mm manufacturing facility in Singapore by the end of 2024. It already produces 200mm and 300mm wafers in Singapore.[243]

The French firm **Soitec** is increasing its global capacity and investing 400 million euros to double its Pasir Ris factory in eastern Singapore to produce two-thirds of its global capacity there,[244] which should see the Singapore site produce two million energy-efficient wafers a year and double its workforce to more than 600 by 2026.[245]

As noted above, US firm **Applied Materials** works closely with the Singapore Institute of Technology for vocational training and with A*STAR for research. It states that half its global SME production takes place in Singapore.[246]

Semiconductor manufacturing equipment

Dutch SME giant **ASML** maintains an office in Singapore in light-industrial development New Tech Park, home to its field service engineers. Dutch SME parts supplier **BESI** maintains an office for support and sales in Singapore, while its regional manufacturing takes place in neighbouring Malaysia. Its office in the city-state is the Die Attach product group contact point for Asia.[247]

Design and contract manufacturing partner **VDL Enabling Technologies Group**, which is part of Dutch carmaker VDL, has a subsidiary in Singapore that works on system integration.[248] US firm Applied Materials is among its customers.[249]

Small Dutch mechanotronics companies **DEMCON**, **Sioux Technologies** and **NTS** also maintain Singapore offices.

[243] Sharon See, 'Global Chipmakers' Investments in Singapore', *The Business Times*, 22 July 2022, https://www.businesstimes.com.sg/government-economy/global-chipmakers-investments-in-singapore.
[244] Sharon See, 'Global Chipmakers' Investments in Singapore', *The Business Times*, 22 July 2022, https://www.businesstimes.com.sg/government-economy/global-chipmakers-investments-in-singapore.
[245] Ovais Subhani, 'French Semiconductor Firm Soitec to Double Production and Manpower in Singapore', *The Straits Times*, 9 December 2022, https://www.straitstimes.com/business/french-semiconductor-firm-soitec-to-double-production-and-manpower-in-singapore.
[246] Andre Barbe and Will Hunt, 'Preserving the Chokepoints: Reducing the Risks of Offshoring among US Semiconductor Manufacturing Equipment Firms' (Washington, DC: Center for Security and Emerging Technology, May 2022), https://cset.georgetown.edu/publication/preserving-the-chokepoints/, p. 3.
[247] 'Company Overview', BESI, accessed December 27, 2022, https://www.besi.com/company/company-overview/.
[248] 'VDL ETG Singapore', VDL Enabling Technologies Group, accessed 27 December 2022, https://www.vdletg.com/en/het-bedrijf/locations/vdl-etg-singapore.
[249] 'VDL ETG Receives Supplier Excellence Award from Applied Materials', *VDL Enabling Technologies Group*, 16 December 2022, https://www.vdletg.com/en/news/vdl-etg-receives-supplier-excellence-award-from-applied-materials.

Industry association

The Singapore Semiconductor Industry Association (SSIA) has brought together companies working in the industry since its founding under the name MIDAS in 2005.[250] In recent years it has organised the annual Semiconductor Business Connect industry event. Given the dominance of foreign firms and the EDB, the SSIA is not as important in determining the direction of development as in countries with a stronger independent domestic manufacturing industry.

3. International posititioning and connections

Relevant geopolitical positioning

Singapore's foreign and economic policies have, from the start, stressed the need to involve as many different actors as possible. The aim is to get both foreign countries and multinational companies to have a stake in maintaining the city-state's independence. Singapore also does not want to miss out on the economic benefits. At the same time, welcoming all also serves to underwrite Singapore's neutrality.

Singapore was involved with the Non-Aligned Movement (NAM) during the Cold War and repeatedly says it does not want to choose between the United State and China,[251] as Prime Minister Lee Hsien Loong warns about the risks of a trade war or escalation.[252] Foreign Minister Vivian Balakrishnan openly worries about the erosion of the post-Second World War order that Singapore sees as an important underpinning of its prosperity.[253]

In practice, Singapore has close relations with the United States dating back to the Vietnam War. Although Singapore is not a formal treaty ally of the United States, unlike the Philippines or Thailand, it has one of the closest military relations with the United States in the region. One-quarter of Singapore's fleet of fighter jets is permanently in the United States. The US Navy has a logistical support centre in Singapore and its 7th Fleet uses Changi Naval Base for maintenance. Paya Lebar Air Base is a regular host to US P-8 military reconnaissance planes.

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[250] 'Singapore Semiconductor Industry Association', SEMI, accessed 5 January 2023, https://www.semi.org/en/resources/member-directory/singapore-semiconductor-industry-association.
[251] Chong Ja Ian, 'Other Countries Are Small Countries, and That's Just a Fact: Singapore's Efforts to Navigate US–China Strategic Rivalry', in *China-US Competition: Impact on Small and Middle Powers' Strategic Choices*, ed. Simona A. Grano and David Wei Feng Huang (Cham: Palgrave MacMillan, 2023), 307–38, https://doi.org/10.1007/978-3-031-15389-1.
[252] Lee Hsien Loong, 'The Endangered Asian Century: America, China, and the Perils of Confrontation', *Foreign Affairs* 99, no. 4 (4 June 2020): 52–58, https://www.foreignaffairs.com/articles/asia/2020-06-04/lee-hsien-loong-endangered-asian-century.
[253] Vivian Balakrishnan, 'Edited Transcript of Speech by Minister for Foreign Affairs Dr Vivian Balakrishnan: 'Staying Together in a Turbulent World' at Singapore Management University, 22 January 2020', *Ministry of Foreign Affairs of Singapore*, https://www.mfa.gov.sg/Newsroom/Press-Statements-Transcripts-and-Photos/2020/01/22012020-SGT.

Unrest in Hong Kong and the decreasing attractiveness of the whole of China because of political and pandemic reasons mean that Singapore's role as a meeting point between East and West is increasing. The inflow of Chinese capital and talent seeking a safe harbour brings opportunities and challenges for Singapore. Its role as a meeting point also applies to Singapore's semiconductor industry. There are some worries about its reliance on customers from China[254] if the Chinese economy worsens or if US extraterritorial restrictions expand. In the meantime, Singapore is positioning itself to 'play both sides of decoupling', even as its sovereign wealth funds are now tasked with taking geopolitical considerations into account.[255] Manufacturers' reliance on EDB support means that they will also have to deal with government stances.

The Singapore government's concern about the tech war between China and the United States is part of its wider concerns over competition.[256] This concern found clear expression in Foreign Minister Vivian Balakrishnan's call in November 2022 for a non-aligned movement for science, technology and supply chains to avoid being caught in the superpowers' fight.[257] It remains to be seen what practical implementation this will bring. Singapore appears to be well positioned to gain from supply chain diversification. As Cornell University's Sarah Kreps told CNBC: 'South Korea and Taiwan can't camouflage themselves, but countries like Vietnam, India and Singapore are positioning themselves as a third way, a neutral bridge between two titans'.[258]

Even though the city-state could serve as a place to interact with the Western world for Chinese businesses, they must deal with the fact that Singapore is aligned with the United States not only on security. The above list of companies demonstrates Singapore's de facto integration into the Euro-American semiconductor supply chain. The only significant Chinese presence is through OSAT company JCET.

If Singapore is forced to limit one of the two superpowers, it is most likely that China's presence will be squeezed. This would probably take a similar form to how Huawei did not end up partaking in building Singapore's 5G network. Telecommunications operators said they had opted for Ericsson and

[254] Nile Bowie, 'Singapore's Chip Revival Hinges on a Wobbly China', *Asia Times*, 14 January 2022, https://asiatimes.com/2022/01/singapores-chip-revival-hinges-on-a-wobbly-china/.
[255] Leo Lewis, 'Singapore Is Well-Positioned to Play Both Sides of Decoupling', *Financial Times*, 24 November 2022, https://www.ft.com/content/269b1a53-dd66-4446-8da8-f54d39403bfc.
[256] Lee Hsien Loong, 'The Endangered Asian Century: America, China, and the Perils of Confrontation', *Foreign Affairs* 99, no. 4 (4 June 2020): 52–58, https://www.foreignaffairs.com/articles/asia/2020-06-04/lee-hsien-loong-endangered-asian-century.
[257] Ng Wei Kai, 'New 'Non-Aligned Movement' Needed for Countries amid US-China Tensions: Vivian Balakrishnan', *The Straits Times*, 10 November 2022, https://www.straitstimes.com/singapore/politics/new-non-aligned-movement-needed-for-countries-to-keep-collaborating-amid-us-china-tensions-vivian-balakrishnan.
[258] Weilun Soon, 'India and Vietnam Could Benefit as Chipmakers Shift Away from China', *CNBC*, 12 December 2022, https://www.cnbc.com/2022/12/13/india-vietnam-may-benefit-as-chipmakers-shift-from-china-amid-us-curbs.html.

Nokia themselves, while the responsible minister stressed that no vendor had been 'explicitly excluded'.[259] Retaliation from China did not follow.

Yet until the tech war also seriously affects Singapore, it raises the interesting prospect of the city-state playing the role of interface between the Western semiconductor chain and Chinese customers. Singapore offers a safe space for all players, both in terms of financial, legal and physical infrastructure, as well as in terms of political fallout.

Relevant political relations with the other countries in the region

The importance of Singapore and the United States for each other in the security realm has been touched upon already. This is mirrored on the economic side, with the important presence of US companies Micron, GlobalFoundries, KLA and Applied Materials.

Although Singapore's long-serving Prime Minister Lee Kuan Yew was initially a staunch anti-communist, he was also pragmatic about diversifying Singapore's reliance. In the 1970s, trade relations with China therefore took off in more serious form, thanks to trade missions by both the government and the Singapore–Chinese Chamber of Commerce and Industry. Famously, China's leader Deng Xiaoping visited Singapore and proposed that it serve as an example for China to learn a few things from. Since then, economic and political interactions have only increased. Singapore's sovereign wealth fund GIC and Temasek are active in the Chinese market, as are the major banks.

China's growing proficiency in the industry is reflected in the JCET presence in OSAT and the purchase of UTAC by a Beijing-based private equity fund. Beyond that, however, Chinese presence is limited, because an aim for self-reliance keeps most of China's industry at home, leaving just a few offices for research and commercial purposes in Singapore. Much more visible is the rise of the large Chinese tech companies' presence in Singapore, because of their need to find talent and engage with the world. Tencent, Alibaba, ByteDance and others all have substantial offices or even global headquarters in Singapore.

Singapore's ties with Taiwan also go back a long way, but have been handled with great care because of their sensitivity. There is a Taipei Representative Office in Singapore and a Singapore Trade Office in Taipei. Singaporean conscripted soldiers have been training in Taiwan every year since the 1970s under Operation Starlight. Until recently, leaders on both sides would engage in many 'private' visits

[259] Abhishek Vishnoi and Yoojung Lee, 'Huawei Loses Main Singapore 5G Networks to Ericsson, Nokia', *Bloomberg*, 24 June 2020, https://www.bloomberg.com/news/articles/2020-06-24/singapore-issues-final-5g-awards-to-singtel-starhub-m1-group.

and economic ties were strong during the boom years. Close ties are reflected by the presence of many Taiwanese tech companies, from ASE and VIS to UMC and TSMC–NXP joint venture, SSMC.

South Korea and Singapore established formal diplomatic relations in 1975. Together with Hong Kong and Taiwan, the two form part of the Four Asian Tigers. Samsung Semiconductors has an office at the Samsung Hub in Singapore. Both South Korea and Japan depend on the Strait of Malacca for sea freight to Europe.

Singapore's relations with Malaysia are complex. Today, many companies maintain a presence on both sides of the border. Singapore's connections and legal infrastructure provide a great home for the headquarters of companies that want to take advantage of Malaysia's cheaper and more plentiful resources for manufacturing. Dutch firm BESI is an example of this approach.

As the centre for the region, Singapore attracts a lot of South-East Asian talent. It also serves as a hub for multinational companies seeking a safe portal to the region. The overview of companies given above shows that several use it as their regional headquarters.

India's role in South Asia and its non-aligned stance, yet critical attitude towards China, make it an important consideration in Singapore's search for balancers. Singapore's GLCs are active in India, including in setting up industrial parks, as they have in China. In practical terms, together with Bangladesh, India serves as an important source of foreign workers in Singapore as well as foreign talents in the technology and finance industries.

