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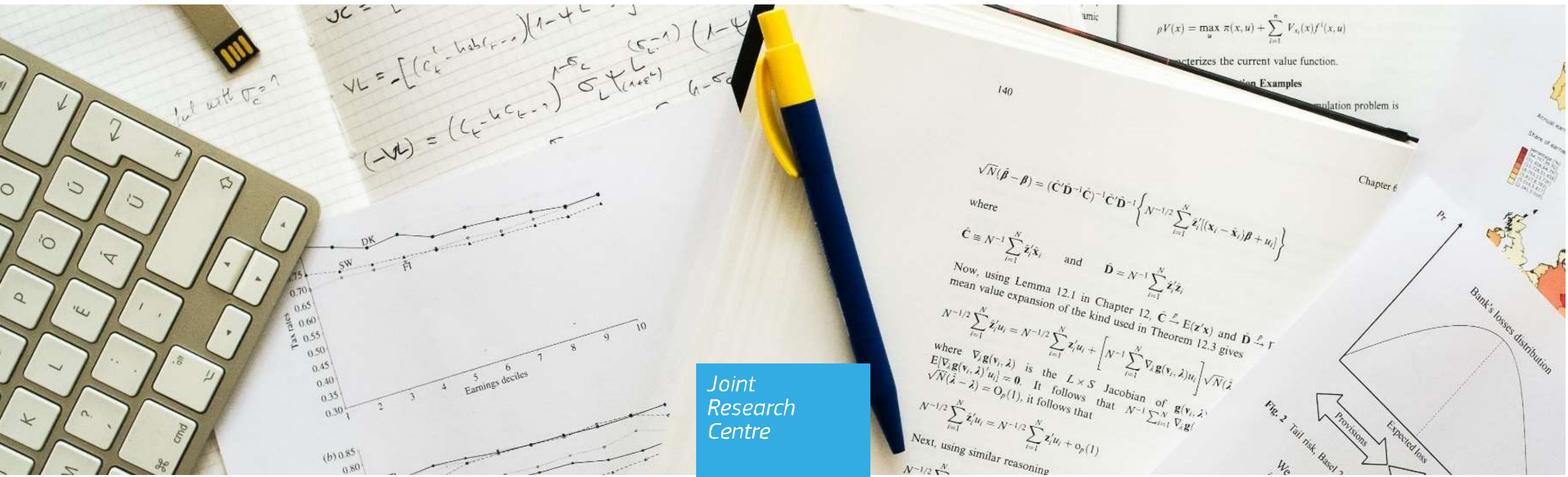

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The position of the EU in the semiconductor value chain: evidence on trade, foreign acquisitions, and ownership

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Executive Summary

Semiconductors have a central role in the modern economy and constitute the backbone of the sectors guiding the ongoing digital revolution such as autonomous vehicles, artificial intelligence, quantum computing, industry 4.0, 5/6G communications, and the internet of things. To a different extent, also more traditional sectors increasingly rely on semiconductors.

This document investigates the position of the EU in the global value chain (GVC) for the production of semiconductors. This production chain is dominated by a handful of countries. Yet, given the high specialization of companies, no country is independent or autonomous over the entire chain, the different countries retain a leading position in specific segments of the chain.

Focusing on product-level trade data, we first describe the position of EU in terms of its trade balance vis-à-vis other important economies in this sector: The People's Republic of China, Japan, South Korea, Taiwan, and the United States. We then use firm-level data to assess and quantify linkages between companies involved in the production of semiconductors and companies operating in other industrial sectors, located outside and inside the EU. We report evidence on foreign investments on EU companies operating in this industrial ecosystem between 2015 and the first semester of 2021 (2021H1).

Finally, we apportion over 1000 companies to the different segments of the value chain and provide evidence on turnover according to the location of the controlling ultimate owner of the companies operating in each segment of the chain.

Indices on sectoral value chain integration, based on trade data, indicate that EU countries increased their integration into the world value chain of electrical and optical equipment, the sector to which semiconductors belong, over the period 2007-2019 due to an increased reliance on imports of intermediates (i.e. backward integration) from China, Taiwan, and South Korea, observed from 2016 onwards.

Relying on product-level trade data, we find that the EU is a net importer of transistors, diodes, and similar semiconductor devices (mostly from China), as well as of electronic integrated circuits (mainly from Taiwan). In particular, Taiwan is the first source of EU imports of processors, other electronic circuits, D-rams and multi-combinational memories. South Korea and Taiwan are world-leaders in the production of the smallest and most technologically advanced chips (10nm and below).[1] However, this may partially change within 3 to 5 years, as leading Taiwanese and South Korean companies plan to build cutting-edge manufacturing plants in the United States.[2]

Upstream in the production chain, the EU is a net exporter of machines for the production of semiconductors. As expected, machines are mostly exported to those countries leading in chip production: China, Taiwan, and South Korea. As expected, the EU is a net importer, mostly from the United States, Russia, and China, of other inputs employed for the production of semiconductors such as beryllium, chromium, germanium, vanadium, and gallium.

[1] Intel started supplying 7nm nodes in 2021. In the meanwhile, TSMC and Samsung are capable to produce 5nm and 4nm nodes. TSMC has control over 85% of the market for nodes between 5nm and 10nm, the rest, 15%, is controlled by Samsung. The market for these nodes is worth 18.5 Billion EUR (Source: Bain, IC Insight, Gartner).

[2] Refer to https://time.com/6123035/samsung-us-chip-plant-texas/ and https://www.reuters.com/technology/tsmc-says-construction-has-started-arizona-chip-factory-2021-06-01/.

Supply chain data confirms that EU companies in semiconductors strongly rely on suppliers and/or customers headquartered outside the EU. We find that, on average, almost 80% of suppliers to European firms operating in the semiconductor industry are headquartered outside the EU. Additionally, EU companies supplying the semiconductors' industry have only 37% of their customers in the EU, on average. The majority of foreign suppliers to European firms in semiconductors is headquartered in the United States, followed by Taiwan, China, South Korea, and Japan. Their EU customers producing electronic components and loaded electronic boards are mostly located in Germany and France, followed by Belgium, and the Netherlands.

European companies operating in semiconductors attracted sizeable investments in the recent years. Narrowing the focus to EU companies in the NACE sector 26.11, manufacturers of electronic components, which is the sector of the official industrial classification that collects most of the companies working in semiconductors, we find that foreign companies between 2015 and 2021H 1 invested 33 billion EUR. In the EU. As much as 91% of the deals concerns portfolio investments: acquisitions where the acquirer, thanks to the deal, gains control over less than 10% of the shares in the target company. During the same period, we observe an average of 16 M&A deals per year.
With more than 54% of minority deals and almost 27% of M&A, US investors have a leading role for FDI received by EU in this sector. Investors based in Norway (14%), Cayman (11.4%), and United Kingdom (10%) follow in the ranking for minority and portfolio deals in the EU. Companies whose ultimate owner is Chinese (21%), Japanese (12%) or Swiss (9%) follow the US in the ranking of M&A deals with EU targets in semiconductors.

