Policy Contribution
Issue n°17/21 | July 2021

A new direction for the European Union's half-hearted semiconductor strategy

Niclas Frederic Poitiers and Pauline Weil

NICLAS FREDERIC POITIERS (niclas.poitiers@bruegel.org) is a Research Fellow at Bruegel

PAULINE WEIL (pauline.weil@bruegel.org) is a Research Assistant at Bruegel

The authors thank Sybrand Brekelmans, Viktor Krozer, Guntram Wolff and Georg Zachmann for their comments.

Executive summary

A BASIC COMPONENT in electronic devices, semiconductors are essential to the production of many products, from smartphones to cars. Securing reliable supplies of semiconductors to safeguard the production lines of a range of industries has thus become an important policy goal, especially in the context of an increasingly confrontational international environment in which high-technology leadership is also associated with military power and geopolitical reach.

THE SEMICONDUCTOR SECTOR is highly concentrated, capital- and R&D-intensive, and particularly exposed to bottlenecks and political risks. High-end chip fabrication is centred in Asia, dominated by the duopoly of Taiwan's TSMC and South Korea's Samsung. In other parts of the supply chain, companies in the United States and Europe hold relative monopolies that have been leveraged for trade sanctions. The United States has taken steps to block the supply of chips and components to emerging tech giants in China, and to contain China's ambitions of building its own cutting-edge chip production capacities.

HEAVY UNITED STATES and Chinese investment poses a challenge to the European Union, which in response has set the goal of increasing European production beyond domestic demand. To increase its presence in this strategic and thriving sector, the EU needs a more targeted strategy that builds on its existing strengths while accommodating its relatively low domestic needs. Instead of investing public funds in a subsidy war over fabrication capacity, the EU should focus on inputs and chip design. However, no economy can hope to fully achieve independence in the sector and ensuring sustainable supply through diplomatic means should therefore also be a priority. Lastly, Europe's small role in global semiconductor production is symptomatic of shortcomings in the European environment for high-tech innovation. These shortcomings should be addressed.

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Recommended citation
Poitiers, N. and P. Weil (2021) 'A new direction for the European Union's half-hearted semiconductor strategy', *Policy Contribution* 17/2021, Bruegel

1 Introduction

Also referred to as integrated circuits, chips and microchips, semiconductors are the core input in technologies, including faster computers, 5G antennas and digital sensors, that are expected to generate extensive productivity gains. Such technology also raises national economic and security concerns. China and the United States are therefore in fierce competition over semiconductor production, and the European Union wants to strengthen its position.

The semiconductor global value chain is highly specialised, concentrated and capital intensive. Fabrication, a critical production step, requires high levels of expertise and billions in capital expenditure, creating high barriers against new entrants. Fabrication of high-end chips is mostly done in Taiwan and South Korea.

The US dominates the design of semiconductors. While US control of critical intellectual property allows it to impose secondary sanctions, Washington sees the dominance of non-US companies in fabrication as a strategic vulnerability. Therefore, the US wants to increase its share of fabrication.

Although the largest producer of electronic hardware, China does not produce domestically the chips required for high-end ICT goods. Because they rely on imports, Chinese companies are vulnerable to American sanctions. A priority of Chinese industrial strategy is thus to become the world leading chip producer.

In the context of US-Chinese competition, and as part of its strategy to improve Europe's economic sovereignty or 'strategic autonomy', the European Commission announced in March 2021 plans to increase the EU's share of high-end chip fabrication. The Commission does not have its own resources but intends to give an impetus to member states' investment plans through a policy in place since 2018 permitting some national state aid to the sector. But the Commission's focus on the fabrication of high-end chips clashes both with the reality that only limited demand for them exists outside East Asia and with Europe's current position. Europe's proposed strategies are insufficient to improve its competitiveness in this extremely capital-intensive sector dominated by consolidated players. Even for the US and China, it is questionable whether the support they provide will be enough to gain control over production, given the high degree of specialisation in the sector.

In this Policy Contribution, we identify four industrial-strategy goals for the EU in relation to semiconductors: achieving security of supply for European businesses, increasing EU leverage in strategic subsectors of the industry, securing the benefits from the sector's high growth potential and arming the EU with policy tools to conduct industrial policy. To reach these goals, the EU should focus on Europe's strength in supplying materials and equipment to the industry. Beyond that, providing support for research and development in chip design and software would be better suited to increase overall European value added and impact in the industry, compared to focusing on fabrication. By increasing its footprint in the right part of the semiconductor industry, the EU could profit from its rapid growth.

2 Semiconductors exposed to trade tensions

As digitalisation has entered into every part of the economy, the underlying digital technologies have become entangled in geopolitics. The association between technological leadership and geopolitical rivalry is nothing new. It is grounded in the assumption that technology can serve innovation in military equipment[1]. Meanwhile, digital technologies have created new security concerns for national governments over the handling of data, both civilian and classified, as government surveillance, hacking and cyber warfare increasingly threaten economic and political stability[2]. Given the centrality of semiconductors in digital technologies, some governments are reconsidering their position in relation to the technology frontier and their hold over the value chain of the semiconductors they consume.

Both the US and China see control over critical components in the networks that drive the digital economy as critical for cyber security[3]. This US-Chinese rivalry is at the heart of what has been described as a "*technological cold war*", in which leadership in high-end technologies is seen as key to obtain or maintain economic and political dominance[4].

In this context, the EU's own concerns about semiconductors intensified in early 2021 when global chip shortages (see section 4) led to production delays for important European industries[5], raising a question about of how the EU can defend its interests in an international environment again shaped by great-power politics[6]. In the global quest for technological leadership, the EU has an edge in digital regulation, notably through the "*Brussels effect*", or the capacity of EU regulations to shape global standards (Bradford, 2020), but relies on external partners for many digital goods and services. This reliance leaves the EU exposed to disruptions arising from the US-China rivalry.

2.1 The global semiconductor supply chain

Semiconductors perform a variety of functions in electronics. The most important are memory and logic functions. Chips consist of a semiconductor material (usually silicon), into which electronic components are embedded. Innovation in the sector focuses on adding more and more components onto increasingly small surfaces to increase processing performance and reduce energy consumption. This is expressed as 'node size', with smaller nodes in principle indicating the most advanced chips (though different firms' node sizes are no longer directly comparable). The latest smartphones use chips with 5 nanometre (5nm) nodes.

Creating nanoscale electronic components is extremely complex and requires high-tech equipment and materials. The complexity and capital intensity of the sector has led to specialisation and concentration of the manufacturing process, with only a few countries having sizeable production capacities: the US, Taiwan, South Korea, Japan, European countries and, increasingly, China.

1 President Obama's Council of Advisors on Science and Technology stated in a 2017 report on semiconductors: *"To maintain its advantage, the US military needs access to leading-edge semiconductors that not all potential adversaries have"* (Holdren *et al*, 2017).

2 For instance, cyber-attacks pose a systemic risk to financial services; see Demertzis and Wolff (2019).

3 A clear example is the sanctions on Huawei, over which the US is exerting pressure on its allies to exclude the Chinese company's components from their telecommunications networks (Barkin, 2020).

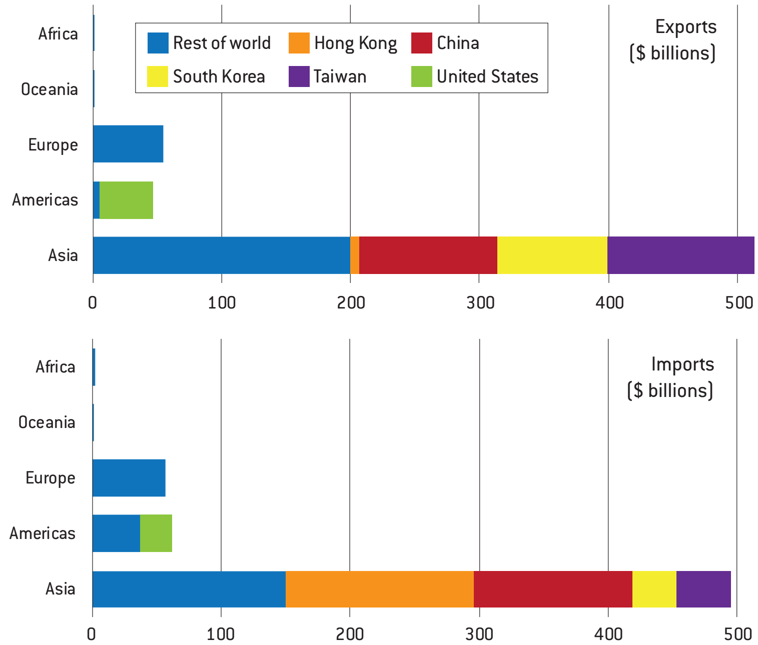
4 See Adam Segal (2020) 'The Coming Tech Cold War With China', *Foreign Affairs*, 9 September, available at https://www.foreignaffairs.com/articles/north-america/2020-09-09/coming-tech-cold-war-china.