In the Netherlands, the recent purchase of the Eindhoven High Tech Campus by Singapore's GIC caused some unrest, after a failed counter-offer by the municipality of Eindhoven and *Stichting* Brainport.[260] In the other direction, ASM International is the Dutch semiconductor company with the greatest reliance on Singapore. NXP has SSMC in its joint venture with TSMC. Other Dutch companies mainly seek a Singaporean presence for sales and service.

4. Implications for the Dutch sector

Singapore is deeply involved in the global semiconductor industry and has been from the start. All the big companies are present in the city-state. Micron, GlobalFoundries and SSMC are the most

[260] Pieter Couwenberg, Erik van Rein and Nelleke Trappenburg, 'Eindhoven probeerde verkoop van High Tech Campus te verijdelen', *Financieel Dagblad*, 11 February 2022, https://fd.nl/bedrijfsleven/1429470/eindhoven-probeerde-verkoop-van-high-tech-campus-aan-singaporezen-te-verijdelen-vfa3caswP62l.

important, but companies from the United States, Germany, the Netherlands, Japan and South Korea all sought a presence in Singapore at the start of their global success.

In every major operation, Singapore's EDB plays a role. Dutch firm ASMI's manufacturing move to Singapore is a case in point. Cooperation with government plans is essential to be able to compete for a spot within Singapore. The up-side is that this does not seem difficult, as Singapore's policy is one of welcoming foreign companies in order to help grow the city-state's share in manufacturing. This is in contrast to the more protectionist policies of countries that have domestic champions they seek to protect.

JTC Corporation is a useful partner in accessing working space for smaller companies yet to establish a Singapore presence. The 'Manufacturing 2030' plan's ambitions require more production to take place within Singapore. The five areas of focus in the EDB's vision for the future semiconductor industry focus on cutting-edge semiconductor production. Smaller Dutch companies seeking to grow in these areas can benefit and take inspiration from the ASMI story, as well as use the research facilities under development.

Singapore's foreign policy of neutrality allows it to play the role of meeting point between the West and China, also in the tech industry. If China remains closed off and Hong Kong's bridging role continues to diminish, amid the heating trade war between Beijing and Washington, Singapore's role as a meeting point will increase in importance. Dutch companies can take advantage of this.

As its government policies prove, Singapore puts a lot of energy into maintaining and expanding its role in the global semiconductor supply chain. Large developments are underway that will ensure that capacity grows. However, Singapore cannot ignore the growing pressure that the United States brings to bear on other countries to fall in line and, as the overlap in shared interests between Washington and Beijing decreases, Singapore's room for manoeuvre shrinks.[261] Singapore has also shown itself in its security practice to be more closely aligned with the United States. At the same time, Prime Minister Lee Hsien Loong's warning against spheres of influence[262] and the strong support for a constructive American role in the region[263] reflect a subtly expressed fear of being locked into the region by China.

[261] Chong Ja Ian, 'Other Countries Are Small Countries, and That's Just a Fact: Singapore's Efforts to Navigate US–China Strategic Rivalry', in *China–US Competition: Impact on Small and Middle Powers' Strategic Choices*, ed. Simona A. Grano and David Wei Feng Huang (Cham: Palgrave MacMillan, 2023), p. 310, https://doi.org/10.1007/978-3-031-15389-1.
[262] Lee Hsien Loong, 'The Endangered Asian Century: America, China, and the Perils of Confrontation', *Foreign Affairs* 99, no. 4 (4 June 2020): 52–58, https://www.foreignaffairs.com/articles/asia/2020-06-04/lee-hsien-loong-endangered-asian-century.
[263] Lee Hsien Loong, 'PM Lee Hsien Loong's Opening Remarks at Joint Press Conference with US Vice President Kamala Harris', Prime Minister's Office, Singapore, 23 August 2021, https://www.pmo.gov.sg/Newsroom/PM-Lee-Opening-Remarks-at-Joint-Press-Conference-with-US-VP-Kamala-Harris.

Dutch companies need to be aware of the opportunities that Singapore offers as a portal to engage with both China and the South-East Asian region. The important role of Singapore government support means that good local connections matter. The overview of companies given in this chapter shows the omnipresence of the EDB in supporting investment. Companies that obtain grants, tax advantages and other help in Singapore have an advantage over competitors without a presence there. Given that it should not be difficult for private parties to engage the EDB, this is mainly a risk to other countries rather than companies per se.

One development to watch is the direction in which the tech war develops. For now, Singapore serves as a safe interface between an OECD-oriented semiconductor supply chain and regional as well as Chinese customers. This actually increases Singapore's attractiveness in the short term. In the long term, it is harder to predict whether this interface will be allowed to continue to exist. But even if it disappears, Singapore will remain an important node of production for the big global companies, as it has been from the start.

South Korea

Jonas Lammertink (LeidenAsiaCentre)

South Korea is a major player in the global semiconductor industry and is home to some of the world's largest chip suppliers. Semiconductors are also very important for the South Korean economy, forming its most valuable export product.[264] South Korea's semiconductor sector has always been shaped by international politics. During the 1980s, an economic dispute between Japan and the United States resulted in less favourable conditions for Japanese semiconductor companies, providing an opportunity for South Korean companies to increase their market share, especially in the segment of memory chips.[265] Nowadays, South Korea finds itself wedged between the United States and China, which are both applying political pressure on Seoul to align itself with their country's interests, including in the semiconductor industry.

The size of South Korea's semiconductor sector, combined with its susceptibility to political forces, make its industry indispensable for Dutch semiconductor interests in Asia in light of (geo)political developments. This chapter therefore discusses the policies of the South Korean government regarding the sector, provides an overview of the industry in the country, lays out connections with the Dutch sector, and maps Seoul's geopolitical positioning and relevant relations with other countries in the region. The chapter concludes with a discussion of the implications of these political and economic developments and regional relations for the Dutch semiconductor sector.

1. Government policies

In recent years, the South Korean government has invested heavily in the semiconductor industry. This is in part to keep up with government support in other countries, but also to tackle a series of challenges that specifically face the industry in South Korea, such as its concentration on memory chip production and consequently its weaker position in system chips and other segments of the value chain (these challenges are discussed in more detail below).

One of the first signs of renewed broad government support for the sector came in 2019, when Seoul presented its System Semiconductor Vision and Strategy, which aligned with Samsung's plans to invest in system chips' production capabilities. The aim of the strategy is to achieve a 10 per cent share of

[264] OEC, „Integrated Circuits in South Korea" (visited 08 february 2023), https://oec.world/en/profile/bilateral-product/integrated-circuits/reporter/kor.
[265] S.R. Kim, „The Korean system of innovation and the semiconductor industry: a governance perspective", December 1996, https://www.oecd.org/korea/2098646.pdf.

the global design (fabless) market, to become a world leader in the foundry segment and to increase the number of employees in the segment of system chips by 27,000 new jobs by 2030.[266] In order to realise this, South Korea's government established several initiatives, such as the so-called 'Alliance 2.0', in which over 20 companies coordinate on technology planning, R&D, and local supply and demand for system chips. South Korea's government also announced several funds to finance its ambitions in these segments of the industry, such as 859 million USD for an R&D fund.[267]

This initial strategy was followed by more policy initiatives. For example, in 2020, Seoul announced a strategy to develop further South Korea's AI semiconductor industry. The aim of this plan is to realise a 20 per cent global market share in this segment by 2030 through public–private collaboration.[268] And in 2021, the so-called 'K-Semiconductor Strategy' was presented, which consists of a plan to create a 'K-Semiconductor Belt' connecting several regions with semiconductor activities into the world's largest chip-making ecosystem.[269] In 2022, it became clear that the South Korean government's goal is to grow the country's non-memory chip global market share from 3 per cent to 10 per cent by 2030.[270]

To support these aims, South Korea's government announced tax reductions for semiconductor R&D and facility investments, as well as other benefits regarding permits and water and energy supplies.[271] The private sector, under the leadership of Samsung and SK Hynix, has committed to investing over 400 billion USD in the next ten years in semiconductor research and production as part of the government's blueprint.[272] These policy plans were established in several acts passed in the South Korean Parliament, although some of the government's commitments appear to have been watered down, resulting in criticism from multiple sides.[273]

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[266] Baek Byung-yeul, 'Korea will become non-memory chip powerhouse by 2030', *The Korea Times*, 30 April 2019, https://www.koreatimes.co.kr/www/tech/2022/06/133_268069.html.
[267] Ha-yan Choi, "Moon announces system semiconductor "vision and strategy" to match Samsung investment", *Hankyoreh,* 1 May 2019, https://english.hani.co.kr/arti/english_edition/e_business/892289.html.
[268] Eun-jin Kim, "South Korea Aiming to Become AI Semiconductor Industry Powerhouse", *BusinessKorea*, 13 October 2022, http://www.businesskorea.co.kr/news/articleView.html?idxno=53036.
[269] KBS World, ""K-Semiconductor Belt Strategy" to establish the world's largest supply network by 2030", 17 May 2021, http://world.kbs.co.kr/service/contents_view.htm?board_seq=403357.
[270] Suk-yee Jung, "South Korea to Make Huge Investment in Semiconductor Industry", *BusinessKorea,* 22 July 2022, http://www.businesskorea.co.kr/news/articleView.html?idxno=97099.
[271] Young-bae Kim, "S. Korea vows to build world's largest semiconductor belt", *Hankyoreh*, 14 May 2021, https://english.hani.co.kr/arti/english_edition/e_business/995284.html.
[272] Sohee Kim and Kim Sam, "South Korea joins global chipmaking race with $450 billion spending plan", *Fortune*, 14 May 2021, https://fortune.com/2021/05/13/south-korea-chip-semiconductor-samsung-hynix/.
[273] He-rim Joh, "'Half-baked' chips act falls short of drastic corporate tax cuts", *The Korea Herald*, 25 December 2022, https://www.koreaherald.com/view.php?ud=20221225000069; Suk-Hyun Ko and Eun-Jee Park, "Korea chips act all but useless, critics argue", *Korea JoongAng Daily*, 26 Dember 2022, https://koreajoongangdaily.joins.com/2022/12/26/business/industry/Kchips-Act/20221226185044592.html.

Furthermore, in 2022 South Korea's government earmarked almost 700 million USD for R&D regarding important materials and parts, including for the semiconductor industry.[274] This followed the earlier 'Materials, Parts and Equipment 2.0 Strategy', which was presented in 2020 and similarly consisted of large investments (4.2 billion USD) to develop technologies in these sectors. The aim of these plans is to reduce foreign dependencies. While the focus was initially on countering reliance on Japan, the policy also targets key items imported from around the world, in part because of the problems that COVID-19 caused in global supply chains.[275]

Finally, in order to train more skilled personnel for the semiconductor sector, the South Korean government announced in 2022 that it will invest public funds in educating and training 150,000 semiconductor engineers in the coming years. More than 700 million USD will be allocated by 2029 towards education and research projects. Limits on student numbers will be removed for semiconductor-related departments, special training sessions for non-engineering majors will be organised and joint research centres are to be established.[276] Furthermore, a special semiconductor academy will open in April 2023.[277] Agreement was also reached by the government, research institutions and semiconductor companies to work together to overcome issues regarding training new personnel.[278]

2. Industry overview

Strengths and weaknesses of the South Korean semiconductor industry

The South Korean semiconductor industry is especially strong in the segment of memory chips. Memory chips are used to store information, while system chips (also known as logic chips) process data to perform tasks and therefore function as the brains of electronic devices. Memory chips generally require less cutting-edge technology and production methods to manufacture and depend more on economies of scale compared to advanced system chips. South Korea managed in part to

[274] Yonhap News Agency, "S. Korea earmarks 841 bln won for key materials, parts development", 3 February 2021, https://en.yna.co.kr/view/AEN20220203003100320.
[275] Ho-Jeong Lee, "2.0 strategy for 3 key materials to cost trillions of won", *Korea JoongAng Daily*, 9 July 2020, https://koreajoongangdaily.joins.com/2020/07/09/business/economy/material-and-parts-MOTIE-Minister-Sung-Yunmo/20200709180200380.html.
[276] Ho-Jeong Lee, "Korea to amass a chip army with huge spending of public funds", *Korea JoongAng Daily*, 19 July 2022, https://koreajoongangdaily.joins.com/2022/07/19/business/economy/Semiconductor-training-talents-Korean-government/20220719190204828.html; Eun-byel Im, "Korea to lift school limits in chip expert push", *The Korea Herald,* 19 July 2022, https://www.koreaherald.com/view.php?ud=20220719000584.
[277] Ho-Jeong Lee, "Chip U established to train Korea's chip army", *Korea JoongAng Daily*, 1 December 2022, https://koreajoongangdaily.joins.com/2022/12/01/business/economy/semiconductor-Korea-academy/20221201182703788.html.
[278] Dong-joon Kwon, "Samsung Electronics planning large framework for customized on-site 'training for semiconductor professionals'", *Korea IT News*, 7 September 2022, https://english.etnews.com/20220907200001.

gain a strong position in the global market for memory chips during the 1980s because of its lower production costs compared to, then, memory chip powerhouse Japan.