We conclude our analysis by mapping companies belonging to the semiconductor value chain at the world level and investigating the turnover of the companies by jurisdiction of their ultimate owner. Total turnover for the top-10 companies, with respect to revenue, among the manufacturers of semiconductors amounts to 266 Billion EUR for year 2020.[3] The same group of companies accounts for 87% of market capitalization of this industry in 2021.[4] Our coverage is uneven across jurisdictions. We have a richer coverage for Europe than for the US and China, given the interest in analysing the European landscape.
Data on turnover by segment shows that EU-owned companies represent a relevant share of the input suppliers for the production of semiconductors (evidence confirmed by De Jong, 2020, as well as by Kleinhans and Baisakova, 2020). Indeed EU companies are among the largest suppliers of chemicals and gases in this supply chain, accounting for 34% of world turnover in 2020. US companies are leaders in the production of equipment used for the production of semiconductors with 31% of the turnover, closely followed by European ones with 27%.
The picture changes when looking at the turnover of EU-owned chip producers (foundries) and chip designers (fabless companies), which is negligible.[5] Taiwanese firms share with South Korean manufacturers the leadership in the foundry segment.
Chinese companies control a sizeable share of world turnover only in the fabless segment (18%), which is dominated by US companies, and in the back-end (27.6%), but are lagging behind in segments placed more upstream in the value chain (i.e. input suppliers).

[3] IC Insights (2020).
[4] Information obtained from the Eikon-Refinitiv database.
[5] The term fabless is a contraction of the fabrication-less.

Introduction

This report provides a multi-faceted overview of the EU position in the semiconductors global value chain (GVC). Incredibly complex, interconnected, and capital intensive, the semiconductors GVC is at the core of the digital economy. Chips power everything from computers, smartphones, cars, servers in data centres, to gaming consoles, and domestic appliances, playing a key role for economic competitiveness and security, and constituting the basic technology for the ongoing digital transformation (Bown, 2020; Bloom et al. 2020).

This document describes the segmentation of the value chain, the different typologies of companies involved in the chain, as well as some characteristics of the corresponding markets looking at trade data but also providing a more granular analysis based on firm-level customers/suppliers data and on ownership links among companies. The aim of this analysis is to highlight strengths and weaknesses of the EU in the different segments of the value chain.

Semiconductors are electronic devices relying on the properties of a semiconductor material for their functioning.[6] There are seven broad categories of semiconductors: memory, logic, micro, analog, optoelectronics, discrete, and sensors. The first four categories – memory, logic, micro and analog semiconductors - are often jointly labelled as integrated circuits (ICs).

Memory includes short-term memory (DRAM) and long-term memory (NAND). DRAM are used for example in personal computers, workstations and servers while NAND can also be found in mass storage devices like USB flash drives, digital cameras and MP3 players, and in scientific, industrial and medical electronics.

Logic circuits integrate different types of circuits to implement specific functionalities responding to the necessities of a particular user (as in ASICs, application specific integrated circuits). Micro includes microprocessors or microcomputers as central processing units (CPUs), graphic processing units (GPUs), and accelerated processing units (APUs) which combine both CPUs and GPUs. Finally, analog integrated circuits, which includes operational amplifiers, power management circuits and sensors, are what makes computers, cell phones, and digital devices work, and can be found inside almost every consumer electronics available today.

In 2020 semiconductor sales totalled 410 Billion EUR, and 80% of that (328 Billion EUR) were IC sales. Sensors (such as microelectromechanical systems, MEMS) optoelectronics (such as LEDs), and discrete semiconductors (single transistors) together made up the remaining 20% of sales in the industry.[7]

The interest on semiconductors has increased exponentially in recent years given their role for the functioning of the modern economy. World market capitalization of semiconductors companies boosted from 438 Billion EUR in 2005 to over 2.5 trillion EUR in 2021 with an average yearly increase of over 30% in the last five years and a record upsurge of +53.7% in 2021 as compared to 2020.[8]

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[6] Primarily silicon, germanium, and gallium arsenide, but also organic semiconductor materials (Semiconductor Manufacturing Materials (eesemi.com)).

[7] Refer to Gartner (2021) in https://www.asml.com/en/news/press-releases/2022/asml-position-paper-on-eu-chips-act and to De Jong (2020).

[8] Thomson Reuters, Data-stream, downloaded Nov. 2021.

A buoyant stock market performance has been fuelled by the chip shortage experimented in 2021. This shortage has harmed the production of goods ranging from cars to consumer appliances, personal computers and smartphones and will likely extend into 2022 and potentially even beyond if new production capacity is not made available soon enough.[9] Mc Kinsey indicates that while the semiconductor industry has increased its production capacity by nearly 180% since 2000, its total capacity is nearly exhausted at the current utilization rate.[10] The growing demand is therefore not likely to find available supply in the medium term. The main world producers are currently expanding productive capacity but this will take time to be operational as a production facility requires between 18 and 24 months to start production, regardless of the billions of Euros that are needed for the investment.[11]

Semiconductors are also at the very heart of the geopolitical scene with tensions rising between US, China and Taiwan.[12] In September 2020, the US government sanctioned the China's largest chipmaker, Semiconductor Manufacturing International Corporation (SMIC), citing military end use in China. Two months later, China released its 14th five-year plan, advocating the autonomy in semiconductor production as a way to achieve technological self-reliance (also based on foreign investments). In 2021, the U.S. Army War College suggested that Taiwan Semiconductor Manufacturing Company (TSMC), the most important chipmaker in the world and China's most important supplier, could have been the main reason behind the pursued Chinese reunification with Taiwan.[13]

The semiconductors' GVC is also at the centre of ambitious national investment plans. In June 2021 the US administration approved a $52 Billion investment plan for domestic semiconductor manufacturing. The European Commission is adopting a European Chips Act by 2022 with the objective to double the EU market share in semiconductors from 10% to at least 20% by 2030.
South Korea approved up to US$65 Billion in support for semiconductor supply chain by 2030 with the ambition to attract more than $450 Billion investment from the private chip sector. The support also includes tax incentives and relaxed regulations[14].

China, another key player, massively increased investment in semiconductors over the last two years. In 2020, investment going into China's semiconductor companies reached RMB 227.6 Billion (around $35.2 Billion).