5 As reported by Joe Miller and David Keohane (2021) 'Car manufacturing hit by global semiconductor shortage', *Financial Times*, 8 January, available at https://www.ft.com/content/e264fd41-7ee9-4fba-be3c-21446298efd9.

6 See remarks made by European Commission Director General for Trade, Sabine Weyand, in September 2020: https://eeas.europa.eu/delegations/united-states-america/85321/eu-open-strategic-autonomy-and-transatlantic-trade-relationship_en.

The geographic breakdown of production appears to have followed a gravitational pull towards its biggest consumers but, as we will argue, is also rooted in national industrial strategies. The semiconductor trade is mostly an Asian business (Figure 1). US firms, including Intel, Texas Instruments and Micron, dominate in terms of production volumes. However, their finished products mostly service the domestic market and therefore the US appears as a relatively small player in trade figures. Europe is both a minor producer and consumer of semiconductors.

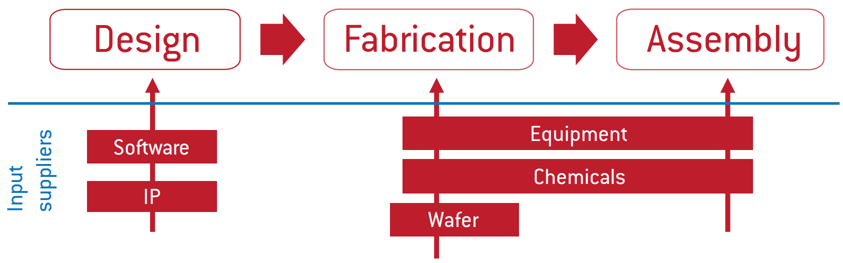
Figure 1: Integrated circuits export and import values 2019, $ billions



Source: Bruegel based on Observatory of Economic Complexity.

The semiconductor sector has been a winner-takes-all innovation race (Hunt and Zwetsloot, 2020). To keep up, firms needed to attract top talent and to spend high amounts on capital items and R&D. For instance, in the last two decades, total semiconductor R&D spending has been close to 15 percent of the industry's global revenues annually – equivalent to the R&D spending in the pharmaceuticals and biotechnology sectors[7].

Figure 2: Semiconductor production



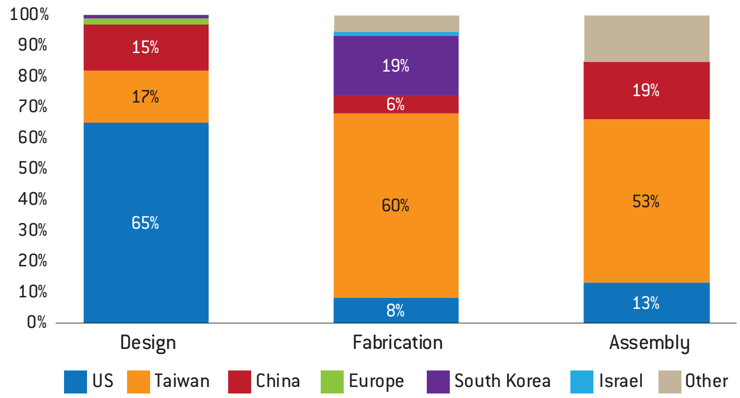
Source: Bruegel based on Kleinhans and Baisakova (2020).

7 See IC *Insight Research Bulletin,* 12 January 2021, 'Industry R&D Spending To Rise 4% After Hitting Record in 2020', available at https://www.icinsights.com/data/articles/documents/1334.pdf; and European Federation of Pharmaceutical Industries and Associations (EFPIA), https://www.efpia.eu/publications/data-center/innovation/rd-spending-as-a-percentage-of-net-sales/.

The semiconductor production process can be separated into three main steps: design, fabrication and assembly (Figure 2; Kleinhans and Baisakova, 2020). The industry is based on two major business models. Integrated design manufacturers (IDM), such as Intel and Samsung, undertake both design and fabrication. This model represents nearly 70 percent of global production, down from nearly 90 percent in 2002[8]. The alternative, the foundry model, is gaining traction. Greater specialisation enables more innovation, thus, the foundry model is the closest to the technology frontier and produces all the chips used in cutting-edge ICT goods. So-called fabless (ie fabrication-less) ICT companies opt to design chips and outsource the manufacturing to specialist foundries (ie fabrication plants). Major players including Apple, Tesla, Alibaba and HiSilicon (Huawei) use this model. In 2020, foundries produced 33 percent of semiconductors.

Figure 3 shows the geographical breakdown of the production steps for the foundry production model. Designers specify the physical architecture of the semiconductor by deciding on its functions, its electronic components and their layout. The US is home to the leading design firms (including Qualcomm, Broadcom, Nvidia and AMD) and accounts for 65 percent of this market. Ranked second, Taiwan also has some major players, including Mediatek, Novatek and Realtek. In third place, China's market share is increasing fast. Chinese firms including Unigroup and Huawei subsidiary HiSilicon have gained market share in recent years. European firms account for a mere 2 percent.

Figure 3: Firms' market shares of semiconductor production steps by headquarter location, 2019



Source: Bruegel based on IC Insights, Seeking Alpha and Stiftung Neue Verantwortung.

The second production step, fabrication, has seen the most concentration in recent years (see section 2.2).

The last step, assembly, refers mostly to the testing and packaging of the chips before they are integrated into other products. This subsector is comparatively labour intensive with lower profit margins. Like the other subsectors, it is consolidated in a few countries and firms. Taiwan is dominant with several top firms, notably ASE Group, while one major assembly firm, Amkor Technologies, is headquartered in the US. China managed to significantly increase its assembly market share with firms such as JCET.

The markets for some critical inputs, such as the silicon wafers and chemicals, and for manufacturing equipment, are also highly concentrated. This is where the EU features most prominently in the value chain. World-leading firms include the Netherlands' ASML (machinery), Germany's Aixtron (chemicals) and France's Riber (machinery) (de Jong, 2020).

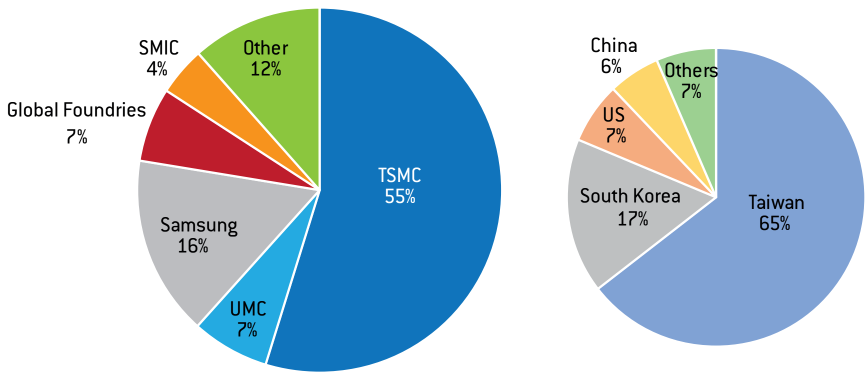
8 See IC Insights (2020) 'Fabless Company Share of IC Sales to Set New Record in 2020 at 32.9%', 28 December, available at https://www.icinsights.com/news/bulletins/Fabless-Company-Share-Of-IC-Sales-To-Set-New-Record-In-2020-At-329-/.

Apart from the EU, the US and Japan also have strong companies operating in these peripheral markets.

2.2 Foundries as the main chokepoint

The foundry subsector has undergone the most concentration over the last 20 years simply because it is the most capital intensive, in terms of capital expenditure and R&D. The five companies that have nearly 90 percent of the semiconductor manufacturing market in the foundry model are based in four countries (Figure 4). TSMC and Samsung are the only firms able to manufacture cutting-edge chips (10 nm nodes and below), with TSMC leading in terms of manufacturing capacities[9]. Meanwhile, in 2018, US Global Foundries and Taiwan's UMC both stopped investing in keeping up with the innovation pace of the industry, and focused instead on producing chips that are not cutting-edge and that are not used for the latest ICT products.

Figure 4: Foundries, global revenue share by firm and location, Q4 2020



Source: Bruegel based on Statista .

Foundries accounted for 36 percent of the $109.1 billion in capital expenditure in the sector in 2020[10]. Leading firms planned to invest substantially in 2021 to keep up with the innovation pace and meet demand. TSMC plans a 63 percent increase in its capital expenditure to $28 billion in 2021, and $100 billion over three years[11]. Samsung spent over $93 billion from 2017 to 2020 and plans to spend another $100 billion over the next decade[12]. These high costs, the need to attract top talent and the need to secure production contracts with design firms before building foundries, make it very difficult for new market entrants to compete with incumbents.

The TSMC and Samsung duopoly over the manufacturing of the chips used in smartphones, laptops and data centres poses supply chain risks. Furthermore, Samsung is historically an IDM firm catering for its own chip needs; its fabrication of chips for external clients, although started in 2005, intensified only in 2017 with the creation of a subsidiary, Samsung Foundry Business[13]. Global demand therefore relies heavily on TSMC.