According to the national investment promotion agency of the South Korean government, South Korea accounts for 18 per cent of global semiconductor production and 57 per cent of the global output for memory chips (in 2020).[279] These exports were worth 99 billion USD, of which memory chips accounted for 64 billion USD, which made South Korea the third largest exporter of chips in the world in 2020.[280]

Chips are, in turn, also of vital importance to the South Korean economy. Semiconductors are South Korea's most important export product: the industry accounted for 18 per cent of total exports in 2019.[281] In 2018, the semiconductor industry produced almost 6 per cent of the country's GDP.[282] Furthermore, about 177,000 people work in the industry in South Korea, which the government expects to grow to over 300,000 in the coming ten years.[283]

However, the South Korean semiconductor industry is recently facing a series of challenges. While the country holds a leading position in the global market for memory chips, its role in the production of system chips, chip design (fabless), equipment and materials is much less strong. This is problematic, because most of the added value in the supply chain takes place at the design level.[284] The market for memory chips is also relatively volatile and recently seems to be losing ground to that of system chips, which are becoming increasingly important as enablers of new technologies such as AI, smart devices, and the Internet of Things.[285] Furthermore, increased competition from Chinese memory chip manufacturers is also challenging the South Korean memory chip industry.[286] Finally, South Korea's

[279] Invest Korea, "Semiconductor", (visited 8 February 2022), https://www.investkorea.org/ik-en/cntnts/i-312/web.do.
[280] OEC, „Integrated Circuits in South Korea"; Invest Korea, "Semiconductor".
[281] Seul-gi Jun, "Overreliance on semiconductors drives S. Korea's economic recovery", *Hankyoreh*, 23 April 2021, https://english.hani.co.kr/arti/english_edition/e_business/992372.html.
[282] Malichanh Chiemsisoulath and Wanwisa May Vorranikulkij, "Revival of Korea's Semiconductor Exports is In Sight", *Amro Asia*, 23 April 2020, https://www.amro-asia.org/revival-of-koreas-semiconductor-exports-is-in-sight/.
[283] Ho-Jeong Lee, "Korea to amass a chip army".
[284] George Calhoun, "Which Companies Add The Most Value In The Semiconductor Industry? (Part 1)", *Forbes,* 30 September 2021, https://www.forbes.com/sites/georgecalhoun/2021/09/30/the-semiconductor-scoreboard-part-1-the-basic-value-chain-and-the-value-added/?sh=724049d738ab.
[285] The Economist, "Why some chipmakers are hurting much more than others", 29 September 2022, https://www.economist.com/business/2022/09/29/why-some-chipmakers-are-hurting-much-more-than-others; Trefis Team, "Why Samsung Plans To Double Down On The $170 Billion Logic Chip Market", *Forbes*, 22 January 2020, https://www.forbes.com/sites/greatspeculations/2020/01/22/why-samsung-plans-to-double-down-on-the-170-billion-logic-chip-market/?sh=5a1c00e140b6.
[286] Samsung, "역동적 혁신성장을 위한 삼성의 미래 준비", 24 May 2022, https://news.samsung.com/kr/%ec%97%ad%eb%8f%99%ec%a0%81-%ed%98%81%ec%8b%a0%ec%84%b1%ec%9e%a5-%ec%9c%84%ed%95%9c-%ec%82%bc%ec%84%b1%ec%9d%98-%eb%af%b8%eb%9e%98%ec%a4%80%eb%b9%84-5%eb%85%84%ea%b0%84-450%ec%a1%b0-%ed%88%ac.

focus on memory chips has created precarious dependencies in other market segments, such as in semiconductor equipment and materials.[287]

Apart from the disadvantages that stem from the concentration on memory chips, other issues are also challenging the industry. For example, South Korean semiconductor companies invest relatively little in R&D when compared to companies from the United States, China, Japan and Taiwan.[288] Moreover, a lack of skilled personnel challenges the development of South Korea's semiconductor industry. According to a survey by the Korea Enterprises Federation, 45 per cent of companies in the sector are understaffed.[289] The Korea Semiconductor Industry Association expects the sector to face a shortage of at least 30,000 workers in the coming ten years.[290]

Major players

While there are many companies operating in the South Korean semiconductor industry, two of them are dominating the sector: SK Hynix; and Samsung Electronics. These two companies both have extensive production and R&D facilities, and together with SK Square (the investor arm of SK Group, of which SK Hynix is a subsidiary) they are the only South Korean companies in the top 100 of semiconductor companies worldwide, based on market capitalisation.[291] Other noteworthy South Korean companies in the industry are LG Chem (a supplier of processed chemicals), SK Siltron (a wafer supplier) and DB Hitek (foundry).

SK Hynix is a public company that specialises in the production of memory chips. It belongs to the IDM segment of the value chain, as it both designs and manufactures semiconductors. Apart from manufacturing its own chips, SK Hynix also has a foundry division, SK Hynix System IC, which was separated from the memory chip division in 2017. In 2022, SK Hynix increased its foundry capacity by acquiring an existing foundry in South Korea.[292] According to the company, strengthening its foundry capabilities serves to enhance its competitiveness in the system semiconductor segment, although its foundries are not focused on producing the most cutting-edge system semiconductors.[293] SK Hynix,

[287] Hyun-bin Kim, "Korea highly dependent on foreign chip equipment: KITA", *The Korea Times*, 3 November 2022, https://www.koreatimes.co.kr/www/tech/2022/11/419_339135.html.
[288] Eun-jin Kim, "R&D Investment-to-Sales Ratio Lower in South Korean Semiconductor Companies", *BusinessKorea,* 26 July 2022, http://www.businesskorea.co.kr/news/articleView.html?idxno=97259.
[289] Suk-yee Jung, "Manpower Shortage Serious in 4 Key Industries", *BusinessKorea*, 9 November 2022, http://www.businesskorea.co.kr/news/articleView.html?idxno=103717.
[290] Man-Su Choe, Ji-Eun Jeong and Ye-Rin Choi, "Why Korean chipmakers struggle with talent shortages", *The Korea Economic Daily*, 10 June 2022, https://www.kedglobal.com/the-deep-dive/newsView/ked202206100004.
[291] Eun-jin Kim, "Only 3 Korean Semiconductor Companies Make It to Global Top 100", *BusinessKorea*, 25 October 2022, http://www.businesskorea.co.kr/news/articleView.html?idxno=102779#:~:text=24%20that%20the%20global%20top,%2C%20Taiwan%20and%20Japan%2C%20respectively.
[292] Ji-hyoung Son, "SK hynix completes Key Foundry acquisition", *The Korea Herald*, 2 August 2022, https://m.koreaherald.com/view.php?ud=20220802000647.
[293] Su-Bin Lee, "SK Hynix in $492 million Key Foundry deal, doubles foundry capacity", *The Korea Economic Daily*, 29 October 2021, https://www.kedglobal.com/semiconductors/newsView/ked202110290013.

together with other companies of the SK Group, also develops AI chips (which are manufactured by the Taiwan Semiconductor Manufacturing Company, TSMC).[294]

Samsung's semiconductor division is one of the largest in the world and, similar to SK Hynix, is especially strong in the memory chip market. However, Samsung is also among the leading companies in the foundry segment of the industry, where it produces advanced system chips. Samsung is one of only three companies (the others being TSMC and Intel) that can manufacture the most advanced system semiconductors.[295] According to Samsung's website, its foundry business is recording an annual growth of approximately 20 per cent and the company invests 'aggressively' in this business by constructing additional production lines with EUV machines for the mass production of 5nm chips. Samsung aims to become the world's number one foundry by 2030, while currently still being a distant second after Taiwan's TSMC.[296] Samsung also hopes to challenge the position of the Taiwanese company by its investments in 3nm production capabilities, while new R&D facilities are also being built.[297] Samsung furthermore has a fabless division that specialises in system semiconductor design.[298] It is an important supplier of memory and advanced system semiconductors in the global market. However, since Samsung is also an end user of semiconductors (for example, for its smartphones), many of the chips it produces are for its own use as well.

Both SK Hynix's efforts to increase its capacities in the foundry business and system semiconductor segment, as well as Samsung's investments in its foundry and design divisions, are in line with the above-mentioned plans presented by the Seoul government to widen South Korea's focus in the industry.[299]

Connections with Dutch players

South Korea is an important industry for the Dutch semiconductor sector. It is one of the largest suppliers of semiconductors and among the few that can produce the most advanced chips, but it does not have a strong equipment sector. The importance of connections between companies in both

[294] Byung-wook Kim, "[CES 2022] SK to launch Sapeon Inc. for AI chip supremacy", *The Korea Herald,* 10 January 2022, https://www.koreaherald.com/view.php?ud=20220109000087.
[295] The Economist, "Chipmaking is being redesigned. Effects will be far-reaching", 23 January 2021, https://www.economist.com/business/2021/01/23/chipmaking-is-being-redesigned-effects-will-be-far-reaching.
[296] Samsung, "Foundry", (visited 8 February 2023), https://semiconductor.samsung.com/about-us/business-area/foundry/; Jeong-Soo Hwang, "Samsung to make 3 nm chips for Nvidia, Qualcomm, IBM, Baidu", 22 November 2022, https://www.kedglobal.com/korean-chipmakers/newsView/ked202211220027.
[297] Samsung, "Samsung Begins Chip Production Using 3nm Process Technology With GAA Architecture", 30 June 2022, https://news.samsung.com/global/samsung-begins-chip-production-using-3nm-process-technology-with-gaa-architecture; Samsung, "Samsung Electronics Breaks Ground on New Semiconductor R&D Complex in Giheung, Korea", 19 August 2022, https://news.samsung.com/global/samsung-electronics-breaks-ground-on-new-semiconductor-rd-complex-in-giheung-korea.
[298] Samsung, "The dream of artificial intelligence realized with system LSI" (visited 8 February 2023), https://semiconductor.samsung.com/about-us/business-area/system-lsi/.
[299] Samsung, "Samsung Electronics to Boost Investment in Logic Chip Businesses to KRW 171 Trillion by 2030", 13 May 2021, https://news.samsung.com/global/samsung-electronics-to-boost-investment-in-logic-chip-businesses-to-krw-171-trillion-by-2030.

countries was underlined when South Korean President Yoon Suk Yeol and Dutch Prime Minister Mark Rutte agreed to strengthen cooperation in high-tech areas (including semiconductors) and elevated diplomatic relations between South Korea and the Netherlands to the level of 'strategic partnership' in November 2022.[300]

For Dutch equipment manufacturer ASML, South Korea was its second largest sales market in 2021, just behind Taiwan. That year, total sales to South Korea reached more than 6.2 billion euros, representing one-third of total net sales.[301] To support its sales in South Korea, ASML has a local sales and customer support office. Moreover, the company also operates a repair and service centre, a research lab at Hangyang University, a manufacturing and refurbishment location in Pyeongtaek, and an office and cleanroom facility in Hwasung.[302] According to its website, over 1,400 people work for ASML in South Korea.[303] New facilities are also being built in South Korea, including training and repair centres.[304] In 2021, ASML reported that it did not have noteworthy R&D activities in South Korea.[305]