[9] The increase in demand, driven by digital transformation and accelerated by the pandemic, the just-in-time manufacturing practices with its low stock-levels and the increased digitalisation of industrial sectors are among the reasons for the current lack of chips in the market.
[10] See The semiconductor shortage in autos: Strategies for success | McKinsey May 27, 2021.
[11] All major chip producers are investing to expand capacity. The word largest chipmaker TSMC plans to spend over $100 bn over the next three years to expand its chip fabrication capacity, while its rival Samsung expects investments for $116 bn over a decade to expand its foundry business. In Europe, Intel is negotiating the opening of a semiconductor plant in Ireland for automakers, and facilities in France and Italy including a production site in Germany for a total investment of €80 bn over the next decade. The EU two largest home-grown chipmakers NXP Semiconductors and STMicroelectronics are also active. The first is expanding its German site by investing 67 million Euro and the second is investing up to $3 billion into its new fabrication plant in Italy shared with the Israeli foundry Tower Semiconductor.
[12] https://www.globaltimes.cn/page/202112/1241579.shtml
[13] This argument is rejected by Chinese authorities, refer to Taiwan Should Destroy Its Chip Industry To Deter Chinese Invasion, Says US Military Journal (ibtimes.com)
[14] Techwire, 18 January 2022, Is the world still too dependent on Asia to solve the chip shortage? (techwireasia.com)

The National Integrated Circuit Industry Investment Fund is the Chinese government's main vehicle for semiconductor investment. Created in 2014 by China's Ministry of Finance and China Development Bank Capital, and other state-owned enterprises, the fund had RMB 138.7 Billion (~$22 Billion) to invest in chip manufacturing and design and promote mergers and acquisitions. In 2019 the fund raised another RMB 204 Billion (~$32 Billion) in a new funding round from the Chinese Ministry of Finance, state-owned enterprises, and local governments. Furthermore, hundreds of local funds have been created to support the industry with more than RMB 300 Billion (~$47 Billion) funding.[15] Additionally, the Chinese government offers a range of other incentives and preferential policies to support semiconductor production in China, including grants, cheap utility rates, low-interest loans, tax breaks, and free or discounted land.[16]

Meanwhile, the chip shortage, public incentives, and technology trends are changing the semiconductors' global value chain. Tech giants like Apple, Amazon, Meta (formerly Facebook), Tesla, and Baidu declared the intention to bring the design aspects of chip development in-house in order to have custom-designed chips rather than relying on generic chips.[17] Concepts such as strategic autonomy in EU, self-sufficiency in China, and protection of national supply chain in the US are shaping public investments and hence triggering the reorganisation of production across the globe.

Prior to any evaluation on strategic dependency of Europe, a reliable mapping of the global value chain for semiconductors is needed. This mapping must be at least firm-level to allow exploring dependencies and choke points within single segments and across segments, and it requires the integration of datasets of very different nature. It is impossible to construct a mapping for the value chain of each single product related to the semiconductors ecosystem, be it a sensor or a heat-resistant glue to fix the integrated circuit to the wafer surface. Therefore, following the literature, we decided to map broad categories and divide the value chain in 7 segments covering the whole spectrum of the production of semiconductors (i.e. the supply side), from the providers of raw materials to the packaging and testing of the chips. What is left out from our mapping is the basic research related to semiconductors, done in universities or other public/private entities. Our mapping has the aim to obtain information on the relative share of turnover controlled by each jurisdiction and dependencies, and this can only be done using balance sheet information. Therefore, the natural subjects of our mapping are commercial companies and not universities or research centres. Another limitation of our analysis is the absence of the demand side. We do not map companies e.g. in automotive, in consumer electronics, or in the energy-related industry that demand chips. Such a mapping is left for future research.

The second challenge encountered has been the search for available data. No official or commercial database is entirely satisfactory for the description of this complex value chain and its interlinkages, as each of them focuses on a given feature but fails to provide the *big picture*. This report, therefore, is also an attempt to bring together different data and provide a multifaceted view of the semiconductor value chain.

[15] Where China is investing in semiconductors, in charts · TechNode
[16] Trivium China Deep Dive, OCTOBER 30, 2021
[17] See Why Tesla, Apple, Google and Facebook are designing their own chips (cnbc.com)

The traditional data to describe value chains is the trade data, i.e. the value or quantity of goods traded across countries. Trade data have been traditionally used to measure geographical dependencies for the different typology of semiconductors (EU Commission, 2017). However, one has to bear in mind that trade data gives information on goods traded across countries and not on where these goods are produced, with the EU representing a single block due to the internal markets rules. Traded goods are not linked to companies and often product descriptions are not detailed enough to distinguish between state of the art and more mature technologies.[18] It is also impossible to differentiate the trade made by domestic companies from that of subsidiaries of foreign companies.

One could think to reconstruct the semiconductor value chain starting from commercial firm-level datasets. The difficulty is that these datasets classify companies according to some official classification code (e.g. the EU-NACE or the US-NAICS). In official classifications, semiconductors are associated to a few sector codes[19], which only partially represent the reality of companies in the value chain. Official sector codes cover about 60% of the companies belonging to the value chain, mainly Fabless (chip design), Foundries (chip production) and IDMs (integrated design manufacturers). Producers of essential inputs such machines to manufacture chips, suppliers of raw materials such as silicon or gallium, and companies dealing with the back-end part of the chain (testing and packaging) are often classified with other sector codes, together with companies totally unrelated to semiconductors. This implies that the reconstruction of the value chain using official sector codes cannot be considered as exhaustive.

Relying on different data sources, we identify and manually apportion more than 1,000 companies headquartered everywhere in the world, to the different segment of the semiconductors' value chain. We cover the supply side of chips, and divide the production chain in several segments: the design stage (fabless companies), the production of chips (foundries), the supply of inputs (machinery and raw materials) and the packaging and testing.
IDMs (integrated device manufacturers) are also mapped. This group of companies performs internally several functions, typically R&D, the design and the production of chips.

We do not cover the entire world market in terms of number of companies, as it is almost impossible to spot all the small or medium size companies working in such a complex and dynamic market. However, in our mapping, the total turnover for the top-10 companies in semiconductors amounts to 266 Billion EUR for year 2020, while external sources estimate total sales for the same group of companies to 268 Billion EUR (IC Insight, 2020). The same group of companies accounts for 87% of market capitalization of this industry in 2021.[20] Our coverage is uneven across jurisdictions. We have a richer coverage for Europe than for the US and China, given the interest in analysing the European landscape.

[18] It is not possible, for example, to distinguish the trade of chips depending on their dimension.
[19] In the Nace rev. 2 classification, the majority of companies in semiconductors are under 26.11 and 26.12 while in the NAICS-2017 classification they are under 334412, 334413, 334416, 334417, 334418, 334419.
[20] Eikon-Refinitiv, extraction done in February 2022.

This report is organized as follows. Section 1 describes the semiconductor value chain (SVC). Section 2 reports evidence on the position of EU using data on trade flows for some products related to this value chain. Section 3 relies on information on the industrial classification of EU companies to describe foreign investments on European firms in the SVC. The same section provides findings on supplier-customer linkages between EU and foreign firms operating in the SVC. Section 4 reports on our mapping of the global value chain and on the ownership of companies in the different segments. Section 5 concludes.