9 See Kathrin Hille (2021) 'TSMC: how a Taiwanese chipmaker became a linchpin of the global economy', *Financial Times*, 24 March, available at https://www.ft.com/content/05206915-fd73-4a3a-92a5-6760ce965bd9.

10 See Statista: https://www.statista.com/statistics/1055209/capital-spending-in-the-semiconductor-industry-by-product-type-worldwide/.

11 As reported by Debby Wu (2021) 'TSMC to Spend $100 Billion Over Three Years to Grow Capacity', *Bloomberg*, 1 April, available at https://www.bloomberg.com/news/articles/2021-04-01/tsmc-to-invest-100-billion-over-three-years-to-grow-capacity.

12 See IC Insights (2021) 'Samsung and TSMC Seeking to Spend Their Way to Worldwide Domination of Advanced IC Technology', 16 March, available at https://www.icinsights.com/news/bulletins/Samsung-And-TSMC-Seeking-To-Spend-Their-Way-To-Worldwide-Domination-Of-Advanced-IC-Technology/.

13 See Samsung, https://www.samsung.com/semiconductor/about-us/business-overview/ (accessed 7 June 2021).

From a Chinese standpoint, external reliance exposes its ICT manufacturers to the risks of US extraterritorial sanctions. China therefore intends to boost the capacity of its domestic champion SMIC. But even though SMIC upgraded its manufacturing process to 14 nm nodes in 2019, the talent and capital needed to produce the next generation of chips (using a manufacturing process dubbed 10 nm or below) appears out of reach in the short to medium term (chapter 13, US National Security Commission on Artificial Intelligence, 2021). Notably, US trade restrictions have prevented Chinese foundries from acquiring some of the essential manufacturing equipment.

From a Western point of view, securing ICT supply chains has been a growing concern in recent years. The shortages in semiconductor supply in 2020 and 2021 increased the political pressure to ensure domestic manufacturing capacities. Although highly concentrated, chip production had kept pace with rising demand. But the current global shortages could signal lasting bottlenecks in the industry and help justify national measures to bring home manufacturing capacities.

3 A strategic sector defined by state support

Wherever the sector has developed significantly, it has been thanks to industrial success stories and also substantial state support. OECD (2019) measured distortions in the global semiconductor value chain from 2014 to 2018 and found government support to be particularly large (over $50 billion for the 21 large firms studied). Support took the form of below-market debt and equity, R&D support and investment incentives.

National governments have focused on the semiconductor industry since its beginnings in the late 1950s. After the Second World War, the invention of transistors paved the way for the breakthrough developments in the US of the integrated circuit (1959) and the microprocessor (1971). These inventions marked the birth of the Silicon Valley and the start of developments in line with Moore's law – that the number of transistors on a chip would double every two years – and led to the rise of Fairchild, Texas Instruments and Intel. The US government, and especially military and space agencies, strongly supported the industry, which was considered strategic (Danish Technological Institute, 2012).

US support was provided through research funding for universities, while public procurement ensured steady demand (Sauvage, 2019). Research collaboration between rivalling firms underpinned the creation of clusters in California. The US led the sector until it moved into mass production in the mid-1970s, opening opportunities for new entrants – most notably Japanese. The Japanese government successfully helped national companies catch-up with their US counterparts (Onishi, 2007). Complaining about unfair competition, US firms lobbied for restrictions on Japanese exports and more access to the Japanese market (Johnson, 1991). The ensuing trade dispute ended only in 1986, when Japan formally agreed to curb semiconductor exports and increase imports from the US. The agreement ultimately led to an increase in semiconductor prices which created an opportunity for South Korean and Taiwanese firms (Bown, 2020a).

Support schemes in different Asian countries were similar, with Taiwan providing a case study. The industry in Taiwan grew out of the political will to develop strategic industries in the 1980s (*Office parlementaire d'évaluation des choix scientifiques et technologiques*, 2008). Technological leadership was a goal intended to safeguard economic independence from China, and establishing domestic state-of-the-art foundries was an explicit government aim. A favourable investment environment was created with the development of industrial clusters (bringing together universities, industries and R&D centres), by ensuring education produced a supply of talent, and through technological support from national R&D centres. Fiscal incentives and financial support programmes were also used to spur investment.

In 1976, 70 percent of global supply came from the US, 20 percent from Europe and 5 percent from Japan, whereas Asia now accounts for over 80 percent of chip imports and exports (Figure 1). Demand has also shifted, from traditional ICT products to wireless products and to the transport sector – with electronics increasingly important in cars, trains and aircraft[14]. The shifts have been punctuated with major innovations and trade conflicts, with numerous disputes filed at the World Trade Organisation.

3.1 How Europe dropped out of race

European foundries have not invested enough to keep up with the industry's fast pace of innovation

The EU's share of global trade in semiconductors declined from a peak of 22 percent in 1998 to 13 percent in 2010 (Coulon *et al*, 2020), subsequently falling to 9 percent in 2017, despite the EU's production value growing on average by 3.8 percent annually from 2010 to 2017 (to $35 billion). Europe still provides cutting edge inputs (wafers and manufacturing equipment), but European firms do not fabricate the most high-end chips.

European foundries did not invest enough to keep up with the industry's fast pace of innovation (Kleinhans, 2021). In 2020, only 3 percent of global investment to equip foundries was in Europe. Major European foundries, including Global Foundries (Germany), STMicroelectronics (France and Italy), Bosch (Germany), Infineon (Germany) and NXP (Netherlands), have a small share of global production capacities and output, estimated at 10 percent of global production. While specialised in their niches, their production capabilities are far from the technology frontier. The only foundries producing modern chips are Global Foundries and STMicroelectronics, but even their models are several generations behind the newest Taiwanese, Korean and American productions (10 nm nodes and below). Nevertheless, in their speciality fields of sensors and radio frequency chips, European firms remain competitive.

These subsectors are driven by innovation focused on materials rather than size reductions. Specialisation has developed around European sectors with fast-growing electronics production, namely automotive (in which Europe represented 27 percent of global electronics production in 2017), industrial electronics (20 percent), and aerospace, defence and security (22 percent). Europe is not specialised in the bigger and more mature segments of smartphones, computers and other consumer digital devices. In total, Europe represented 14 percent of end use of semiconductors in 2017 (Coulon *et al*, 2020).

The current state of the semiconductor industry in Europe proceeds from its industrial and innovation ecosystem. European innovation in semiconductors has long been characterised by strong basic research, with research units linked to universities, and the dominance of large consumer products firms, which supported the development of the consumer industries (Guadagno *et al*, 2015). At first, the semiconductor industry in Europe was in the hands of large integrated firms including Philips (Netherlands) and Siemens (Germany). Similarly to Japan, the technologies were first applied for commercial uses (unlike in the US, where military demand fuelled adoption). Focusing on the consumer electronics market (home electronics such as TV, video and telephones), these firms did not invest in production of chips for computers and electronic devices.

The focus on consumer electronics also favoured mass production rather than the entrepreneurship of tech start-ups that was seen in the US. Economies of scale and the development of champions were also limited by the fragmentation of the European market, through national procurement in telecommunication for instance, and by the lower level of attention and support from the state compared to the US and Asia[15]. Furthermore, firms in Europe had less access to funding because of the relatively small and fragmented nature of the venture capital market.

14 See https://www.reportlinker.com/p05865839/Global-Discrete-Semiconductor-Market-Growth-Trends-and-Forecast.html.

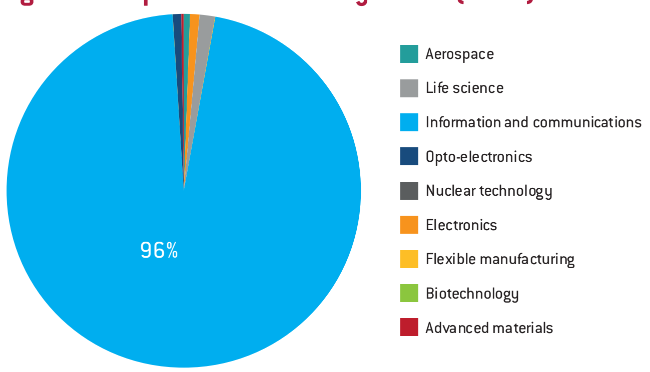
15 See Kearney 'Rebooting Europe's high-tech industry', available at https://www.es.kearney.com/communications-media-technology/article?/a/rebooting-europes-high-tech-industry (accessed 7 June 2021).

For these historical industrial reasons and systemic characteristics, Europe is not a leader in the ICT sector. The European Commission's 2020 Industrial R&D Investment Scoreboard analyses the 2500 firms that invested most in R&D in 2019 – accounting for about 90 percent of global privately funded R&D[16]. Although the EU accounts for 21 percent of the total (including 45 percent of global R&D investment in the automotive sector), it accounts for only 13 percent of total investment by ICT producers (which is, incidentally, the sector investing the most).