Dutch equipment manufacturer ASMI is also very active in South Korea. The country, with important customers such as Samsung and SK Hynix, represents the second largest sales market for ASMI and is also home to several important suppliers. ASMI operates a manufacturing and R&D facility in Dongtan, which it is looking to enlarge. The number of ASMI employees in South Korea in 2021 was 392, representing 12 per cent of ASMI's total number of employees. ASMI also collaborates with academic institutions in South Korea on research projects.[306]

Dutch chipmaker NXP has two sales and support locations in South Korea (in Seoul and Gyeonggi-do).[307] This is unsurprising, considering that among NXP's ten largest original equipment manufacturer (OEM) end customers, three are South Korean: Samsung; LGE; and Harman Auto (a Samsung subsidiary). Nonetheless, NXP's revenue in South Korea in 2021 was relatively limited: 467 million USD (only 4 per cent of its global revenue).[308]

[300] Government of the Netherlands, "Joint Statement on the Establishment of a Strategic Partnership between the Government of the Republic of Korea and the Government of the Kingdom of the Netherlands", 23 November 2022, https://www.government.nl/documents/diplomatic-statements/2022/11/17/joint-statement-on-the-establishment-of-a-strategic-partnership-between-the-government-of-the-republic-of-korea-and-the-government-of-the-kingdom-of-the-netherlands.
[301] ASML, "Annual Report 2021" (visited 8 February 2023), https://www.asml.com/en/investors/annual-report/2021.
[302] ASML, "Annual Report 2021"; for the website of the lab at Hanyang University, see: http://asmllab.hanyang.ac.kr/kor/page/index.php
[303] ASML, "Working in South Korea" (visited 8 February 2023), https://www.asml.com/en/careers/working-at-asml/south-korea.
[304] Hyeong-woo Kan, "ASML to strengthen foothold in Korea: CEO", 15 November 2022, https://www.koreaherald.com/view.php?ud=20221115000589.
[305] ASML, "Annual Report 2021".
[306] ASMI, "Growth through Innovation. Annual Report 2021" (visited 8 February 2023), https://www.asm.com/Downloads/2021_ASMI_Annual_Report.pdf.
[307] NXP, "NXP in Korea" (visited 8 February 2023), https://www.nxp.com/company/about-nxp/worldwide-locations/korea:KOREA.
[308] NXP, "Annual Report 2021", (visited 8 February 2023), https://www.nxp.com/docs/en/supporting-information/2021-IFRS-STATUTORY-ANNUAL-REPORT.pdf.

Smaller Dutch companies also have connections with South Korea. Equipment manufacturer BESI, for example, operates a sales office in Seoul and aims to increase its penetration of the Korean market. BESI's revenue in 2021 in South Korea was 64 million euros (8.5 per cent of its total revenue).[309] Furthermore, Nearfield Instruments opened a subsidiary in South Korea in 2021 in order to support the introduction of its machines at Samsung, which in 2017 had invested in the Dutch company to develop further its equipment.[310] In 2021, Nearfield received further investment from a South Korean investor (Eugene Investment & Securities Co.).[311] In addition, Dutch biochemical company Corbion has an office in Seoul to support its sales to South Korean semiconductor companies, which increasingly value the use of bio-based chemicals.[312]

3. International positioning and connections

Geopolitical developments

South Korea finds itself, even more than many other countries, wedged between the technology ambitions of the United States and China. Both the US and China are pressuring Seoul to align with their country's interests, but South Korea is traditionally quite successful in avoiding picking one side over the other in the US–China rivalry. This is crucial, as Seoul relies on the United States for its security in the face of North Korean threats, while South Korea's economy is very dependent on China, as 30 per cent of South Korean exports are shipped to China or Hong Kong.[313]

However, this balancing act has become increasingly difficult to perform now that the rivalry between the two superpowers is intensifying. Recently, the South Korean government opted to align itself further with the US in the area of security, deploying an advanced American missile-interceptor defence system (named THAAD) and increasing its military cooperation both with Washington and Tokyo. China opposes these moves and considers them as running counter to its own security interests.

[309] BESI, "Annual Report 2021" (visited 8 February 2023), https://www.besi.com/fileadmin/data/Investor_Relations/_Semi__Annual_Reports/Annual_Report_2021.pdf.
[310] Innovation Industries, "Innovation Industries And Samsung Ventures Investment Corporation Invest In TNO Spin-Off Nearfield Instruments B.V.", 5 September 2017, https://www.innovationindustries.com/news/innovation-industries-and-samsung-ventures-investment-corporation-invest-in-tno-spin-off-nearfield-instruments-b-v; Paul van Gerven, "Nearfield Instruments richt Koreaanse dochter op", *High-Tech Systems*, 28 June 2021, https://hightechsystems.nl/artikel/nearfield-instruments-richt-koreaanse-dochter-op/.
[311] Computable, "12 mln voor chipmeettechniek Nearfield Instruments", 3 August 2021, https://www.computable.nl/artikel/nieuws/technologie/7224084/5182002/12-mln-voor-chipmeettechniek-nearfield-instruments.html.
[312] Corbion, "Contact Asia" (visited 8 February), https://www.corbion.com/en/About-Us/Our-company/Our-global-presence/Asia.
[313] The New York Times, "'Yankees, Go Home!': Seoul Gets Squeezed Between the U.S. and China", *19 October 2022,* https://www.nytimes.com/2022/10/19/world/asia/korea-china-us-thaad-missiles.html; WITS (World Bank), "Korea, Rep. Trade" (visited 8 February 2023), https://wits.worldbank.org/CountrySnapshot/en/KOR.

In response to THAAD, Beijing retaliated by restricting Chinese tourism to South Korea, as well as South Korean exports to China.[314]

As competition between China and the United States is increasingly tense in the area of technology, South Korea's semiconductor industry is particularly affected. First, President Biden is trying to convince Seoul to join his proposed initiative to increase coordination and collaboration between US allies in the semiconductor sector. The programme, dubbed the 'Chips 4 Alliance', is widely interpreted as not only serving to secure the supply of chips to the United States, but also as countering China's growing power in the industry.[315] Japan and Taiwan have also been invited to join this grouping and appear relatively open to joining forces with the US, while South Korea has expressed wariness.

Seoul's caution is understandable, since China strongly opposes the alliance (to which it was not invited) and is urging South Korea not to join. Chinese state media outlet *Global Times* has called the alliance a 'semiconductor barrier' against China and has stated that if South Korea joins the initiative, this would be equivalent to 'committing commercial suicide'.[316] Such language has to be taken seriously in Seoul, considering that almost 60 per cent of South Korean chips are exported to China.[317] In August 2022, South Korean Foreign Minister Park assured his Chinese counterpart that when South Korea meets with the United States on semiconductors, it is not intended to isolate any specific country.[318] Nonetheless, in December 2022, South Korean media outlets reported that South Korea was seriously considering joining the initiative.[319]

Another issue facing South Korea's semiconductor industry is the fact that the new US Chips Act (see chapter 3) restricts the operations of South Korean semiconductor companies in China. The Chips Act prohibits shipments to China of certain advanced semiconductor-related products that contain US technology or involve US personnel. This also applies to the Chinese facilities of foreign companies. Because of the Chips Act, South Korean companies such as Samsung and SK Hynix, which have extensive production facilities in China, need permission from the United States to ship some of the equipment used at their Chinese microchip fabrication plants (known as fabs). For now, both companies have received a one-year waiver regarding the restrictions.[320]

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[314] The New York Times, "'Yankees, Go Home!'".
[315] Arjun Gargeyas, „The Chip 4 Alliance Might Work on Paper"; Financial Times, „US struggles to mobilise its East Asian 'Chip 4' alliance".
[316] Global Times, "S.Korea should have courage to say 'no' to US coercion: Global Times editorial", 21 July 2022, https://www.globaltimes.cn/page/202207/1271044.shtml.
[317] He-rim Jo, "Minister confirms South Korea's participation in US-led chip alliance", *The Korea Herald*, 18 December 2022, https://www.koreaherald.com/view.php?ud=20221218000120.
[318] Esther Chung, "Park tries to assuage Wang on chips in Qingdao", *Korea JoongAng Daily,* 10 August 2022, https://koreajoongangdaily.joins.com/2022/08/10/national/diplomacy/korea-china-semiconductor/20220810170408001.html.
[319] He-rim Jo, "Minister confirms South Korea's participation in US-led chip alliance".
[320] Reuters, "Samsung gets one-year exemption from new U.S. chip restrictions on China – WSJ", 13 October 2022, https://www.reuters.com/technology/samsung-gets-one-year-exemption-new-us-chip-restrictions-china-wsj-2022-10-13/.

Despite this waiver, Samsung and SK Hynix are unable to bring all the equipment they want to their facilities in China. For example, the US regulations still require licences for the export of certain equipment from other companies, such as ASML, to entities in China.[321] This potentially obstructs SK Hynix's plans to upgrade one of its Chinese manufacturing sites with ASML's advanced EUV machines. How the US restrictions will unfold in practice is still unclear, although Washington is lobbying the Dutch government to block also the shipment to China of less advanced equipment (such as ASML's deep ultraviolet (DUV) machines).[322]

Another effect of the US Chips Act is that it offers large incentives for major semiconductor manufacturers around the world, including in South Korea, to invest in the United States. Samsung, for example, might benefit from these provisions with its investments in a semiconductor plant in Texas.[323] However, what complicates the situation is that a recipient of such benefits under the Chips Act is not allowed to expand its semiconductor manufacturing capabilities in China for ten years. This might pose problems for Samsung with its large facilities in China.[324]

Relevant political relations with other countries in the region

Japan is an important player for South Korea in the semiconductor sector and the two countries appear to complement one another. While South Korea is strong in chip manufacturing, Japan is strong in the equipment and advanced materials segments of the value chain. However, political relations between the two countries sometimes stand in the way of this complementary relationship.

In 2019, a trade dispute flared up when Tokyo strengthened export restrictions on certain high-tech goods to South Korea and downgraded South Korea's status as a trade partner in response to a ruling by South Korea's Supreme Court on compensations for Japanese activities during Japan's occupation of the Korean peninsula (1910–1945).[325] Among the restricted goods are three materials that are critical for semiconductor production and for which Japan has a dominant position in the global market.[326] This gave rise to an effort by South Korea to invest in domestic production of these items,

[321] Alexandra Alper and Karen Freifeld, "Exclusive: Samsung, SK Hynix to be spared brunt of China chip crackdown by U.S.", *Reuters*, 7 October 2022.
[322] Robyn Mak, "Chip dilemma will buy Beijing precious time", *Reuters*, 19 December 2022, https://www.reuters.com/breakingviews/chip-dilemma-will-buy-beijing-precious-time-2022-12-19/; Eun-jee Park and Ho-Jeong Lee, "U.S. grants waiver to SK hynix for tech transfers to China", *Korea JoongAng Daily* 12 October 2022, https://koreajoongangdaily.joins.com/2022/10/12/business/tech/Korea-US-export-control/20221012180226419.html.
[323] Eun-jin Kim, "Tax Cuts in the U.S. and Korea to Give Momentum to Samsung's Future Investment", *BusinessKorea*, 4 January 2023, http://www.businesskorea.co.kr/news/articleView.html?idxno=107165.
[324] Jae Chang and Andy Hong, "CHIPS Act: Outlook and Implications for South Korea", 24 August 2022, *KEI*, https://keia.org/the-peninsula/chips-act-outlook-and-implications-for-south-korea/.
[325] Ian Bremmer, "Why the Japan-South Korea Trade War Is Worrying for the World", *Time*, 3 October 2019, https://time.com/5691631/japan-south-korea-trade-war/.
[326] The Korea Herald, "S. Korea earmarks W841b for key materials, parts development", 3 February 2022, https://www.koreaherald.com/view.php?ud=20220203000584.

in order to decrease its dependence on Japan. In some cases, import dependencies on Japan did lessen, while some Japanese companies expanded their production capacity in South Korea in order to circumvent the restrictions.[327] However, South Korean companies continue to import most of the materials from Japan on a large scale. Samsung, for example, remains a crucial customer for Japanese material suppliers.[328]