1. The semiconductors' value chain

The value chain for the production of semiconductors can be divided into different stages (EU Commission, 2016; Kleinhans and Baisakova, 2020). As illustrated by Figure 1, the chain starts with the **research and design stages**. The research segment is characterized by the presence of companies and other entities, which are active in the development of innovations leading to intellectual property rights associated to the manufacturing of chips.[21]
Designing chips requires remarkable investments and recently many companies entered this segment of the chain to design application-specific (ASIC) chips.[22] The design of chips is possible thanks to highly sophisticated software, which is supplied by the electronic and design automation (EDA) companies. As this market is highly concentrated due to high upfront investments, a handful of companies at the global level constitute the whole EDA sector.[23] EDA suppliers keep pace with the industry's extremely short innovation cycles relying on deep understanding of the fabrication process and on close linkages with chip manufacturers.

The next stage of the chain is the one devoted to the manufacture of chips, which takes place in **"foundries" or "fabs"**. Over the last twenty years, the production process became increasingly complex due to the rampant technological evolution of the industry (Thompson and Spanuth, 2018). The fabrication of chips is highly capital-intensive. Building a fab producing the most advanced nodes easily exceeds 13 Billion EUR.[24] Consequently, the foundry market is also concentrated among a limited number of players worldwide.[25]

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[21] Other entities include universities and other research institutions which might be a result of joint ventures or collaboration agreements with or between private companies.

[22] Designing a 5nm node costs about 470 million EUR including validation and IP qualification. The amount required to design 10nm chips is around 153 million EUR, while designing a 7nm chip is estimated in the order of 260 million EUR (McKinsey, 2020).
Chips that are specifically designed to work on machine learning models are called "AI chips" and are a type of application-specific integrated circuit (ASIC). Companies like Alibaba, Alphabet (Google), Amazon, Facebook-Meta, and Tesla,, in the recent years started designing application-specific circuits (Kleinans and Baisakova, 2020).

[23] Three US-based companies control the EDA market: Cadence Design Systems, Mentor, and Synopsys. Mentor was acquired by the EU based Siemens in 2017 but it's production facilities are entirely based in the United States. Synopsis and Cadence invest more than 35 % of their revenue in R&D (Moody's Orbis-global, data retrieved in Feb. 2022). In the case of Synopsis, the largest company among the three, this corresponds to 1.26 Billion EUR in 2021.

[24] The new production site of TSMC in Phoenix (Arizona, US) will include six production sites and its estimated cost is in the order of 30 Billion EUR. The site is expected to start production in 2024. https://www.abc15.com/news/business/taiwan-semiconductors-phoenix-plant-likely-three-times-larger-than-originally-announced

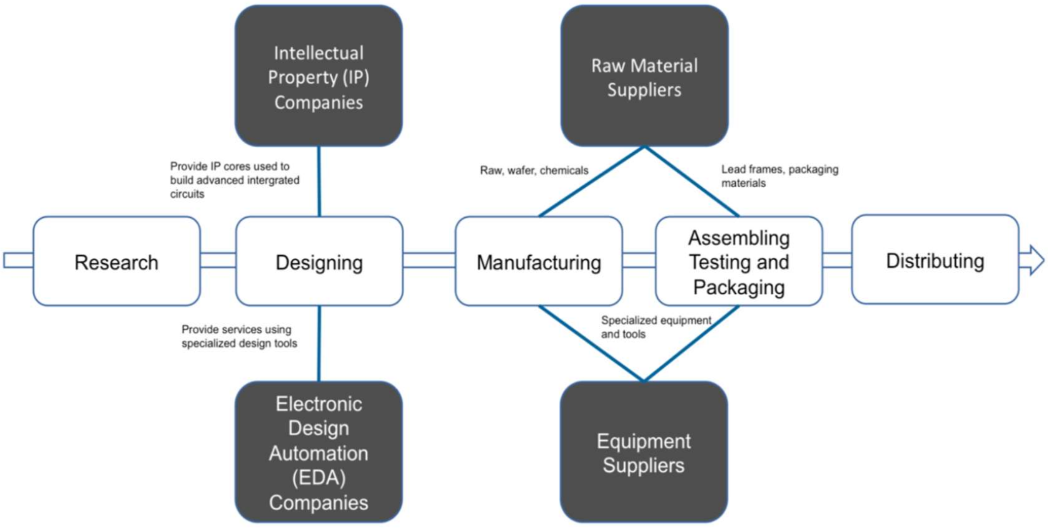
[25] The manufacturing of chips involves complex production stages which make the manufacturing process take up to 26 weeks (Falan, 2021). A measure for the technological advancement of a foundry is the minimum size of chips it can produce, measured in nanometers (nm). Currently only two companies worldwide, the South Korean Samsung and the Taiwan-based TSMC can produce 7nm chips while the frontier of research is with the 2.5 nm chips. Just to give a term of comparison the dimension of a molecule of the DNA is 2.5nm.

Companies manufacturing chips can operate as contractors for other companies, which are only focusing on the design of chips, the "**fabless**" companies, or in alternative, exclusively manufacture chips for their parent companies. Fabless companies emerged recently in the production chain as a new business method due to the increased specialization and the relevant costs associated with the design of chips. Fabless companies design and outsource the production of the most advanced chips (7nm and below) for their applications in consumer electronics (informatics and smartphones).

Foundries receive inputs from other companies. Among them, the suppliers of raw materials and the suppliers of semiconductors manufacturing equipment (SME). **Suppliers of raw materials** to foundries produce chemical products and/or wafers of different diameters, which are employed in the lithography process done at foundries[26]. Silicon wafers are largely employed in the production process, but also gallium arsenide (GaAs), gallium nitride (GaN), and silicon carbide (SiC) wafers are used for specific applications. In most cases, the suppliers of raw materials and basic chemicals operate in the production of inputs for other manufacturing industries (Goodman et al., 2019).

Equipment suppliers manufacture the machines, often automated, employed to produce semiconductors. Different types of equipment are needed to manufacture integrated circuits, while even the largest companies in this segment focus their output on machines for specific phases of the production process (e.g. etching, dying, and testing). The most advanced machines for the production of chips, which rely on extreme ultra-violet lithography technology, are traded for values in the order of a hundred million EUR.

Figure 1: The Semiconductor Value Chain.



Source: SIA, DECISION Étude & Conseil.

[26] Slices of semiconductor material (usually silicon), called wafers, are grabbed either physically or chemically according to a given scheme to crate grooves in the surface where the integrated circuit will be placed. The grabbing phase is called lithography.