3.2 China's ambitions

Estimates suggest that 90 percent of smartphones, 67 percent of smart televisions and 65 percent of personal computers are now at least partly made in China (Bown, 2020a). ICT goods have become China's main export, making up 26 percent of total exports in 2017, and 96 percent of its high-tech exports to the US (Figure 5)[17]. Following Taiwan and South Korea, China first gained market shares in low-skilled labour-intensive parts of the sector, such as assembly and packaging, and received substantial foreign investment.

Figure 5: US high-tech imports from China by sector (2017)



Source: Bruegel based on UN Comtrade

In 2015, China set a goal of reaching self-sufficiency in high-tech industries by 2025 and securing leadership in innovation by 2050. Dubbed *Made in China 2025*, the strategy intends to shed reliance on external suppliers and to secure a move up the value chain for technology production, notably for semiconductors (Casanova and Weil, 2019; ISDP, 2018). Semiconductors have duly become China's single biggest import, surpassing even oil (Figure 6). The stated goal is that 70 percent of Chinese semiconductor demand will be supplied by Chinese companies by 2025. However, the distance to the intermediate goal makes clear how large the challenge is: China aimed for 40 percent of its semiconductor demand to be supplied by domestic production by 2020, but it had only reached 16 percent in 2019, while half of the domestic production came from non-Chinese firms (Lewis, 2019). In global chip production, it only reached by 2019 market shares of 15 percent in chip design, 6 percent in fabrication and 19 percent in assembly. It seems highly unlikely China will achieve its 2025 goal.

Semiconductors have been subject to Chinese strategic considerations since their early development[18]. The first Chinese integrated circuit was created in 1965 – much earlier than in Taiwan and South Korea. China is lagging behind in an industry where it had a head start. Although China invested heavily in equipment, the country lacked local know-how, and the

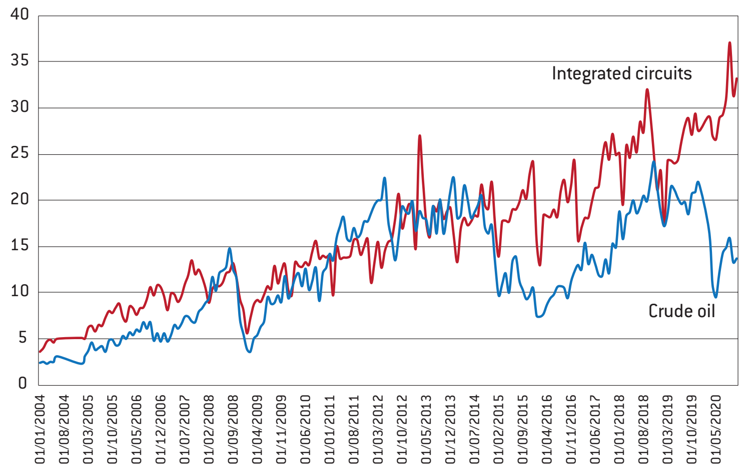
16 European Commission 2020 Industrial R&D Investment Scoreboard, available at https://iri.jrc.ec.europa.eu/rd_monitoring (accessed 7 June 2021).

17 Source: UNCTAD, available at https://data.worldbank.org/indicator/TX.VAL.ICTG.ZS.UN?locations=CN.

18 See Zen Soo and Meng Jing (2019) 'How China is still paying the price for squandering its chance to build a home-grown semiconductor industry', *South China Morning Post*, 28 August, available at https://www.scmp.com/tech/big-tech/article/3024687/how-china-still-paying-price-squandering-its-chance-build-home-grown.

Cultural Revolution (1966-1976) led to the loss of a generation of talents. As a result, China trailed in R&D and adopted reverse engineering strategies, placing the industry in a catch-up position. Now, the talent gap remains a key challenge (the China Semiconductor Industry Association estimates a shortfall of around 300,000 ICT engineers to reach the government's goals), but China seeks to tackle its talent shortage by attracting foreign know-how and through education (Thomas, 2021).

Figure 6: Integrated circuits have become China's main import ($ billions)



Source: Bloomberg.

More recently, Chinese industrial strategy in the sector has been decidedly aggressive. A taskforce working with high-ranking government officials and industry leaders was given a budget of 1 trillion renminbi ($170 billion) to spend between 2014 and 2024 to create semiconductor national champions (Orr and Thomas, 2014). The funds were meant to support R&D and to sponsor acquisitions of foreign companies. Two examples of Chinese companies illustrate the strategy. State-owned enterprise (SOE) Tsinghua Unigroup bought two out of the four leading Chinese chip design companies in 2013 for a total of $2.1 billion in an effort to consolidate national champions. In 2021, SMIC, China's most promising foundry, announced the construction of a new foundry in Shenzhen based on a $2.35 billion joint investment between the local government and the firm[19]. These two rising stars enabled China to increase its semiconductor production capacity, but their manufacturing process (14 nm and older) is two to three generations behind the current technology frontier.

The Chinese government has initiated numerous industrial strategies and investments to reduce its reliance on imports of cutting-edge chips. While some initiatives have failed and others have been successful, the takeaway remains that in this sector, leadership is a hard-won battle. As other global players continue to invest heavily in R&D ($68 billion for global R&D investment in 2020 alone), China will continue to lag behind its counterparts[20]. In the semiconductor innovation race, top-tier players will not be dislodged in the short term.

19 See Che Pan (2021) 'SMIC joins Shenzhen government in US$2.35 billion chip foundry as China pushes for self-sufficiency in semiconductors', *South China Morning Post*, 18 March, available at https://www.scmp.com/tech/big-tech/article/3125908/smic-joins-shenzhen-government-us235-billion-chip-foundry-28-nm-node.

20 See *Semiconductor Digest* (2021) 'Industry R&D spending to rise 4% after hitting record in 2020', 22 January, available at https://www.semiconductor-digest.com/2021/01/22/industry-rd-spending-to-rise-4-after-hitting-record-in-2020/.

4 Semiconductor shortages and US-China rivalry

In late 2020, several factors led to a global shortage of semiconductors and a spike in prices. Demand was pushed by COVID-19-induced lockdowns, which saw increased sales of ICT goods and cloud-computing services[21]. New ICT products, including 5G compatible devices and video-game consoles, also contributed to the surge in demand. At the same time, Chinese firms stockpiled chips in fear of new US export restrictions[22].

Being unable to serve all customers, chip manufacturers prioritised their main clients, the ICT sector[23]. The automotive industry cut chip orders during the pandemic and their designated production was redirected to other clients[24]. As the automotive industry resumed production in late 2020, it reportedly faced challenges. By April 2021, most major automakers worldwide had to halt or reduce production, including General Motors, Ford, Volvo, Volkswagen, Renault, Peugeot, Hyundai and Nio (Chinese electric vehicles). Eventually, the chip shortage also reached the ICT sector[25]. New smartphones from Apple and Samsung, and gaming consoles from Sony and Microsoft, suffered either launch delays or rapid stock depletion.

The reasons for the bottleneck are clear: a limited number of chip producers and production capacities that cannot be adapted rapidly. Shortages are not new to the sector[26]. The 2020-2021 shortages followed a 12 percent decline in revenue in the industry in 2019. Since 1990, every four to five years, there has been a decline in sales that has lasted 12-15 months and increased price competition (Duthoit, 2019). This rhythm to the sector's performance is correlated with saturation of end-markets and R&D cycles.

The question is whether the 2020 event indicates new systemic issues. Current trends hint that the shortage could last well into 2022[27] and Samsung has communicated fears of a "*serious imbalance*" in the market for the most cutting-edge chips[28]. The semiconductor market has grown from \$33 billion in 1987 to \$433 billion in 2020[29] and increased digitalisation implies continuing high-growth potential. However, risks related to inputs, volatile demand and unsuccessful R&D make returns on investment uncertain. Building a foundry takes on average two years and then at least four years to break even (Bauer *et al*, 2020), while manufacturing a chip can take several months. The industry's massive investments are made with reference to long-term horizons rather than relatively short-term shortages. There is no fast

21 See Vincent Fagot (2021) 'Le monde de l'industrie s'inquiète d'une pénurie de puces électroniques,' *Le Monde*, 23 January, available at https://www.lemonde.fr/economie/article/2021/01/23/le-marche-des-semi-conducteurs-face-a-la-penurie_6067305_3234.html.

22 See *Bloomberg News* (2021) 'China Stockpiles Chips, Chip-Making Machines to Resist U.S,' 2 February, available at https://www.bloomberg.com/news/articles/2021-02-02/china-stockpiles-chips-and-chip-making-machines-to-resist-u-s.

23 See Joe Miller, David Keohane and Kana Inagaki (2021) 'Car manufacturing hit by global semiconductor shortage,' *Financial Times*, 8 January, available at https://www.ft.com/content/e264fd41-7ee9-4fba-be3c-21446298efd9.