In 2022, Tokyo and Seoul began an effort to improve their diplomatic ties under their new leaderships.[329] Apart from advanced materials, the connections with Japan are also strong in the area of equipment. In 2021, South Korean imports of such equipment from Japan grew to $6.3 billion USD worth, making it the top import by value.[330] In 2020, 26 per cent of the semiconductor equipment used by Samsung and other South Korean companies was supplied by Japanese businesses.[331]

China is another country with which the South Korean semiconductor industry has many connections. First, Chinese memory chip manufacturers are increasingly competing with those from South Korea.[332] Second, South Korea is very reliant on China as a sales market for semiconductors: almost 60 per cent of South Korean chips are exported to China, representing about 40 per cent of the total value of South Korean semiconductor exports in 2021.[333] Third, Samsung and SK Hynix both have very large manufacturing plants in China. 40 per cent of Samsung's NAND flash memory chip production takes place at its plant in Xi'an, which equals 10 per cent of global output.[334] SK Hynix produces 50 per cent of its dynamic random-access memory (DRAM) chips in Wuxi, representing 15 per cent of the world's production.[335]

Taiwan is mainly a competitor of the South Koreans' semiconductor industry. TSMC is, together with Intel in the United States, the only company with the capacity to compete with Samsung in the area of advanced chips. Considering that the South Korean industry is aiming to reduce its focus on the

[327] Eun-Jee Park and Young-min Kim, "Japanese firms start making photoresists in Korea", *Korea JoongAng Daily,* 2 July 2020, https://koreajoongangdaily.joins.com/2020/07/02/business/industry/photoresist-TOK-EUV/20200702200000423.html; Korea JoongAng Daily, "Korea significantly reduces dependence on Japan", 1 July 2021, https://koreajoongangdaily.joins.com/2021/07/01/business/economy/Japan-Trade-war-Ministry-of-Trade/20210701152200453.html.
[328] Hosokawa Kotaro, "South Korea struggles to decouple from Japan in key chipmaking materials", *Nikkei Asia*, 28 June 2022, South Korea struggles to decouple from Japan in key chipmaking materials - Nikkei Asia.
[329] Alastair Gale and Timothy W. Martin, "Japan and South Korea Seek Diplomatic Reset With Change of Leadership in Seoul", 26 April 2022, https://www.wsj.com/articles/japan-and-south-korea-seek-diplomatic-reset-with-change-of-leadership-in-seoul-11650966395.
[330] Hosokawa Kotaro, "South Korea struggles".
[331] Eun-jin Kim, "South Korea Still Heavily Dependent on Semiconductor Equipment from Japan", *BusinessKorea*, 7 September 2020, http://www.businesskorea.co.kr/news/articleView.html?idxno=51363.
[332] Samsung, "역동적 혁신성장을 위한 삼성의 미래 준비".
[333] He-rim Jo, "Minister confirms South Korea's participation in US-led chip alliance"; Ji-Eun Jeong, "Korean chip exports to China rise thirteenfold in 21 years", *The Korean Economic Daily*, https://www.kedglobal.com/economy/newsView/ked202208220014.
[334] Eun-jee Park and Ho-Jeong Lee, "U.S. grants waiver to SK hynix for tech transfers to China".
[335] Che Pan, "Tech war: SK Hynix executive says Korean chip maker may sell China fab under 'extreme' US pressure", *SCMP*, 26 October 2022, https://www.scmp.com/tech/tech-war/article/3197331/tech-war-sk-hynix-executive-says-korean-chip-maker-may-sell-china-fab-under-extreme-us-pressure.

memory chip market and grow in the more-advanced chip and foundry segments, competition with TSMC might very well only increase. The competition between Taiwan's TSMC and South Korea's Samsung and SK Hynix can also be affected by the geopolitical considerations of other companies. For example, when important foundry clients are looking to reduce their reliance on one company, they could therefore opt to become a customer of both Samsung and TSMC.[336]

Samsung also has plans to increase its presence in **Singapore**, where it has entered a joint venture with German company Siltronic to construct a new 2 billion euro 300nm manufacturing facility in the city-state by the end of 2024.[337] In **India**, Samsung has plans to expand semiconductor R&D facilities.[338]

4. Implications for the Dutch semiconductor sector

South Korea is an important semiconductor industry for the Netherlands. Samsung and SK Hynix are among the largest customers of equipment manufacturers such as ASMI and ASML. South Korea is also an important sales market for NXP, while ASML and ASMI collaborate with South Korean academic institutions. These connections are affected by geopolitical pressures, domestic government policies and regional relations in the following ways.

The South Korean government, together with the private sector, has committed itself to serious investments in the semiconductor sector, in particular in non-memory segments such as system chips and the foundry business. This could provide opportunities for Dutch equipment manufacturers to supply the new plants with much-needed equipment. Furthermore, although some memory chip manufacturers also make use of EUV machines, this technology is essential for producing the most advanced system chips. South Korea's turn towards system chips and the foundry business means that demand for this ASML technology could grow even further. This can also benefit other Dutch actors in these segments, now that South Korean companies will be looking for R&D partners.

Another potentially beneficial development for the Netherlands is South Korea's aim to decrease its dependence on Japan because of the two countries' highly political trade dispute, which exposed South Korea's reliance on Japan for certain semiconductor-related goods. Seoul is already diversifying

[336] Eun-jin Kim, "Samsung and TSMC Competing to Secure Foundry Customers", *BusinessKorea,* 1 December 2022, http://www.businesskorea.co.kr/news/articleView.html?idxno=105184.
[337] Sharon See, 'Global Chipmakers' Investments in Singapore', *The Business Times*, 22 July 2022, https://www.businesstimes.com.sg/government-economy/global-chipmakers-investments-in-singapore.
[338] Samsung, "Samsung Strengthens its India Commitment, Plans to Hire around 1,000 Engineers from IITs & Top Engineering Institutes to Work on Cutting-Edge Technologies like AI, ML, IoT & Deep Learning", 30 November 2022, https://news.samsung.com/in/samsung-strengthens-its-india-commitment-plans-to-hire-around-1000-engineers-from-iits-top-engineering-institutes-to-work-on-cutting-edge-technologies-like-ai-ml-iot-deep-learning.

its supplies of many materials.[339] Its diversification strategy away from Japan could provide opportunities for Dutch equipment makers, since Japan is also strong in this segment of the supply chain. Furthermore, South Korea's government and private sector are investing in domestic production capabilities for materials and equipment in order to overcome dependency on Japan. This, similarly, provides opportunities for Dutch companies, which can collaborate with South Korean partners on R&D or on joint ventures in these segments.

However, the political developments that affect the South Korean semiconductor industry also have potentially negative effects for Dutch players in this sector. The fact that SK Hynix and Samsung are no longer able to expand their facilities in China without having to consider restrictions by the United States could damage Dutch equipment suppliers. Obviously, it is unfortunate for ASML that some of their biggest non-Chinese customers have large facilities in China. On the other hand, if Washington manages to persuade these companies to open plants in the United States instead, this could make up for the potential losses of these equipment suppliers.

Another potential negative effect for the Netherlands is that South Korea's investments in domestic production of semiconductor equipment in order to lessen foreign dependencies could, in the long run, mean more competition from South Korea in the equipment market. However, Dutch equipment manufacturers argue that they will continue to invest in order to stay ahead of any competition and continue to lead this segment of the industry.

[339] Joyce Lee and Hyunjoo Jin, "South Korea government, Samsung team up for self-sufficiency after Japan export curbs on chip material", *Reuters*, 14 September 2020, https://www.reuters.com/article/us-southkorea-japan-chip-analysis-idUSKBN26501U.

Taiwan

Tycho de Feijter (LeidenAsiaCentre)

Taiwan is a major player in the global semiconductor market. The island has a highly developed and advanced semiconductor industry, with companies such as TSMC (Taiwan Semiconductor Manufacturing Company) and UMC (United Microelectronics Corporation) being central players. These companies provide a wide range of products and services to customers in various industries, including computers consumer electronics and telecommunications sectors. Additionally, Taiwan is also a major hub for the design and manufacturing of semiconductor equipment and materials. This industry plays a vital role in the Taiwanese economy and has been a key driver of Taiwan's technology and economic development.

Taiwan has a large number of foundries, which are the companies that manufacture semiconductor devices commissioned by companies that design these chips. Foundries provide a range of services, including manufacturing, testing, and packaging of semiconductor devices. TSMC is the largest foundry company in the world and specialises in the manufacturing of advanced process nodes, such as 7nm, 5nm and 3nm. UMC is also a major player in the foundry market and specialises in the manufacturing of a wide range of process nodes.

Taiwanese foundries are known for their advanced technology and high quality, making them a popular choice for companies in the semiconductor industry. They have a strong network of suppliers, which allows them to provide customers with a one-stop shop for all their semiconductor manufacturing needs. Taiwanese foundries are also playing a vital role in the production of cutting edge technologies like high-performance computing, internet of things, artificial intelligence, and 5G.

1. Government

The government of Taiwan has played an important role in the development of the country's semiconductor industry. It has implemented various policies and initiatives to support the growth and competitiveness of the industry, such as:

- Providing financial assistance and tax incentives for companies in the semiconductor industry
- Investing in research and development to promote innovation and the development of advanced technology
- Building infrastructure and facilities to support the semiconductor industry, such as technology parks and research centres

- Encouraging collaboration and partnerships between industry, academia, and government to drive innovation and promote the development of new technologies
- Promoting the adoption and integration of new technologies such as Internet of Things (IoT), 5G and AI in various sectors to maintain the competitiveness of Taiwan's economy.

The government of Taiwan also works closely with the private sector to identify and address industry challenges and opportunities. This government-industry collaboration has been a key factor in the success of Taiwan's semiconductor industry, and is likely to continue to play an important role in the industry's future growth and development.

2. Overview of the industry

There are several risks that the Taiwanese semiconductor industry faces, including:

1. Dependence on a small number of key customers: Many Taiwan semiconductor companies rely heavily on a small number of key customers for a large portion of their revenue. This can make them vulnerable to changes in demand or shifts in the business strategies of these customers.
2. Strong competition: The semiconductor industry is highly competitive, with companies from different regions vying for market share. Taiwanese semiconductor companies are competing with companies from countries such as South Korea, Japan, and China.
3. Intellectual property risks: The semiconductor industry is heavily reliant on intellectual property (IP) and proprietary technology. Taiwanese semiconductor companies may be at risk of IP infringement, theft, or misappropriation.
4. Political risks: Taiwan is a politically sensitive area, and any political developments or changes in relations between Taiwan and other countries can have a significant impact on the Taiwanese semiconductor industry.
5. Supply chain risks: Taiwan’s semiconductor industry relies heavily on a global supply chain and disruptions in materials, equipment, or logistics can have a significant impact on the production and delivery of products.
6. Technology risks: The semiconductor industry is rapidly evolving, and companies must continuously invest in research and development to stay competitive. Failure to do so can put a company at a disadvantage in the market.

To mitigate these risks, companies in the Taiwanese semiconductor industry are diversifying their customer base, investing in advanced technology, and focusing on IP protection, among other strategies. Additionally, the Taiwanese government also actively works on risk mitigation plans to ensure the stability and competitiveness of the Taiwanese semiconductor industry.

One specific risk for The Taiwanese semiconductor industry is the potential for a military conflict between China and Taiwan, which has several negative consequences:

1. First, Taiwan's semiconductor industry is closely tied to mainland China, as many of the companies in the industry have production facilities or supply chains in China, and many of the industry's customers are based there as well. In the event of a military conflict, these ties could be severed, causing disruptions in production and supply chain, and resulting in losses for Taiwan's semiconductor companies.
2. Second, a military conflict could also lead to economic sanctions or trade restrictions on Taiwan, which could have a negative impact on the country's economy and the semiconductor industry.
3. Third, a war could also result in severe damage to the infrastructure and facilities, which could take a long time to recover, resulting in long-term impacts on the industry.
4. Fourth, the uncertainty of a potential war could also discourage foreign investment in Taiwan, which could impede the growth of the semiconductor industry.

Given the importance of the semiconductor industry to Taiwan's economy, the government is likely to take steps to protect the industry in the event of a military conflict with China. However, the industry would still face significant risks and challenges in such a scenario.