The last stage of the production chain is the one of the **assembling, testing, and packaging** of chips. This segment is characterized by the presence of outsourced semiconductor assembly and test (OSAT) companies, and is more labour intensive than capital intensive, contrary to the preceding segments of the production chain. OSAT companies receive as inputs the machines for the testing, cutting, and assembly of chips, as well as the lead frames and the packaging materials. These last stages of the production process can be also done internally in companies manufacturing chips.

The value chain sees also the presence of companies jointly operating in the design, the manufacturing, the assembling, testing, and packaging of semiconductor devices. These companies are labelled as **integrated device manufactures** (IDMs). Some of the largest conglomerates are active as IDMs in this production chain.

2. Inferring the position of EU in the value chain using trade data

Sector level data on GVC integration obtained from World Integrated Trade Solution (WITS) of the World Bank provides first insights on how connected is the EU to GVCs in this industrial sector.[27] Given the aggregate information available from this source, we report data on GVC integration focusing on the "*electrical and optical equipment*" sector, to which the semiconductors belong, relying on data for the period 2007-2019.[28] The total GVC index represents how integrated is a country-industrial sector, in global value chains by computing the amount of output (in Million EUR) that can be assigned to GVC linkages. This index is determined, for each country, by the average of pure backward GVC integration (the amount of domestic output in the *electrical and optical equipment* sector – in Million EUR - that depends on foreign imports) and pure forward integration (the amount of domestic output exported abroad).[29] The higher is backward GVC integration the more dependent is a country/region on foreign suppliers/clients, while the opposite holds for forward integration.

Data reported in Figure 2 for the all EU member states (left-hand side) shows that GVC integration, represented by the GVC index, in this sector has increased by more than 10% from 2007 to 2019, especially starting from 2016, after a sizeable downturn recorded in 2009.[30] In this period, European countries increased their reliance on foreign suppliers (backward integration) but at the same time increased their connections with the rest of the world by exporting more of their output (forward integration). Data on GVC integration for countries in the rest of the world (right-hand side) shows a slightly different pattern: the growth of total GVC integration is larger and equal to 47% in the same period. Contrary to what observed for EU countries, this is fuelled by an increase in forward integration rather than by backward integration. Germany is by far the most integrated member state in the value chain for this sector, this country accounts for almost a third of total GVC integration in the EU. The Netherlands and Italy follow with 9%, while France accounts for 8% (Figure 3).

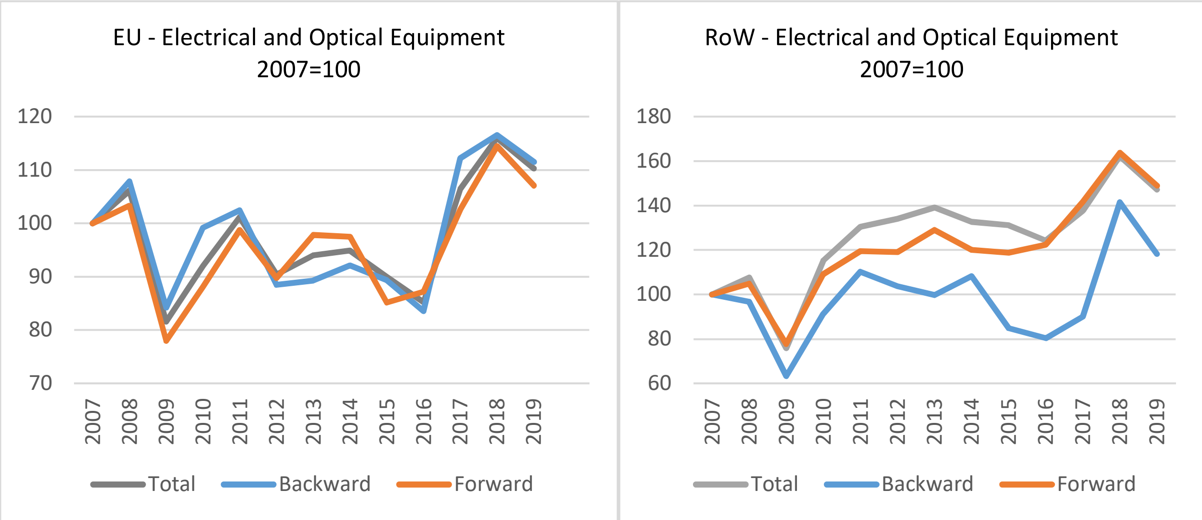
[27] The most updated data on GVC integration available on WITS is provided by the ADB (Asian Development Bank) following the methodology discussed in Borin and Mancini (2019).

[28] Given the features of this database is not possible to infer the share of GVC integration due to semiconductors for this industrial sector.

[29] The reader is also referred to Arto, I., Dietzenbacher, E. and Rueda-Cantuche (2019) which propose a framework that enables to decompose the factor content of bilateral trade measured at the border and account for the role of the different countries and industries participating in the global vale chain.

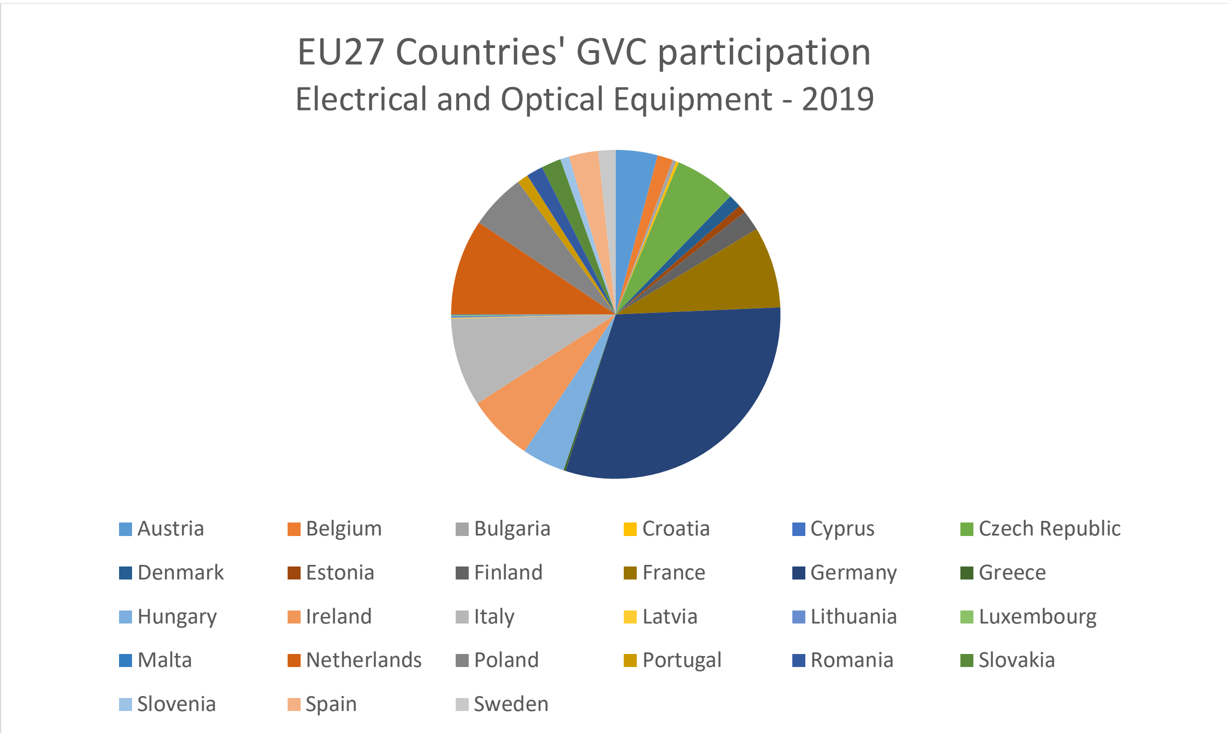
[30] The index measures the amount of output, in US Dollars, that can be assigned to GVC integration in the different countries-sectors. To provide insights on the evolution over time of this index, we rescaled it taking the value recorded in year 2007 as the base year.