24 See Mark Sweney (2021) 'Global shortage in computer chips "reaches crisis point",' *The Guardian*, 21 March, available at https://www.theguardian.com/business/2021/mar/21/global-shortage-in-computer-chips-reaches-crisis-point.

25 See Cristina Criddle (2021) 'Chip shortage: Samsung warns of "serious imbalance",' *BBC News*, 17 March, available at https://www.bbc.com/news/technology-56433082.

26 Source: Statista, https://www.statista.com/statistics/266976/forecast-revenue-growth-in-the-semiconductor-industry-worldwide/.

27 See Kathrin Hille (2021) 'Foxconn warns components shortage to last until 2022,' *Financial Times*, 30 March, available at https://www.ft.com/content/e1fcca5f-5937-4711-ac95-d690ce536e2d.

28 See Ian King, Debby Wu and Demetrios Pogkas (2021) 'How a Chip Shortage Snarled Everything From Phones to Cars,' *Bloomberg*, 29 March, available at https://www.bloomberg.com/graphics/2021-semiconductors-chips-shortage/.

29 Source: Statista, https://www.statista.com/statistics/266973/global-semiconductor-sales-since-1988/.

and easy fix to the current supply-demand mismatch.

The shockwave impact of the shortage on a wide range of industries and the increased geopolitical sensitivity of semiconductors have been highlighted by firms and policymakers as justifying a push to reduce risks in the supply chain. This has translated into ambitious investment plans to diversify suppliers and create domestic production sites. Supply chain risks, market imbalances and political risks arguably give governments a reason to yet again provide support for capacity building in the industry.

4.1 The US and China pushing for self-sufficiency

In the semiconductor sector, the preferred strategy of both the US and China appears to be self-reliance. In this, China may be at a disadvantage. The US is currently not able to produce cutting-edge chips domestically, but thanks to both national players such as Intel[30], and foreign investments, such as from TSMC[31], it appears closer to self-sufficiency than China. Meanwhile, "*no other industry in China shows a wider gap between stated policy goals and the technological reality*" (Duchâtel, 2021).

A March 2021 report by the US administration recommended rebuilding US "*semiconductor superiority*" (US National Security Commission on Artificial Intelligence, 2021). The report does not expect Intel to be able to compete with TMSC or Samsung on cutting-edge chips in the medium term. But it recommended that the US should aim to remain two generations ahead of China in the sector, and calls on US allies to control exports that would help China upgrade its industry. Specifically, the US target is to keep SMIC production two generations away from the current tech frontier – SMIC can produce currently at 14 nm nodes. Although the US is also on the wrong side of a technology gap, it seeks to leverage its own champions and geopolitical alliances to starve China's military and up-and-coming tech firms. The high degree of specialisation in the sector makes US export bans on a few companies an effective tool to hobble Chinese attempts to move up the value chain (Duchâtel, 2021).

Leadership in the first production step allows US export controls to limit contracts to Chinese firms downstream in the supply chain. Semiconductor designs rely on specific software for which the market is highly concentrated around three US-based firms, Cadence, Synopsy and Mentor. It is in this part of the value chain that US sanctions have been most effective in blocking Huawei HiSilicon.

US export bans on American-made technologies and US diplomatic pressures give US sanctions an extraterritorial reach by making international firms bow to sales restrictions. TSMC, which uses some US technologies for its chip fabrication processes, stopped selling to Huawei in 2020[32]. Most observers agree that once Huawei has gone through its current chip inventories, production lines for a number of flagship products will have to stop[33]. Other restrictions limit SMIC's ability to source the inputs required for the fabrication of high-end chips[34]. Manufacturing-equipment export bans applied to Silicon Valley firms including Applied Materials and Lam Research have been put in place for SMIC[35]. The US govern-

30 See Patrick McGee (2021) 'Intel to step up chip manufacturing with $20bn plants', *Financial Times*, 24 March, available at https://www.ft.com/content/987b5761-6b59-48f3-8f52-52a4fb84264e.

31 See Bob Davis, Kate O'Keeffe and Asa Fitch (2020) 'Taiwan Firm to Build Chip Factory in U.S', *The Wall Street Journal*, 14 May, available at https://www.wsj.com/articles/taiwan-company-to-build-advanced-semiconductor-factory-in-arizona-11589481659.

32 See Kathrin Hille and Kiran Stacey (2020) 'TSMC falls into line with US export controls on Huawei', *Financial Times*, 9 June, available at https://www.ft.com/content/bad129d1-4543-4fe3-9ecb-15b3c917aca4.

33 See Kathrin Hille, Edward White and Kana Inagaki (2020) 'Chip and phone supply chain shaken as Huawei faces mortal threat', *Financial Times*, 18 August, available at https://www.ft.com/content/bdd2a70f-ecd2-4aff-b6c7-c0624bfdeebb.

34 US Department of Commerce press release, 18 December 2020; see https://2017-2021.commerce.gov/news/press-releases/2020/12/commerce-adds-chinas-smic-entity-list-restricting-access-key-enabling.html.

35 See Karen Freifeld and Alexandra Alper (2021) 'Exclusive: Amid shortage, U.S. suppliers to Chinese chip giant SMIC struggle to get export licenses', *Reuters*, 4 March, available at https://www.reuters.com/article/us-usa-china-smic-exclusive-idUSKBN2AW18B.

ment has also successfully influenced Dutch ASML and Japanese Electron to stop sales to SMIC. ASML has a monopoly on extreme ultraviolet photolithography equipment required to manufacture high-end chips – below 14 nm nodes (Collins and Erickson, 2020). The US campaign to block sales to China started in 2018[36] and officially came to fruition in 2021 when the Dutch government granted ASML a licence to export some equipment to SMIC[37], but not cutting-edge equipment. SMIC should thus be able to build new foundries and manufacture widely-used chips (28 nm), notably in the automotive sector, but not in high-tech ICT products (below 14 nm).

Amid this unfolding 'tech cold trade war', there is risk of further digital decoupling. The confrontation has made both China and the US more eager to master the technology themselves. In November 2020, the Chips for America Act was introduced to the US House of Representatives, with a plan to put in place tax incentives and a trust fund to increase US manufacturing capacities[38]. Meanwhile, US restrictions are pushing Beijing to also invest in self-reliance in the sector[39]. In 2020, stockpiling of chips went in hand with stockpiling of chip-making equipment by SMIC. Although semiconductors were among the first targets of US tariffs against China, China has not imposed any trade barriers in the sector and continued to increase semiconductor imports from the US during 2020 (Bown, 2020a). Experts agree it will take years for China to be able to substitute banned US technologies or built capacities to fabricate cutting-edge chips domestically (Triolo, 2021).

Box 1: The Taiwan case

The Taiwan Semiconductor Manufacturing Company (TSMC) is of major importance for the global semiconductor industry. It has a 55 percent share of the semiconductor fabrication market (in the foundry business model) and produces most high-end chips. Global reliance on one firm in one country for such a crucial product involves risks. For example, the semiconductor industry is water-intensive, while Taiwan relies on a rainy season to replenish its water supplies for the drier winters. In 2020-2021, an unusually dry winter and spring led the government to cut water supplies to some companies[40]. This drought is not expected to affect TSMC, but Taiwan's exposure to climate and natural disaster risks provides a justification for diversification of production locations.

TSMC is of major importance to the Taiwanese economy. It is the country's biggest company by market capitalisation, accounting for a third of local stock market value. Revenue from semiconductors, in which TSMC is dominant, is equivalent to 15 percent of Taiwanese GDP[41]. The reliance of the world economy on TSMC for high-end chips exposes Taiwan to political pressure from foreign powers but also gives it some political leverage. In January 2021, amid the shortage, Taiwan used TSMC as a bargaining chip when seeking help from Germany

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

37 See Frank Chen (2021) 'China takes first baby step towards chip self-reliance', *Asia Times*, 23 March, available at https://asiatimes.com/2021/03/china-takes-first-baby-step-towards-chip-self-reliance/.

38 H.R.7178; see https://www.congress.gov/bill/116th-congress/house-bill/7178.

39 See *Bloomberg News* (2021) 'China Stockpiles Chips, Chip-Making Machines to Resist U.S.', 2 February, available at https://www.bloomberg.com/news/articles/2021-02-02/china-stockpiles-chips-and-chip-making-machines-to-resist-u-s.

40 See Debby Wu and Cindy Wang (2021) 'Taiwan Cuts Water Supply for Chipmakers as Drought Threatens to Dry Up Reserves', *Bloomberg*, 24 March, available at https://www.bloomberg.com/news/articles/2021-03-24/taiwan-raises-red-alert-over-water-cuts-supply-for-chipmakers.