The defence industry is one of the potential areas where Taiwan's semiconductor industry can play a role. Semiconductors are an essential component in a wide range of defence systems, including radar, electronic warfare, and communication systems.

- Taiwan's semiconductor industry has a strong reputation for producing high-quality, advanced technology products, which makes it well-suited for the defence industry.
- Taiwan's government has been actively promoting the development of the defence industry, including the development of indigenous defence capabilities. As part of this effort, the government has been encouraging the participation of the semiconductor industry in the development of defence systems.
- Taiwan's semiconductor companies have been involved in various defence projects, including the development of radar systems, electronic warfare systems, and communication systems.
- Taiwan's semiconductor industry has also been working with the defence industry on the development of new technologies, such as AI, IoT, and 5G, which have applications in defence systems.
- Taiwan's government also has been actively working on securing the supply chain and protecting the intellectual property to ensure the stability and competitiveness of the Taiwan semiconductor industry, which also includes the defence industry.

Major companies in the Taiwanese semiconductor sector

Taiwan Semiconductor Manufacturing Company (TSMC) is a foundry company based in Taiwan and one the world's largest semiconductor companies.[340] TSMC is a foundry, which means that it manufactures semiconductor commissioned and designed by other companies. TSMC's customers include major companies such as Apple, Qualcomm, and Nvidia. TSMC's focus is on the production of cutting edge technology like high-performance computing, internet of things, artificial intelligence, and 5G. TSMC has been investing heavily in R&D to stay competitive in the industry. TSMC has been actively expanding its operations globally, including building new manufacturing facilities in the United States, to diversify its production base, and to reduce the dependence on China. TSMC has 10 fabs in Taiwan. These fabs are mainly located in two cities: Hsinchu and Tainan. In 2022, TSMC announced that a new fab in the city of Kaohsiung would start operations in 2024.[341] TSMC's most advanced 5 and 3 nm chips are made in Tainan.[342]

United Microelectronics Corporation (UMC) is a semiconductor foundry that manufactures integrated circuits (ICs) for various industries, including consumer electronics, communications, automotive, and industrial. UMC's products include a wide range of ICs, including microprocessors, memory chips, digital signal processors, and power management ICs. UMC also provides services such as design support, technology development, and wafer fabrication. UMC's customers include major companies such as Marvell, Broadcom, and MediaTek. UMC was founded in 1980 as a spin-off of Taiwan's government-backed Industrial Technology Research Institute (ITRI, see below).

Powerchip Semiconductor Manufacturing Corporation (Powerchip/PSMC) is a semiconductor company founded in 1994 and based in Hsinchu City. It offers foundry services, design, and test services. It is one of the largest DRAM memory chips manufacturers in Taiwan. The company provides a range of products, including mobile DRAM, server DRAM, and specialty DRAM, for customers in the computer, consumer electronics, and communications industries.

Research and development

Taiwan's semiconductor industry has a strong relationship with universities and research institutions, which plays an important role in the development of advanced technology and the training of a skilled

[340] NASDAQ, "An Overview of the Top 5 Semiconductor Foundry Companies", 1 October 2021.
[341] Taipei Times, "TSMC starts construction of new fab in Kaohsiung", 22 November 2022.
[342] TSMC official website, "Foundry technology", https://www.tsmc.com/english/dedicatedFoundry/technology/logic/l_3nm.

workforce. This relationship allows for the transfer of knowledge and technology between academia and the industry, and helps to ensure a steady supply of skilled workers for the industry.

- Taiwan's semiconductor companies have significant R&D capabilities and invest heavily in R&D to stay competitive in the industry. They invest in the development of new technologies, such as advanced process nodes, and in the improvement of existing technologies to increase efficiency and reduce costs.
- Taiwan has a number of universities and research institutions that specialise in the field of semiconductors and related technologies, such as National Taiwan University, National Tsing Hua University, and National Chiao Tung University.
- These institutions have a strong focus on research and development in advanced technologies, such as 5G, IoT, and AI, and have been working with various companies and organizations to develop and implement these technologies.
- Taiwan's universities and research institutions have a strong collaboration with the industry, with many professors and researchers working on projects with companies such as TSMC, UMC, and Powerchip. This allows for the transfer of knowledge and technology between academia and the industry.
- The universities also have a strong focus on training the next generation of semiconductor engineers and researchers, which helps to ensure a steady supply of skilled workers for the industry.
- Taiwan's government also encourages and funds research and development in the field of semiconductors and related technologies, in order to promote innovation and the development of advanced technology.

The Industrial Technology Research Institute (ITRI) is a government-sponsored research institute in Taiwan. It conducts R&D in various fields such as electronics, materials, systems and communication technologies. The aim of ITRI is to promote technological innovation and industrial competitiveness in Taiwan. ITRI also assists with the development of defence technologies, mainly in the fields of communication, information security, and various inspection & testing programs.[343] ITRI's semiconductor division focuses on developing advanced semiconductor technologies and solutions for various applications.[344] Some of their areas of research and development include advanced process technologies for manufacturing semiconductors, design of integrated circuits, and the development of advanced packaging solutions. ITRI has close connections to the local semiconductor industry. There

[343] Global Security – ITRI. & ITRI Announcements - "Ministry of National Defense 5G Private Network Design Planning and Research and Development" plan, visited 8 February 2023; Industrial Cooperative Development Report under the Taiwan Ministry of National Defence and the Ministry of Economic Affairs.
[344] ITRI website – "Intelligentisation Enabling Technology, Semiconductor" visited 8 February 2023, https://www.itri.org.tw/english/ListStyle.aspx?DisplayStyle=01&SiteID=1&MmmID=1071732317047353240.

are many joint research projects between ITRI and various chip makers. UMC was even established at ITRI, and spun off in 1980.

Industrial Technology Investment Corporation (**ITIC**) is an investment firm wholly owned by ITRI.[345] ITIC invests in high-tech companies active in semiconductors, precision machinery, opto-electronics, biotech, automotive, and other sectors. The firm has invested in various Taiwanese semiconductor companies, including: UMC, APAQ Technology, and GlobalWafers.[346]

The Taiwan Semiconductor Research Institute (TSRI) was founded in 2019 after a merger of two earlier semiconductor research centres. TSRI is a part of the larger government-backed National Applied Research Laboratories (NARLabs). TSRI functions as both a research institute and as a service-provider for the semiconductor industry. In its introduction, TSRI says: "An integrated research environment for related fields of study in Taiwan is urgently required to enhance the overall cultivation of quality talents in response to the introduction of the 3-nm node, [several other new technologies], and challenges posed by countries including European countries, the United States, Japan, and South Korea. "

Connections with the Netherlands

Overall, the relationship between Taiwan and the Netherlands in the semiconductor industry is not as significant as other Taiwanese relationships in the sector, such as the one with the United States, but it has been growing in recent years and has the potential for further growth in the future.

- The Netherlands has a strong semiconductor industry, which is focused on research and development, rather than manufacturing. This has led to some cooperation between Dutch and Taiwanese companies in terms of technology transfer, knowledge sharing, and joint research projects.
- Some Taiwanese companies have established a presence in the Netherlands, mainly to access the European market and to have better access to the Dutch semiconductor ecosystem.
- The Netherlands is also an important hub for the semiconductor equipment and materials industry, which allows Taiwan's semiconductor companies to access the latest equipment and materials.
- Taiwan and the Netherlands have signed a bilateral investment agreement which allows the companies of both countries to invest in each other's economies more easily.

[345] ITIC official website, visited 8 February 2023; CSIS, "The Pillars Necessary for a Strong Domestic Semiconductor Industry", 20 May 2022.
[346] ITIC official website, "Portfolio", visited 8 February 2023.

- Taiwan has also been actively seeking to expand its semiconductor industry relationships with European countries, including the Netherlands, to diversify its partnerships, and reduce the dependence on China and the United States.

TSMC was founded in 1987 as a joint venture between Dutch electronics company Philips, the Taiwan government, and several local investors.[347] Initially, TSMC mainly manufactured chips for Philips. Later, it expanded its sales to other customers. When TSMC was founded, Philips owned 28% of the shares.[348] Starting in the early 2000s, Philips started to reduce its stake in TSMC, and in 2008 Philips sold its final block of shares.[349] TSMC and Philips have had collaborations in research and development projects in the semiconductor industry. TSMC has also supplied semiconductor chips to Philips for use in its products. TSMC is one of the major customers of ASML and uses its advanced lithography systems to manufacture semiconductor devices with smaller feature sizes and higher performance. TSMC and ASML have a strategic partnership, in which they work together to develop and implement new technologies, such as EUV (extreme ultraviolet) lithography, which allows for the production of smaller and more advanced semiconductor devices.

ASML sold its first lithography machine to Taiwan in 1988. In 2003, it established a Taiwanese headquarters in Hsinchu. In its 2021 annual report, ASML says it will continue to expand its operations in Taiwan. Taiwan is already ASML's largest market worldwide. In 2021, customers in Taiwan represented 39.4% of the company's 2021 total net sales. That represented a net sales number of $7.327 billion.[350] Within Taiwan, TSMC is ASML's biggest customer.[351] ASML operates facilities in Taiwan, including: manufacturing plants in Linkou and Tainan for system refurbishment and for optical metrology systems, a 'Global EUV Training Centre'[352], a repair centre, facilities for metrology and inspection system assembly, and a global support centre. TSMC employs about 3600 people in Taiwan.[353]

In the risk category 'Political', ASML says about Taiwan: "Changes in relations between Taiwan and the People's Republic of China, Taiwanese government policies, and other factors affecting Taiwan's political, economic or social environment could have a material adverse effect on our business, financial condition and results of operations." ASML employs only 3% of its total R&D staff in Taiwan, the same as in China. But ASML's Taiwan operations own 5% of its total IP portfolio patents. The rest,

[347] Any Silicon, "History and Milestones of TSMC", 11 November 2019.
[348] SemiWiki, "A Brief History of TSMC", 8 February 2012.
[349] PC World, "Original TSMC Investor Philips Sells off Final Shares"14 August 2008.
[350] ASML 2021 annual report, p. 117 and 189, https://www.asml.com/-/media/asml/files/investors/financial-results/a-results/2021/asml-annual-report-us-gaap-2021-unsvf2.pdf?rev=dc3209ddcdd045589fa34b43e30e6cbf
[351] Reuters, "ASML shares fall 9% after Taiwan customer says it's cutting capital spending", 13 October 2022.
[352] ASML press release, 20 August 2020.
[353] ASML, "Careers", visited 8 February 2023.

95%, is owned by ASML in the Netherlands. ASML has several educational projects in Taiwan, some in cooperation with Taiwanese educators. These projects train teachers and students, and are aimed at improving "basic scientific knowledge".[354]. ASML also donated to scientific programs and runs a scholarship program in Taiwan.

ASMI sells chip-making equipment in Taiwan. Its main customers are TSMC and UMC. ASM has three sales & service facilities in Taiwan but it does not manufacture there.

NXP has four facilities in Taiwan, for design, manufacturing, and sales. NXP is mainly active in the automotive sector in Taiwan. The manufacturing (back-end) focuses on technology and products in the fields of automotive (car-access, in-vehicle networking, ADAS), NFC, and Mixed-Signal & Power. TSMC produces semiconductors designed by NXP, including 16 nm and 5 nm radar and vehicle-network chips.[355] NXP runs several joint ventures in Taiwan and recently announced two new ones: In mid-2022, NXP announced it would form a joint venture with Taiwanese electronics firm Invented to create an "ecosystem" for automotive electronics.[356] Also in mid-2022, NXP and Taiwanese electronics & manufacturing firm Foxconn announced they would jointly develop "platforms for a new generation of smart-connected vehicles".[357] Foxconn is best known for producing iPhones in China, but the company also has an automotive division. It wants to expand to contract-car manufacturing and launch its own line of vehicles as well.

3. International positioning and connections

The relationship between Taiwan and the **United States** has been a significant factor in the development and success of the Taiwan semiconductor industry. The United States is one of Taiwan's major trading partners and a major customer for Taiwan's semiconductor products. Overall, the relationship between Taiwan and the United States has been positive for the Taiwanese semiconductor industry and is likely to continue to play an important role in the industry's future growth and development.