Figure 2: Total, backward, and forward GVC integration, EU.



Source: JRC elaboration on World Bank data (WITS), data access Nov. 2021. Backward integration: amount of domestic output that depends on foreign imports. Forward integration: amount of EU output exported. Figures report the rescaled value for sums of the various indexes for all EU27 member states.

Figure 3: EU involvement in GVC: Total Integration, 2019



Source: EU27 GVC output as a share of total EU27 GVC output. JRC elaboration on World Bank data (WITS).

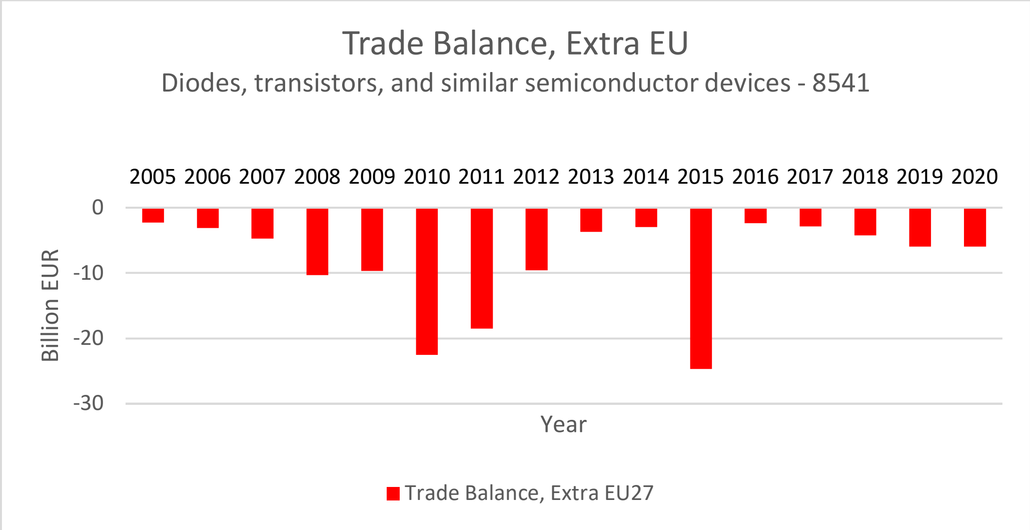
A second, more detailed, snapshot of the role of the EU in the global trade of products pertaining to the semiconductors' value chain, can be obtained looking at Comext data on product-level trade for goods in the different segments of the production chain.[31] It is important to underline that inference drawn on this data might be affected by the presence of re-exports.[32]
In particular, we investigate the trade balance for specific categories of products/inputs vis à vis the other main players in this value chain (i.e. China, Japan, South Korea, Taiwan, and the United States). In the Comext HS (Harmonized System) 4-digit classification, the most representative product categories that include outputs of the SVC are (1) *diodes, transistors, and similar semiconductor devices* (HS 8541) and (2) *electronic integrated circuits such as processors, memories, and amplifiers* (HS 8542).

Data for HS 8541 (*diodes, transistors, and similar semiconductor devices),* which includes **the less advanced semiconductor devices**, reported in Figure 4, shows that EU is a net importer of these goods with a trade deficit higher than 4 Billion EUR from 2018 onwards.[33] Focusing on specific HS 8-digit products belonging to this product category (Table 1), we find that China is the leading exporter to the EU of photosensitive semiconductor devices, transistors, light emitting diodes, diodes, and mounted piezoelectric crystals. Taiwan is the second exporter of photosensitive semiconductor devices and diodes to the EU, while Japan takes this position for the other products included in this category.

Imports from China accounted for more than 30 % of total imports from trade partners outside the EU starting from 2007 onwards (Figure 5). Interestingly, both in 2019 and 2020, China accounts for more than 50% of EU imports in this category. China is the country mostly involved in back-end production phases (mainly testing and packaging) for these products.

[31] OECD (2019) provides a list of HS 6-digit products which are traded along this value chain.
[32] Rueda Cantuche, Pedauga, and Madras (2022) take this issue under consideration and provide insights for trade flows of solar PV technologies, among others. See also chapter 6 of Eurostat (2019) for a description of this methodology.
[33] The trade deficit was larger than 20 Billion EUR in 2015 and 2010.

Figure 4: Diodes, transistors, and similar semiconductor devices. EU Trade Balance versus extra-EU countries.



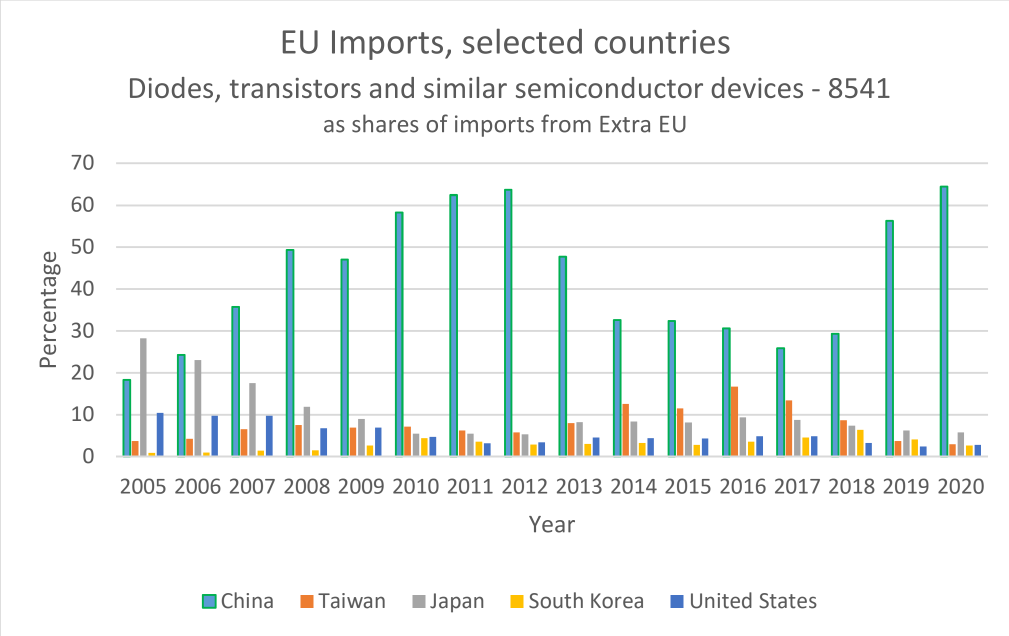
Source: JRC elaboration on Comext Data.