41 See Cheng Ting-Fang and Lauly Li (2021) 'Taiwan's economy feels heat as TSMC feeds global chip boom', *Nikkei Asia*, 9 February, available at https://asia.nikkei.com/Spotlight/Asia-Insight/Taiwan-s-economy-feels-heat-as-TSMC-feeds-global-chip-boom.

to secure COVID-19 vaccine supplies[42].

TSMC is also relevant to Taiwan's sovereignty. Mainland China considers Taiwan to be part of its territory and has never renounced the threat of force to carry out its reunification plans. China's clampdown in Hong Kong and more Chinese military exercises near the Taiwan Strait have fed fears that the increased pressure on Taiwan may soon lead to the annexation by force of the democratic island[43]. Some observers believe that the global imperative to keep TSMC plants running helps protect Taiwan from a military invasion that could halt production[44]. Beyond military threats, the semiconductor industry allows Taiwan to be an essential trade partner to China, offsetting its economic reliance on China (Lee and Kleinhans, 2020). China absorbs over 25 percent of Taiwanese exports, nearly 40 percent of which are semiconductors[45].

Chinese company Huawei, itself the subject of disputes between the US and China, is TSMC's second largest customer behind Apple, accounting for over $5 billion of TSMC's revenues in 2019[46]. Huawei subsidiary, Hisilicon, design its own chips but outsources fabrication to TSMC. Hisilicon itself does not rely on US inputs, but TSMC does, and because of US sales restrictions has had to curb sales to Huawei. TSMC could have sourced required inputs from non-US suppliers, but chose to comply with US sanctions (Bown, 2020b). In the long run, Western countries, most notably the US, are pushing to diversify their supply of cutting-edge chip, most notably by reshoring production. But as TSMC is expected to remain ahead in terms of innovation and production capacities, the semiconductor industry provides an incentive for the US, and others, to defend Taiwanese independence (Lee and Kleinhans, 2020). Retaining chip leadership will remain a major asset for Taiwan, even if production is done at facilities beyond the island: TSMC is also working to expand production capacities in the United States and Japan, for example[47].

4.2 US-China rivalry and its impact on the EU and third countries

High-technology products that cannot easily be substituted provide easy targets for trade sanctions in the semiconductor sector. In its quest to limit the rise of Chinese firms, the US has targeted bottlenecks beyond its own jurisdiction (the US accounts for only 5 percent of China's chip imports; Bown, 2020a). The US has done so by banning the sale to Chinese firms of products in which US know-how makes up at least 25 percent of their value, but also by pressuring allied governments to implement their own export bans[48].

These restrictions are costly for all affected firms that end up cut off from the world's

42 See Reuters (2021) 'Taiwan asks Germany to help obtain coronavirus vaccines,' 28 January, available at https://www.reuters.com/article/us-health-coronavirus-taiwan-idINKBN29X11P.

43 See Oriana Mastro (2021) 'The Taiwan Temptation: Why Beijing Might Resort to Force,' *Foreign Affairs*, July/August, available at https://www.foreignaffairs.com/articles/china/2021-06-03/china-taiwan-war-temptation.

44 See Raymond Zhong (2020) 'In U.S.-China Tech Feud, Taiwan Feels Heat From Both Sides,' *The New York Times*, 1 October, available at https://www.nytimes.com/2020/10/01/technology/taiwan-china-tsmc-huawei.html.

45 Source: The Observatory of Economic Complexity; see https://oec.world/en/profile/country/twn?yearSelector1=exportGrowthYear25.

46 See Cheng Ting-Fang and Lauly Li (2020) 'TSMC halts new Huawei orders after US tightens restrictions,' *Nikkei Asia*, 18 March, available at https://asia.nikkei.com/Spotlight/Huawei-crackdown/TSMC-halts-new-Huawei-orders-after-US-tightens-restrictions.

47 See Sherisse Pham (2020) 'Taiwan chip maker TSMC's $12 billion Arizona factory could give the US an edge in manufacturing,' *CNN Business*, 15 May, available at https://edition.cnn.com/2020/05/15/tech/tsmc-arizona-chip-factory-intl-hnk/index.html.

48 See US International Trade Administration, 'China - Country Commercial Guide,' available at https://www.trade.gov/knowledge-product/china-us-export-controls (accessed June 7, 2020).

foremost semiconductor consumer, China, which accounts for half of global chip sales[49]. The global semiconductor industry association (SEMI) reported that bans on the export of US-origin designs and equipment to Huawei and affiliates, put in place in mid-May 2020, had already resulted in $17 million in lost sales by mid-July 2020[50]. In December 2020, European executives and diplomats voiced concerns that trade restrictions tend to favour US firms because some are granted licences to sell to Huawei or SMIC, while EU competitors are kept out of the Chinese market[51]. Samsung and Sony have also been granted licences for non-5G related components[52].

The long reach of US export bans underlines the political risks to the global industry, most notably from US policymaking. Some countries, such as South Korea which has so far managed to balance its reliance on the US for security and on China for trade, may be forced to choose sides in what may be become an increasingly expensive high-technology rivalry[53].

5 The EU amid the digital decoupling push

European companies could be casualties of US measures that aim to limit technology transfers to China. Most importantly, sanctions could disrupt the production of semiconductors, leading to economic damage for European consumers, as shown by the effects of the shortages in the automotive sector in 2020. Cerdeiro *et al* (2021) found that, because of the high share of foreign value added in high-tech exports (notably from China and ASEAN countries), technological decoupling would be detrimental to global productivity and innovation in the sector. In their worst scenario they found that technological decoupling could lead to significant GDP losses – assessed at 4 percent of GDP for the EU, South Korea and China.

More broadly, the deterioration of the multilateral system caused by the US-China rivalry has led the EU to rethink its dependence on American foreign policy. The EU possesses few foreign policy tools. The separation of trade policy, which is centralised at the EU level, from foreign and security policy, which remain largely in national hands, is a limiting factor in the defence of the EU's interests internationally (Leonard *et al*, 2019). Concern about maintaining 'strategic autonomy', introduced in 2013 mostly in relation to the defence industry, has been broadened to include geostrategic and economic considerations[54]. The challenge is to increase European sovereignty, or geopolitical clout, while not appearing protectionist or undermining the rules-based international order (Borrell Fontelles, 2020). The EU's struggle with this trade-off is clearly laid out in the paradigm of 'open strategic autonomy', which emphasises both autonomy and openness (European Commission, 2021a).

These considerations have entered into the Commission's proposals for the digital transformation of the European economy (European Commission, 2021). While the EU is no longer home to ICT manufacturing plants, the digitalisation of its manufacturing sector,

49 See Alan Crawford, Debby Wu, Colum Murphy and Ian King (2020) 'The U.S.-China Conflict Over Chips Is About to Get Uglier', *Bloomberg*, 22 October, available at https://www.bloomberg.com/news/articles/2020-10-21/the-u-s-china-conflict-over-chips-is-about-to-get-even-uglier.

50 Source: SEMI ; see https://www.semi.org/en/news-media-press/semi-press-releases/semi-export-control.

51 See Yuan Yang (2020) 'European tech accuses US of using sanctions to shut it out of China', *Financial Times*, 23 December, available at https://www.ft.com/content/7baa8caf-ca3f-4d95-967c-e315a3ee348f.

52 See Kathrin Hille, Edward White and Kana Inagaki (2020) 'US allows sales of chips to Huawei's non-5G businesses', *Financial Times*, 29 October, available at https://www.ft.com/content/508b0828-bcd5-46a6-84f8-d05cb2887e0a.

53 See Jeong-Ho Lee and Sohee Kim (2021) 'Biden Finds a Key Ally Wary of His Bid to Outpace China on Chips', *Bloomberg*, 25 March, available at https://www.bloomberg.com/news/articles/2021-03-25/south-korea-s-chip-industry-is-trapped-between-the-u-s-and-china.

54 European Council Conclusions of 20 December 2013; see https://www.consilium.europa.eu/uedocs/cms_Data/docs/pressdata/en/ec/140245.pdf.

dubbed 'Industry 4.0', is crucial to ensure European competitiveness in the fourth industrial revolution[55]. Digitalisation is of major importance to the automotive sector, which employs around 6 percent of European workers and represents more than 7 percent of EU GDP. Cars are becoming 'computers on wheels' and, especially in a potential self-driving future, semiconductors will become a core part of automotive technology. Digital technologies are also key for the transition to a climate neutral and resilient economy.

In March 2021, when launching the '*digital decade*' initiative, the Commission considered digital technologies as increasingly strategic and argued that the coronavirus pandemic and the lockdown context has provided an impetus for strategic action in the sector[56]. The digital decade would be based on digital transformation targets to be achieved by 2030[57], including a target for increasing the European footprint in the global semiconductor value chain.

On semiconductors, the EU has set a target of increasing Europe's market share in the fabrication of high-end chips (defined as between 2 nm and 5 nm) to 20 percent by 2030, thus doubling the current European production capacities (European Commission, 2021b). To reach these targets, the Commission plans a European industry alliance on microelectronics that would bring together research centres, firms and national governments. This industrial development has also become a headline policy of the updated 2020 New Industrial Strategy (European Commission, 2021c).