- United States companies such as Apple and Qualcomm are among the major customers of Taiwan's semiconductor industry. This has helped Taiwan's semiconductor companies to grow and become major players in the global market.
- The US government has also provided Taiwan with financial and technical assistance to support the development of its semiconductor industry. This assistance has helped Taiwan to

[354] ASML 2021 annual report p. 79 and 138.
[355] Taiwan News, "Taiwan's TSMC working with NXP to release 5nm automotive chip", 25 May 25 2022.
[356] Digitimes, "NXP, Inventec team up for automotive electronics ecosystem in Taiwan", 5 August 2022.
[357] Taipei Times, "Hon Hai, NXP partner to enhance EV development", 22 July 2022.

build infrastructure and develop advanced technology, which has been key to the industry's success.

- The US government has also worked to promote Taiwan's participation in international organizations and has supported Taiwan's participation in various trade agreements, which has helped Taiwan's semiconductor industry to access global markets.
- The US government has also been a vocal supporter of Taiwan's political and economic independence, which has helped to provide stability and predictability for Taiwan's semiconductor industry.
- However, the US government has also been increasing its pressure on Taiwan to reduce its reliance on China, as Beijing has been becoming more assertive on the international stage.

In July 2022, TSMC completed the initial construction phase of its first fab in the United States, near Phoenix in Arizona. The 12 billion USD plant was completed in less than a year, which is very quick for US standards, underlining the importance of the project.[358] Currently, TSMC is outfitting the plant with chip-making tools from, among others, ASML, Applied Materials, KLA, Lam Research, and Tokyo Electron. The fab will mainly produce 5 nm chips, with production set to start in early 2024.

But that is just the beginning. In late 2022, TSMC announced it intended to expand the facility with a second production line and with tools to produce 3 nm chips. The added investment is 28 billion USD, bringing the total investment of TSMC in the Arizona project to 40 billion USD.[359]

The Chinese government has not officially responded to TSMC's investment in the US. But various 'opinion/editorial' pieces and news articles in state-media make clear that Beijing is not happy. Fuzzily enough, the various experts quoted in the articles are mainly expressing their worries about Taiwan losing its edge in chip-making to the US. This seems intended to stir up more division in Taiwan, where opinions about the US investment are divided. A nice example is the headline of an editorial in Global Times: "Alarm is sounded after TSMC becomes 'USSMC'."[360] At the same time, media articles also try to frame the move as a disruption of global supply chains. For example: "The US' selfishness behind TSMC's manufacturing outflow will only further disrupt the international supply chain, deepen existing conflicts of interest among its allies and undermine its influence in the Asia-Pacific region."[361]

[358] Tom's Hardware, "TSMC Completes Construction of 5nm Fab 21 in Arizona", 29 July 2022.
[359] Anand Tech, "TSMC Unveils Major U.S. Fab Expansion Plans: 3nm and $40 Billion by 2026", 7 December 2022.
[360] Global Times, "Alarm is sounded after TSMC becomes 'USSMC': Global Times editorial", 9 December 2022.
[361] Global Times, "TSMC set to expand US investment under political pressure, but faces huge pains", 6 December 2022.

In January 2023, TSMC said it was considering a fab in **Europe**, "focusing on automotive-specific technologies based on the demand from customers and level of government support"[362]. Earlier, TSMC was more specific, saying it was considering a fab in Germany.[363]

The risks of a military conflict between **China** and Taiwan have been discussed above. Despite the high political tensions, the economic relationship in the semiconductor industry is strong, and Taiwanese companies have many connections with China.

TSMC has a complex relationship with China. TSMC has production facilities in China and many of the company's customers are based in the country. This has led to a strong economic relationship between TSMC and China. However, the Chinese government has been actively seeking to develop its own semiconductor industry and reduce its dependence on foreign companies, such as TSMC. This has led to increased competition for TSMC in the Chinese market. In recent years, the Chinese government has also been tightening regulations and increasing scrutiny of foreign companies operating in China, including TSMC. This has led to concerns about the stability and predictability of the business environment for TSMC in China. Recent US sanctions make it more difficult for TSMC to operate in China, and the company may be forced to cancel contracts with Chinese customers that are blacklisted by the US.

TSMC has two fabs in China, in Nanjing and Shanghai. The company names are TSMC Nanjing Company Limited and TSMC China Company Limited (Shanghai) respectively. Due to new US sanctions, it has become increasingly difficult for TSMC to send chimp-making equipment to these fabs. In October 2022, the US granted TSMC a "one year waiver" to send equipment to its fabs in China.[364] Whether this waiver will be extended is yet unknown. If not, operating these fabs will become much harder in the near-future.

The $3 billion Nanjing fab was completed in 2017 and mainly produces 14, 16 and 28 nm chips.[365] In 2021, TSMC announced a US$2.87 billion plan to expand its 28 nm line, a move that worried both Beijing and Taipei. Beijing because the expansion would mean more competition for local Chinese chip makers and Taipei because it doesn't want TSMC to outsource more production to the Chinese mainland.[366] A Chinese IT expert, quoted by a South Korean newspaper, said: "TSMC is going to dump 28-nm process semiconductor products in China. This will pose a threat to Chinese semiconductor

[362] Bits & Chips, "TSMC is mulling an automotive fab in Europe", 13 January 2023.
[363] Bits & Chips, "TSMC mulls building a fab in Germany", 28 July 2021.
[364] South China Morning Post, "TSMC gets one-year equipment waiver for mainland China chip plant", 13 October 2022.
[365] Securities and Exchange Commission, "Taiwan Semiconductor Manufacturing Company Ltd.", 28 March 2016.
[366] South China Morning Post, "Why has TSMC's Nanjing expansion plan stirred up a hornets' nest in Beijing and Taipei", 1 May 2021.

companies."[367] However, the project was eventually approved by the Taiwanese government and the Chinese government didn't officially object. [368] The new expansion is expected to begin operations by mid-2023. Partially in response to TSMC's expansion, China's SMIC announced in September 2021 it would build a new $8.87 billion fab in Shanghai.[369] That is also where TSMC's second China-fab is based.

TSMC's Shanghai fab is much older. It was completed in 2004 and expanded in 2010.[370] This fab mainly makes less-advanced 180 nm chips.[371] However, this may be a blessing in disguise, as US sanctions against China currently do not include 180 nm chips. The US has not announced an exact 'sanction size', but the current unofficial sanction-limit is at 14 nm. However, this will probably be expanded to 28 nm. That means that TSMC's Nanjing fab is in trouble, as discussed above, but the Shanghai fab is not, at least not yet.[372]

UMC also has a significant presence in China. UMC has manufacturing facilities in Xiamen and Suzhou and a design centre in Shanghai. These facilities in China allow UMC to serve the growing demand for semiconductor products in the Chinese market, as well as provide support for UMC's global customers who have operations in China.

Hejian Technology Corporation (HJTC) is a chip company founded in 2003 and based in Suzhou. In 2013, HJTC was fully acquired by Taiwan's United Microelectronics Corporation (UMC), making it one of the very few Chinese chip makers with 100% foreign ownership. HJCT makes relatively basic chips, the most advanced is 110 nm, that are mainly used in consumer electronics and automotive applications.[373]

United Semi[374] was established in 2014 as a joint venture between UMC, the city government of Xiamen, and several local-state owned electronics companies.[375] Over the years, UMC enlarged its stake in United Semi, and in 2022 it said it would take full control and turn United Semi into a 100% owned subsidiary in 3 years.[376] United Semi makes 40-28 nm chips.

Nexchip Semiconductor Corporation (Nexchip) is a foundry joint venture between Hefei City Construction Investment Holding and PSMC, founded in 2015 and based in Hefei. Nexchip makes 90 -

[367] Business Korea, "TSMC Nanjing Plant Heightens Tension between China and Taiwan", 6 May 2021.
[368] Taipei Times, "Taiwan approves TSMC's plan to expand in Nanjing", July 31, 2021.
[369] Seeking Alpha, "SMIC building $9 billion Shanghai chip fab in capacity battle with TSMC", 3 September 2021.
[370] EE Times, "TSMC signs Shanghai wafer fab deal, says report", 6 June 2003.
[371] Used for, among others, applications in automotive, industrial, controls, and aerospace.
[372] Twitter, Wen-Yee Lee 李玟儀., July 29, 2022, https://twitter.com/Wenyee_Lee/status/1553072449285066753.
[373] Evertiq, "UMC's Hejian subsidiary resumes production", 24 February 2022.
[374] Also known as United Semiconductor or United Semiconductor Xiamen Co. Ltd.
[375] UMC, press release, 16 November 2016.
[376] Digitimes, "UMC to make United Semi into 100% owned subsidiary in 3 years", 28 April 2022.

150 nm chips. Hefei City Construction Investment Holding (HFJTJT) is a state-owned investment holding company based in Hefei, Anhui Province, China. The company is involved in various construction and real estate development projects. The main aim of the company is to promote economic development in Hefei and the surrounding areas.[377]

Taiwan and **Japan** have a competitive relationship in the semiconductor industry, as both countries have developed advanced technology and have significant market share in the industry.

- Taiwan's and Japan's semiconductor industries are complementary, with Taiwan focusing more on the manufacturing of semiconductor devices and Japan focusing more on the development of advanced technology and the design of semiconductor products.
- Both Taiwan and Japan have been investing in the development of new technologies, such as 5G, IoT, and AI, and have been working with various companies and organizations to develop and implement these technologies.
- Taiwan and Japan have been actively seeking to expand their semiconductor industry relationships with other countries and regions, such as the US and Europe, to diversify their partnerships and reduce their dependence on China.
- Both countries have also been working on technology transfer agreements with each other, to share their expertise and knowledge and develop mutually beneficial relationships.

Taiwan and **South Korea** have a competitive relationship in the semiconductor industry, as both countries have developed advanced technology and have significant market share in the industry.

- Taiwan and South Korea have a similar focus on the production of cutting edge technology like high-performance computing, internet of things, artificial intelligence, and 5G.
- South Korea's semiconductor industry is heavily dependent on Samsung, which is the largest player in the industry and generates significant revenue for the country. Taiwan's semiconductor industry is more diversified, with a number of companies with different specialties and capabilities.

TSMC has a significant presence in **Singapore**. The company has been operating in Singapore since 1984, and currently has multiple fabs in the country. TSMC's Singapore fabs produce a wide range of semiconductor products, including microprocessors, memory chips, and image sensors. The company's Singapore facilities are considered to be some of the most advanced and efficient in the world, and are equipped with the latest semiconductor manufacturing technologies, including the latest 5nm and 3nm processes.

[377] Hefei City Construction Investment Holding. Official homepage.

TSMC's Singapore operations are an important part of the company's global semiconductor operations, and the company has been investing heavily in the country to expand its production capacity and capabilities. In May 2022, media reports claimed TSMC was considering a new "multibillion-dollar factory" in Singapore, partially funded by the Singapore government.[378] The facility would make 7 to 28 nm chips. In addition to production, TSMC also has a strong research and development presence in Singapore, with a dedicated R&D centre in the city-state. The company has also been working closely with the Singaporean government and local universities to support the development of the country's semiconductor industry and to nurture talent.

Systems on Silicon Manufacturing Company (SSMC) is a Singapore-based joint venture between Dutch NXP and TSMC, founded in 1998. SSMC makes 110 - 250 nm chips for automotive, RFID, smartphone, and IoT applications.

UMC has one fab in Singapore, making 130-40 nm chips, and a R&D facility. In early 2022 the company announced it would invest 5 billion USD in a second fab in the country. This new fab will start production in 2024 and make 22-28 nm chips for 5G, IoT, and automotive applications.[379]

Systems on Silicon Manufacturing Company (SSMC) is a Singapore-based joint venture between Dutch NXP and TSMC, founded in 1998. SSMC makes 110 - 250 nm chips for automotive, RFID, smartphone, and IoT applications.