Table 1: Diodes and transistors,
leading imported products and leading third countries exporting to EU

Averages: period 2017-2020	1st	2nd	3rd
1.Photosensitive semiconductor devices	China	Taiwan	South Korea
2.Transistors with a dissipation rate >= 1 w	China	Japan	United States
3.Light-emitting diodes	China	Japan	South Korea
4.Diodes	China	Taiwan	Japan
5.Mounted piezoelectric crystals	China	Japan	Taiwan

Note: Products have been selected based on the ranking of cumulated imports from extra-EU countries in the period 2017-2020. The ranking of source countries is obtained computing average import shares relative to total imports from extra-EU countries in the specific product category.
8-digits HS codes for selected product categories. Diodes "85411000, transistors with a dissipation rate >= 1 W "85412900", light-emitting diodes "85414010", photosensitive semiconductor devices "85414090", mounted piezoelectric crystals "85416000".

Figure 5: Diodes, transistors, and similar semiconductor devices. EU imports by trade partner.



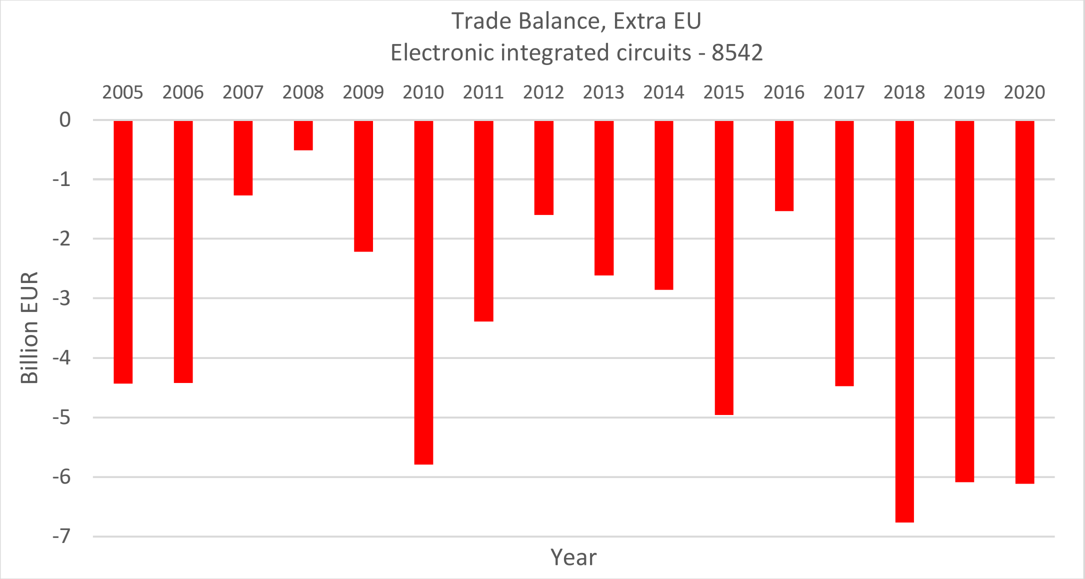
Source: JRC elaboration on Comext Data.

The EU is also a net importer of goods in the product category 8542, which includes electronic integrated circuits such as processors, memories, and amplifiers. The most advanced chips and memories, which are then employed by the consumer electronics, the automotive, and the space industry, are traded under this category. As reported in Figure 6, the EU trade deficit in this category has consolidated around 6 billion Euro from 2016 onwards. Taiwan is the leading exporter of integrated circuits to the EU (Table 2), accounting on average, for around 20% of EU imports in the period 2017-2020. This holds true for processors, electronic integrated circuits, D-Rams, and multi-combinational memories, while the Asian country follows the United States as a leading exporter of amplifiers to the EU. For this specific product category, exports from China are smaller (Van Hezewijk, 2020).

When US companies (and before the EU, notably Phillips[34]) began shifting to fabless models over the last 15 years, Taiwan Semiconductor Manufacturing Company (TSMC) and South Korea's Samsung took advantage as they began to invest heavily in leading-edge manufacturing technology. Taiwan gained the position of leading exporter to the EU from 2010 onwards (Figure 7), taking the position held before by South Korea (2009-2011), and the United States (2005-2008).

[34] Back in 1984, Phillips split off part its activities on semiconductors creating a joint venture with the Dutch ASM International, under the name of ASML, which is now one of the world's leading manufacturer of chip production machines. In 1985, Phillips was the largest founding investor in TSMC, which was established as a joint venture between Phillips, the Taiwan Government, and other private investors. In 2006 Phillips split off its semiconductor division and created the company NXP, which was sold to US investors shortly afterwards.

Figure 6: Electronic integrated circuits, EU trade balance versus extra-EU partners.



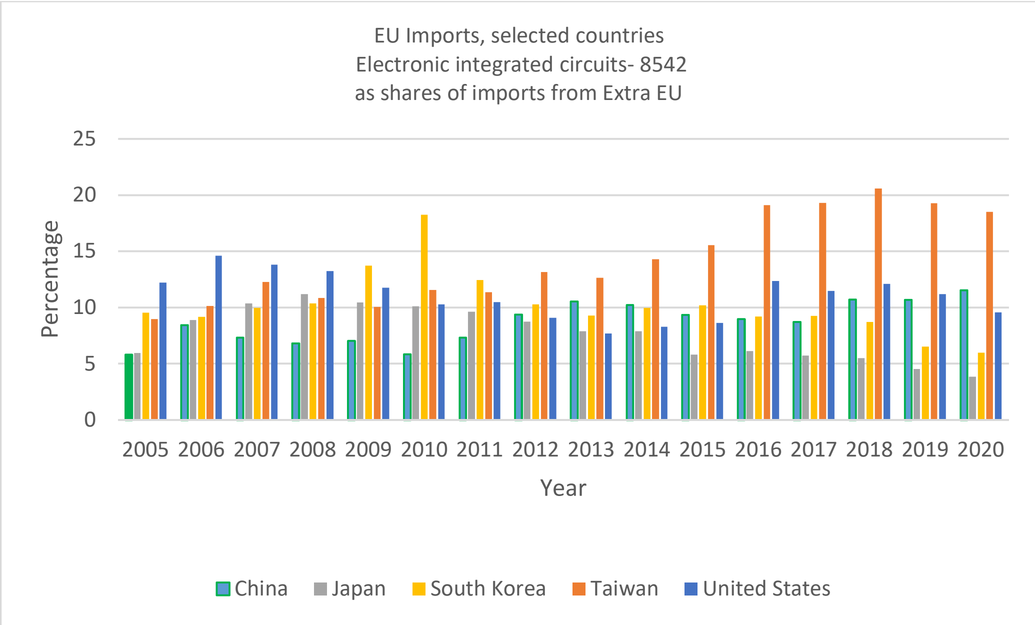
Source: JRC elaboration on Comext Data.