On closer inspection, the goal and approach appear vague. For a start, the Commission's stated goal is to double the EU's share of the high-end chip market, from 10 percent to 20 percent. But, the current share of high-end fabrication in the EU is actually zero (as correctly reflected in other Commission documents), even if some inputs from the EU are important in the added value of high-end chips production. The EU has a 10 percent market share in overall semiconductor production capacity, but mostly at the lower end of the technology spectrum[58]. Only Samsung and TSMC are producing the last generation of chips (5 nm nodes), and only three companies have developed second-last generation (below 10 nm) production capacities (Samsung, TSMC and Intel)[59]. None of them currently has high-end foundries in the EU.

The EU's main tool to support the semiconductor industry has been to allow otherwise prohibited state aid

Given its lack of substantial own resources or tax powers to provide subsidies, the EU's main tool to support the industry has been to allow national governments to provide otherwise prohibited state aid[60]. The Commission has defined criteria under which to allow state aid within the single market through so-called important projects of common European interest (IPCEI; European Commission, 2014). IPCEI allows member states to supplement private funds for transnational projects in sectors of strategic importance for the EU. Microelectronics became an eligible sector in 2018. So far, the state aid permitted under the microelectronics IPCEI has amounted to €1.7 billion (Szczepański, 2020). What is more, a Horizon 2020 partnership on the development of low-power chips for supercomputers (the European Processor Initiative), with a budget of €80 million, also benefits the sector[61].

The Commission has said the industrial alliance on microelectronics will be built on "*an initial combined public and private investment of €20 billion to €30 billion*"[62]. What this

55 For instance, digitalisation and industry 4.0 are key components of the German Industrial Strategy, which has the goal of halting the decline in manufacturing and increasing its share of the economy; see BMWI (2019).

56 See https://ec.europa.eu/commission/presscorner/detail/en/ip_21_983.

57 See https://ec.europa.eu/info/strategy/priorities-2019-2024/europe-fit-digital-age/europes-digital-decade-digital-targets-2030_en.

58 Source: Statista, https://www.statista.com/statistics/510374/worldwide-semiconductor-market-share-by-country/.

59 A fourth company, GlobalFoundries, stopped development of below-10 nm chips. See Samuel K. Moore (2018) 'GlobalFoundries Halts 7-Nanometer Chip Development', *IEEE Spectrum*, 28 August, available at https://spectrum.ieee.org/nanoclast/semiconductors/devices/globalfoundries-halts-7nm-chip-development.

60 See 'Joint declaration on processors and semiconductor technologies', available at https://digital-strategy.ec.europa.eu/en/library/joint-declaration-processors-and-semiconductor-technologies.

61 See https://www.european-processor-initiative.eu/.

62 Speech by Commissioner Thierry Breton at Hannover Messe Digital Days, 15 July 2020; see https://ec.europa.eu/commission/presscorner/detail/en/SPEECH_20_1362.

alliance will look like is at the time of writing not clear. Public subsidies would come either from member states under the IPCEI, or from EU funds dedicated to digital transition under the post-COVID-19 Recovery and Resilience Facility. But there is no guarantee the total investment target, which also relies on future private investment, will be reached. While it is not possible to directly compare the subsidy regimes of different countries, announced public investment in the US and China is much larger. The Biden infrastructure plan includes a $50 billion public investment package for the semiconductor industry[63], while the Chinese government planned to spend $170 billion from 2014 to 2024.

To gain market share at the high end of the chip fabrication industry in the face of established industrial clusters in East Asia and in an environment with a high level of subsidies, a much larger level of public support will be needed. European governments do not have the incentives or the resources that could allow them to match US or Chinese subsidies[64]. To justify significant support, more than just a vague sense of strategic autonomy will be needed. We argue that a strategy more tailored to the European position is needed, as it would be unwise for the EU to enter into a global subsidy war over fabrication with the US, China, Taiwan and South Korea. This would not only be a waste of public funds; it could also result in the detrimental fragmentation of this highly specialised industry, if trade restrictions are used to compel companies to locate to particular jurisdictions.

5.1 A more targeted strategy for Europe's semiconductor industry

Instead of mirroring the US's and China's focus on chip fabrication, the EU's semiconductor strategy should have three objectives: improving the security of chip supply to European industries; increasing EU leverage in strategic subsectors and supporting high-tech employment. Lastly, to take stock of the challenges posed by the increased politicisation of trade relationships, the EU should be armed with policy tools to conduct industrial strategies.

Security of supply

The EU's most important goal is to ensure security of supply of chips to its domestic industries. We do not see risks of the EU suffering a shortage of supply of the ICT goods or services that have become crucial to all economic activities. Rather, the concern is the supply of semiconductors as inputs to the production of other goods, in particular, for the EU, industrial machinery and vehicles. With the increasing digitalisation of industrial processes and cars, the demand for chips in European manufacturing is likely to increase, while the concentration of chip production in just a few places creates risks.

Production in the EU is not necessary to increase the security of supply. It can also be achieved through diversification outside the EU. As other countries, in particular the US, are already luring fabrication plants, the EU can 'free ride' on the geographical diversification created by US subsidies. However, this strategy might still run a risk of US politics prioritising American interests over European interests. This leads us to the second objective.

Increasing leverage in strategic subsectors

Diversification of the supply chain can alleviate risks from local factors, such as droughts or regional conflicts. It is also an effective strategy to hedge against political risks in segments of the market without high degrees of concentration, because export restrictions imposed by one country could be compensated for by exports from others. However, countries with monopolistic power in key parts of the value chain could still effectively disrupt supply. This is what the US has done to Chinese companies: it has used the centrality of US technology to, in effect, stop sales to Huawei.

The EU has two priorities. One is to reduce its exposure to political pressure, from the US

63 White House Press Briefing, 31 March 2021; see https://www.whitehouse.gov/briefing-room/statements-releases/2021/03/31/fact-sheet-the-american-jobs-plan/.

64 See footnote 56.

or China. The other is to invest to realistically compete in an industry in which high-end production is done by East Asian players and coveted by the US (and for which it is prepared to provide large subsides). We propose two ways forward. First, the EU should use strategically its own companies with monopolistic power in the value chain and protect them from foreign takeovers. Companies including Trumpf and Zeiss (both German) provide critical components for the machines made by ASML, which itself is a monopolist in the production of the latest generation of manufacturing equipment. These companies should be protected from takeovers and technology transfers. Second, the EU should invest in research and development in sectors in which monopolistic power currently resides within just one jurisdiction, in order to reduce the threat potential. Considering that luring high-end fabrication to the EU would be expensive and would ultimately meet only limited domestic demand in the EU, the US dominance of the software and design of chips would be the most important target here. Increasing the weight of EU players in these subsectors would extend the EU's share of value added in the sector and could reduce the US's ability to unilaterally apply extraterritorial trade restrictions. Upstream parts of the value chain, such as design and software, which are less capital-intensive, offer a better return on investment (Kleinhans, 2021). These are also more in line with the EU's budget resources. Horizon 2020 funds and research initiatives could be used to support research into chip design and software.

Positioning the EU in the high-tech sector

The final objective for EU semiconductor industrial policy should be to harness the economic potential of a high-tech sector with high growth rates. This offers opportunities to create industry clusters with high-skill employment. These opportunities should be capitalised on with EU needs and existing players in mind. The most important customer by far for semiconductors is the ICT sector, which is by and large not European. Although cars, an important sector to the EU, are becoming 'computers on wheels,' they are produced in much smaller quantities: for instance, 75 million cars were sold in 2019 compared to 1.5 billion smartphones[65][66] . The automotive industry accounted for only 8 percent of total semiconductor sales (Cornet *et al*, 2019). The EU as a whole accounts only for 9 percent of semiconductor imports, compared to Asia which accounts for 83 percent of exports and 81 percent of imports. This confirms that significantly increasing semiconductor production in the EU would meet only limited domestic demand.

For European chip fabrication companies, the EU could foster the existing trend of competing on aspects of semiconductor innovation other than reducing node size, such as materials innovation. This would also be a better fit with the chip needs of European industries. With a strong focus on sensors, power electronics, embedded security solutions and security chips, European firms such as NXP, Infineon and STMicroelectronics already play a dominant role when it comes to automotive, industrial applications and encryption.

Thanks to the high degree of specialisation of firms in the industry, the EU could create industry leaders in design for specific chip applications, whereas foundries have such high upfront capital costs that they cannot afford to limit their production to narrow sub-segments. This same logic applies to the provision of support for inputs into the production process, such as ASML's manufacturing equipment. Providing R&D subsidies would help such European companies secure their leading positions. Meanwhile, the overall dynamism of the sector in Europe should be strengthened by ensuring a strong European pool of expertise.