TSMC has been exploring the possibility of setting up operations in **India**. TSMC has reportedly been in talks with the Indian government and local partners to explore the possibility of setting up operations in India.[380]

In January 2023 Powerchip officially announced that it is in "preliminary talks" with several Indian companies about jointly producing chips in India.[381] One of the possible partners is reportedly the Tata Group, which said in December 2022 that it wants to produce chips in India either alone or via a partnership.[382]

[378] The Business Times, "World's No. 1 chipmaker TSMC eyes multibillion-dollar plant in Singapore", 23 May 2022.
[379] Businesswire, "UMC Announces New 22nm Wafer Fab in Singapore", 24 February, 2022.
[380] Bloomberg, "India Woos Intel and TSMC to Set Up Local Semiconductor Plants", 26 April 2022.
[381] Moneycontrol, "Taiwanese chipmaker Powerchip in talks with Indian players to help build new plants", 12 January 2023.
[382] Outlook India, "Tata Group To Soon Begin Semiconductor Chip Manufacturing In India: Report", 9 December 2022.

4. Implications for the Netherlands

Dutch companies have a strong presence in Taiwan. However, any heightening of tensions between Taiwan and China and/or between China and the US will have an immediate effect on their operations. ASML especially seems vulnerable to disturbances. US sanctions make it harder for Taiwanese foundries to serve Chinese customers, which over time may reduce demand for specific chip-making equipment. NXP seems less vulnerable, it sells directly to the booming automotive supply chain and has partnerships with several Taiwanese companies. But again, new restrictions on trade or an escalating trade war could risk NXP's operation in Taiwan.

5. Conclusions

Based on the discussions in the country chapters, it is possible to draw a few general conclusions about the (geo)politicisation of the semiconductor industry in Asia and its impact on the Dutch sector, although doing so is challenged by the complexities of the semiconductor value chain. While the segments of this value chain are actually quite straightforwardly divided among different countries in the region, this nonetheless results in complicated fragmentations and relationships.

This complexity is illustrated by the fact that, according to some acconts, China is both the world's largest exporter and importer of semiconductors, while Chinese semiconductor companies capture only a relatively small market share. Such situations are possible because many companies only design chips and outsource the actual manufacturing to foreign manufacturers, which might in turn operate manufacturing plants in a third country. Who is then actually producing these semiconductors, and who is exporting them?

Moreover, despite public attention focusing on cutting-edge chips, there are many types of semiconductors. Less-advanced chips are also in high demand and indispensable. Despite these complexities, the following conclusions can be drawn, albeit cautiously.

The Asian semiconductor industry and politics

The Asian semiconductor industry has always been a theatre for politics. It was never a globalised free market and the US–China tech rivalry is only the latest example of politics affecting the industry. Historically, many governments in Asia, from Japan to Singapore, have played a very active role in supporting the development of the semiconductor sector in their country through investments, tax benefits and other encouraging measures. More recently, the governments of China and now also India have adopted such strategies as well. Such active government support predates the recent political priority that Washington gives to semiconductors. However, it is clear that the US Chips Act set in motion a new wave of investment plans by Asian governments to ensure that their industry does not fall behind.

Political relations between countries in the region have also already shaped the industry for many decades. For example, when the US industry and government felt threatened by the dominant position of the Japanese semiconductor industry in the 1980s, they pressured Tokyo to sign agreements that were unfavourable to Japanese companies. South Korean enterprises were, in turn, able to benefit from these conditions and began to take over Japan's market share in memory semiconductors. Much later, political friction over an unrelated historical issue between Seoul and

Tokyo resulted in Japan restricting the export of semiconductor materials to South Korea, which in response invested in phasing out its dependence on Japan in the semiconductor industry. It appears that the nature of the semiconductor industry, which is crucial for modern technologies and whose value chain is fragmented among countries, has always made it susceptible to political intervention.

Moreover, the US–China tech rivalry, specifically in the semiconductor industry, is reshuffling the political relations between countries in Asia, as well as between the region and the Netherlands. Countries such as South Korea and Taiwan have for a long time quite successfully balanced Chinese and American demands, benefiting from what both sides could offer. They are now being heavily pressured by Washington to pick a side more distinctly because of the US semiconductor blockade of China. These countries appear to be giving in, thus seriously deteriorating their relationship with Beijing.

Furthermore, relations between countries, which have sometimes historically been problematic, might become closer, both because of pressure from the US to collaborate on semiconductors and because of these countries' own interest to balance China's growing power in general. Japan and India have found one another in the Supply Chain Resilience Initiative, while the Chips 4 Alliance is enhancing coordination among Seoul, Tokyo and Taipei. India's role as a potential alternative to China is highlighted, as is Singapore as a relatively neutral space where Chinese and foreign players can continue to meet.

On the bilateral level, certain relations also appear to be improving, with the new administrations of Japan and South Korea seeking rapprochement, while Taipei and Tokyo are exploring the further expansion of Taiwanese semiconductor companies in Japan. The Netherlands and South Korea have sought to increase collaboration in the semiconductor sector in the face of the US–China rivalry. Recently, the Netherlands also appeared to have coordinated with Japan, as both countries at the same moment signed onto the US plan to curb exports of semiconductor equipment to China.

Implications for Dutch interests in the Asian semiconductor industry

The Dutch semiconductor sector is highly connected with the industries of countries analysed in this study. Semiconductor equipment companies and chip producers from the Netherland have major customers in China, Taiwan, Singapore and South Korea, operate design and production facilities in India, China and Singapore and make use of Chinese and Taiwanese foundries. Several R&D facilities with connections to the Netherlands can also be found in the region, as well as links between universities in the area of semiconductors. These connections are shaped in various ways by the different political developments in the semiconductor industry in the region.

Obviously, the United States preventing other countries from supplying advanced semiconductors and equipment to China has negative consequences for the Dutch industry. ASML is barred by the Dutch government, under pressure from Washington, from shipping its most advanced EUV machines to China, and the same now appears to be true for the later versions of its less-advanced DUV machines. China was ASML's third-most important export market in 2021, and one with a large potential for growth, so this is a significant loss. The new US export restrictions introduced in October 2022 also impact Dutch companies. For example, ASM International (which earns 16 per cent of its revenue in China), expects that 40 per cent of its sales in China will be affected by the new restrictions.

Apart from the direct loss of revenue in the Chinese market, it is not impossible to imagine Beijing or indeed Chinese consumers retaliating against Dutch economic interest, in response to possible Dutch alignment with Washington's efforts to frustrate China's semiconductor development. Of course, this is not to say that the Dutch government should give in to such pressure, but it does emphasise that the Netherlands should remain focused on its own interests while facing demands from both sides. The United States and China certainly act in their own interest. It is obvious that the Netherlands would stand stronger against such pressures as part of the EU bloc, which questions the Dutch government's decision to negotiate with Washington bilaterally about joining the US restrictions on China.

However, these disadvantageous outcomes might be mitigated by other political developments. First, many Asian governments have recently committed themselves to invest extensively in strengthening their domestic semiconductor sector and to lessen dependencies. They do so in part to keep up with the large investments by Washington in the US semiconductor sector and because recent events have exposed the downsides of relying on overseas semiconductor production. For example, think of the supply chain issues exposed by the COVID pandemic, the supply chain risks associated with a potential reunification of Taiwan with China by military force, or the fact that South Korean and Taiwanese companies are blocked by the United States from using advanced semiconductor equipment at their extensive manufacturing facilities in China. This convinces governments to attract domestic and foreign semiconductor companies to invest in production facilities within their country, something the United States is also looking to do through its Chips Act.

Such efforts often focus on increasing a country's chip manufacturing capacity, especially regarding advanced chips. This will result in more supply and possibly ultimately in overcapacity. This could challenge the profitability of any advanced chip manufacturing plant that the EU would like to see built in Europe, as well as the EU's stated goal to double its global market share in chip production.

However, for Dutch equipment companies that can provide the necessary machines for these new plants, this mainly offers opportunities, at least in the short turn. The latest data from ASML, for example, show that the company's revenue continued to grow in 2022, despite its inability to sell EUV machines to China.[383] This is in part because large semiconductor manufacturers are building new plants across Asia (for example, Samsung in South Korea and Singapore, TSMC in Japan and the US, Foxconn in India and UMC in Singapore) and in the United States (Samsung and TSMC). ASML cannot keep up with demand: it has orders worth 40 billion euros still outstanding.

Some countries have also committed themselves to developing their semiconductor equipment industry. The South Korean government does so because it wants to decrease its dependence on Japanese equipment, while Japanese equipment companies want to strengthen their competitiveness. This does provide opportunities for Dutch R&D organisations that have expertise in this field. However, in the long run, increased investments by South Korean and Japanese companies could result in competition for the Dutch equipment sector, which will, in turn, argue that it will continue to invest in order to stay ahead of the competition.

China is a special case, however. Being cut off by the United States and its allies from advanced semiconductors and equipment means that China's government, universities and companies are extra motivated to develop their own advanced equipment. Serious progress can be expected. However, the Chinese still have a long way before they arrive at the level of world-leading equipment manufacturers, and the US sanctions on Chinese R&D institutes will hamper this progress. Eventually, however, China's large investments and motivation to advance in this area could result in serious competition for Dutch equipment-makers in the long run.

[383] ASML, "ASML reports €21.2 billion net sales and €5.6 billion net income in 2022", visited 8 February 2023, https://www.asml.com/en/news/press-releases/2023/q4-2022-financial-results.

List of acronyms and abbreviations

AI	Artificial intelligence
AIST	(Japan's) National Institute of Advanced Industrial Science and Technology
ALD	Atomic layer deposition
ASEAN	Association of South-East Asian Nations
ASMPT	ASM Pacific Technology
A*STAR	(Singapore) Agency for Science, technology and Research
ATMP	Assembly, testing, marking and packaging
BOM	*Brabantse Ontwikkelings Maatschappij* (Brabant Development Agency)
C2S	(India's) Chips to Startup programme
CITC	Chip Integration Technology Centre (in the Netherlands)
DRAM	Dynamic random-access memory
DUV	Deep ultraviolet (radiation)
EBL	Electron beam lithography
EDA	Electronic design automation
EDB	(Singapore's) Economic Development Board
EMC 2.0	(Indian government's) Modified Electronics Manufacturing Clusters Scheme
EODB	(World Bank) Ease of Doing Business (rankings)
ESDM	Electronics system design and manufacturing
ESG	Environmental, social and governance
EU	European Union
EUV	Extreme ultraviolet (radiation)
Fab	Microchip fabrication plant
GDP	Gross domestic product

GLC	Government-linked companies
IC	Integrated circuit
IDM	Integrated device manufacturer
IIT	Indian Institute of Technology
IP	Intellectual property
IPCEI	Important Project of Common European Interest
IPEF	Indo-Pacific Economic Framework
ISM	India Semiconductor Mission
ITA	(WTO) Information Technology Agreement
ITE	Institute of Technical Education
JASM	Japan Advanced Semiconductor Manufacturing
MEITY	(India's) Ministry of Electronics and Information Technology
MEMS	Microelectromechanical systems
METI	(Japan's) Ministry of Economy, Trade and Industry
MSME	Micro, small and medium enterprises
MTI	(Singapore's) Ministry of Trade and Industry
NAM	Non-Aligned Movement
NEDO	(Japan's) New Energy and Industrial Technology Development Organisation
NFC	Near-field communication
NFIA	Netherlands Foreign Investment Agency
nm	Nanometre
NOW	Netherlands Organisation for Scientific Research
OECD	Organisation for Economic Cooperation and Development
OEM	Original equipment manufacturer

OSAT	Outsourced semiconductor assembly and test
PAP	(Singapore's) People's Action Party
PLI	(India's) production-linked incentive scheme
R&D	Research and development
R&D&I	Research, development and innovation
RF	Radio frequency
RVO	Netherlands Enterprise Agency
SCRI	Supply Chain Resilience Initiative
SGD	Singapore dollar
SME	Semiconductor manufacturing equipment
SPECS	(Indian government's) Scheme for Promotion of Manufacturing of Electronic Components and Semiconductors
SSIA	Singapore Semiconductor Industry Association
SSMC	Systems on Silicon Manufacturing Company
TEL	(Japan's) Tokyo Electron
TNO	(Dutch) National Organisation for Applied Scientific Research
TSMC	Taiwan Semiconductor Manufacturing Company
UN	United Nations
US	United States
USD	US dollar
VIS	Vanguard International Semiconductor
VLSI	(Japan's) Very Large-Scale Integrated project
WTO	World Trade Organisation