Policy tools for an industrial strategy

Going beyond the narrow question of what the right policy is to support the industry, given the current institutional constraints, the case of the semiconductor industry highlights the structural challenges for Europe's strategic autonomy. The lack of European resources and

65 Source: Statista, https://www.statista.com/statistics/200002/international-car-sales-since-1990/.

66 Source: Statista, https://www.statista.com/statistics/263437/global-smartphone-sales-to-end-users-since-2007/.

Europe's constraints in implementing industrial policy mean that industrial policy projects rely on national governments. Whether the approach of white-listing sectors for national state aid results in an effective targeted industrial strategy is questionable, as it relies heavily on national initiatives, while strategic collaboration between EU countries has not yet happened. In this respect, the industrial alliance proposed by the European Commission in 2021 is encouraging but its objectives, members and resources are still largely undefined. The lack of deep European venture capital markets also impedes the growth of European start-ups. Furthermore, investment screening and protection against technology transfers remains a national prerogative[67]. Only 18 of the 27 EU countries currently have investment screening mechanisms, and the decision on whether or not they greenlight transactions depends entirely on national governments[68]. In all these areas of foreign and trade policy, the advantages of a common policy seem clear. If the EU wants to become a major international player and to be able to protect its economic interests against Chinese (and American) influences, increased centralisation of these policy decisions at European level is necessary.

References

Barkin, N. (2020) 'Export controls and the US-China tech war', *MERICS China Monitor*, Mercator Institute for China Studies

Bauer, H., O. Burkacky, P. Kenevan, S. Lingemann, K. Pototzky and B. Wiseman (2020) *Semiconductor design and manufacturing: Achieving leading-edge capabilities*, McKinsey

Borrell Fontelles, J. (2020) 'Why European Strategic Autonomy Matters', *EEAS blog*, 3 December, European External Action Service

Bown, C. (2020a) 'How the United States marched the semiconductor industry into its trade war with China', *Working Paper* 20-16, Peterson Institute for International Economics

Bown, C. (2020b) 'How Trump's export curbs on semiconductors and equipment hurt the US technology sector', *Trade and Investment Policy Watch*, Peterson Institute for International Economics

Bradford, A. (2020) *The Brussels Effect: How the European Union Rules the World*, Oxford University Press

BMWi (2019) *Industriestrategie 2030: Leitlinien für eine deutsche und europäische Industriepolitik*, Bundesministerium für Wirtschaft und Energie

Casanova, C. and P. Weil (2019) 'From copycat to early bird: Taking stock of China's 5G ambitions', *Coface Economic Publications*, Coface

Cerdeiro, D., J. Eugster, R. Mano, D. Muir and S. Peiris (2021) 'Sizing Up the Effects of Technological Decoupling', *IMF Working Paper* WP/21/69, International Monetary Fund

Chen, A., L. Chen, W. Chou, R. Chung, J. Shao and L. Zhou, (2019) *Semiconductors – the Next Wave: Opportunities and winning strategies for semiconductor companies*, Deloitte

Collins, G. and A. Erickson (2020) 'Policy Options to Impose Costs on Beijing's Coercive Envelopment of Hong Kong: Version 1.0', *China SignPost*, 30 June

Cornet, A., H. Deubener, R. Dhawan, T. Möller, A. Padhi, P. Schaufuss and A. Tschiesner (2019) *Race 2050 – A Vision for the European Automotive Industry*, McKinsey Center for Future Mobility

67 The 2019 Investment Screening Regulation ((EU) 2019/452) only introduces information sharing mechanisms and allows the European Commission to issue (non-binding) opinions; see http://trade.ec.europa.eu/doclib/press/index.cfm?id=2006 (accessed on 7 June 2021).

68 Status as of 30 March 2020; see https://trade.ec.europa.eu/doclib/docs/2019/june/tradoc_157946.pdf.

Coulon, O., J. Olliver, G. Dubois, L. Saint-Martin and M. Vodovar (2020) *Study on the Electronics Ecosystem: Overview, Developments and Europe's Position in the World*, Publications Office of the European Union

Danish Technological Institute (2012) *Study on internationalisation and fragmentation of value chains and security of supply, Case Study on Semiconductors*, report prepared for European Commission, DG Enterprise and Industry

de Jong, E. (2020) 'Semiconductor winners – European companies with strong positions', *Edison Investment Research*, 16 August

Demertzis, M. and G. Wolff (2019) 'Hybrid and cybersecurity threats and the European Union's financial system', *Policy Contribution* 2019/10, Bruegel

Duchâtel, M. (2021) 'The Weak Links in China's Drive for Semiconductors', *Policy Paper*, January, Institute Montaigne

Duthoit, A. (2019) 'A 2020 semiconductor slump will send shockwaves across the global electronics industry', *The View*, 30 October, Euler Hermes Allianz Economic Research

European Commission (2014) 'Criteria for the analysis of the compatibility with the internal market of State aid to promote the execution of important projects of common European interest', 2014/C 188/02, *Official Journal of the European Union*

European Commission (2021) 'Strategic dependencies and capacities', *Staff Working Document*, SWD(2021) 352 final

European Commission (2021a) 'Trade Policy Review - An Open, Sustainable and Assertive Trade Policy', COM(2021) 66 final, available at https://trade.ec.europa.eu/doclib/docs/2021/february/tradoc_159438.pdf

European Commission (2021b) 'Annex to the Communication 2030 Digital Compass: the European way for the Digital Decade', COM(2021) 118 final, available at https://eur-lex.europa.eu/resource.html?uri=cellar:12e835e2-81af-11eb-9ac9-01aa75ed71a1.0001.02/DOC_2&format=PDF

European Commission (2021c) 'Updating the 2020 New Industrial Strategy: Building a stronger Single Market for Europe's recovery', COM(2021) 350 final, available at https://ec.europa.eu/info/sites/default/files/communication-industrial-strategy-update-2020_en.pdf

Guadagno, F., T. Hoeren and S. Wunsch-Vincent (2015) 'Breakthrough technologies – Semiconductor, innovation and intellectual property', *WIPO Economic Research Working Paper* No. 27, World Intellectual Property Organisation

Holdren, J., P. Otellini, R. Beyer, W. Bush, D. Farrell, J. Hennessy … L. Whitman (2017) *Ensuring Long-Term U.S. Leadership in Semiconductors*, Report to the President, President's Council of Advisors on Science and Technology

Hunt, W. and R. Zwetsloot (2020) 'The Chipmakers: U.S. Strengths and Priorities for the High-End Semiconductor Workforce', *CSET Issue Brief*, Center for Security and Emerging Technology

ISDP (2018) 'Made in China 2025', *Backgrounder*, June, Institute for Security and Development Policy

Johnson, B. (1991) 'The U.S.-Japan Semiconductor Agreement: Keeping Up the Managed Trade Agenda', *Backgrounder* No. 804, The Heritage Foundation

Kleinhans, J. and N. Baisakova (2020) *The Global Semiconductor Value Chain: A Technology Primer for Policy Makers*, Stiftung Neue Verantwortung

Kleinhans, J. (2021) 'The lack of semiconductor manufacturing in Europe', *Policy Brief*, April, Stiftung Neue Verantwortung

Lee, J. and J. Kleinhans (2020) 'Would China Invade Taiwan for TSMC?' *The Diplomat*, 15 December

Leonard, M., J. Pisani-Ferry, E. Ribakova, J. Shapiro and G. Wolff (2019) 'Redefining Europe's Economic Sovereignty', *Policy Contribution* 2019/9, Bruegel

Lewis, J. (2019) *Learning the Superior Techniques of the Barbarians: China's Pursuit of Semiconductor Independence*, China Innovation Policy Series, Center for Strategic and International Studies

OECD (2019) 'Measuring distortions in international markets: The semiconductor value chain', *OECD Trade Policy Papers* No. 234, OECD Publishing, Paris

Office Parlementaire d'évoluation des choix scientifiques et technologiques (2008) 'Rapport sur l'évolution du secteur de la micro/nanoélectronique', *Annexe au procès-verbal de la séance du 25 juin 2008*, Sénat, Session Ordinaire de 2007-2008, N° 417

Onishi, K. (2007) 'The restructuring of Japanese semiconductor industry', 専修商学論集 (*Specialised Commerce Studies*) 84: 127-133

Orr, G. and C. Thomas (2014) 'Semiconductors in China: Brave new world or same old story?' McKinsey, 1 August

Sauvage, J. (2019) 'Let the chips fall where they may: a story of subsidies and semiconductors', OECD.org, 4 December, Organisation for Economic Cooperation and Development

Szczepański, M. (2020) 'Important projects of common European interest: Boosting EU strategic value chains', *Briefing*, PE 659.341, European Parliamentary Research Service

Thomas, C. (2021) 'Lagging but motivated: The state of China's semiconductor industry', *TechStream*, Brookings, 7 January

Triolo, P. (2021) 'The Future of China's Semiconductor Industry', *American Affairs* vol. V, no. 1

US National Security Commission on Artificial Intelligence (2021) *Final Report*, available at https://www.nscai.gov/2021-final-report/