Table 2: Electronic integrated circuits,
leading imported products & leading third-countries exporting to EU

Averages: period 2017-2020	**1st**	**2nd**	**3rd**
1.Processors	Taiwan	China	United States
2.Electronic integrated circuits (others)	Taiwan	United States	South Korea
3.D-Rams, storage > 512 mbit	Taiwan	South Korea	China
4.Multi-combinational memories	Taiwan	United States	South Korea
5.Amplifiers	United States	Taiwan	China

Note: Products have been selected based on the ranking of cumulated imports from extra-EU countries in the period 2017-2020. The ranking of source countries is obtained computing average import shares relative to total imports from extra-EU countries in the specific product category. 8-digits HS codes for selected product categories. Processors “85423190”, electronic integrated circuits (others) “85423990”, D-Rams, storage > 512 mbit “85423239”, multi-combinational memories “85423290”, amplifiers “85423390”.

Figure 7: Electronic integrated circuits, EU imports by trade partner.



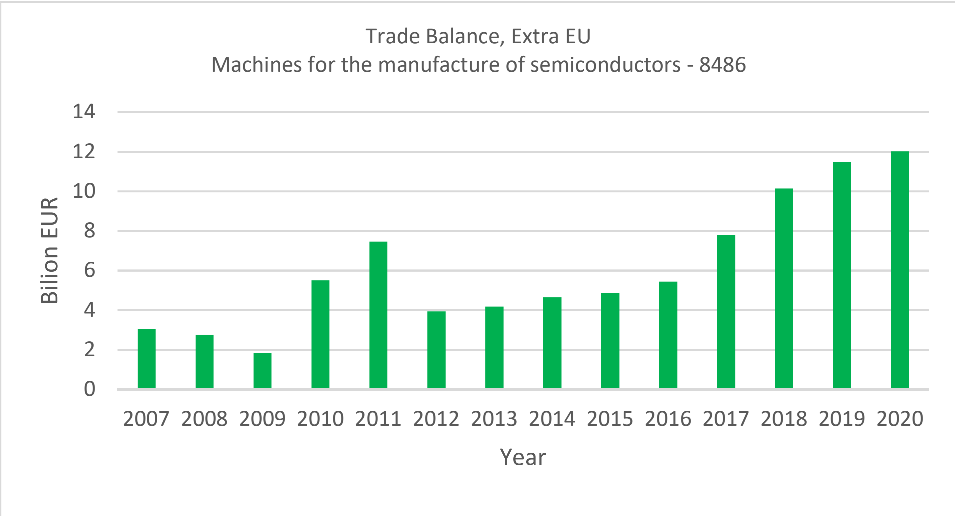
Source: JRC elaboration on Comext Data.

Looking into the trade figures for inputs employed by chip producers, such as the machines for the manufacture of semiconductors (HS 8486), we find that EU is a net exporter of these products (Figure 8). This is mostly due to the role of specific European manufacturers (e.g. ASML, ASM, Rhode and Schwarz, Trumpf) which gained a leading position in the production of machines during the last decade.

Moreover, the small numbers of foundries located nowadays in the EU (mainly the French-Italian STM and the German NXP) explains the lack of imports of machines from extra-EU countries and incentivizes European producers of machines to find customers mainly in East Asia.

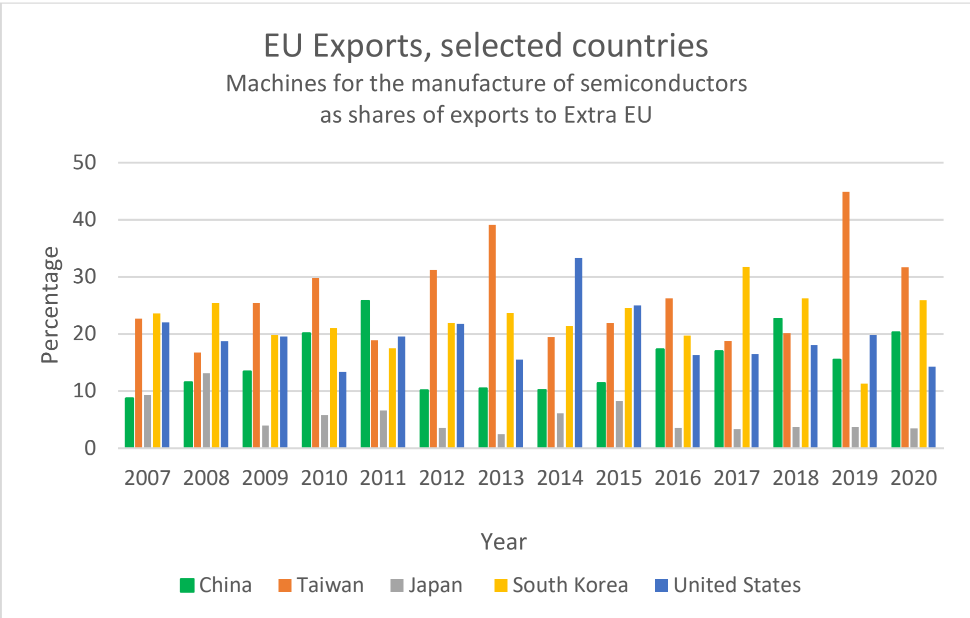
Taiwan and South Korea, and more recently China, are the countries accounting for the majority of EU exports of manufacturing machines (Figure 9). In particular, Taiwan is the main destination market for EU machines for the production of semiconductors and integrated circuits (Table 3), while China is the main importer of EU machines for the production of boules and wafers, and for the production of flat panel displays.

Figure 8: Machines for the manufacture of semiconductors, EU trade balance versus extra-EU partners.



Source: JRC elaboration on Comext Data.

Figure 9: Machines for the manufacture of semiconductors, EU exports by trade partner.



Source: JRC elaboration on Comext Data.

Table 3: Machines for the manufacture of semiconductors,
leading exported products and leading third-countries importing from EU

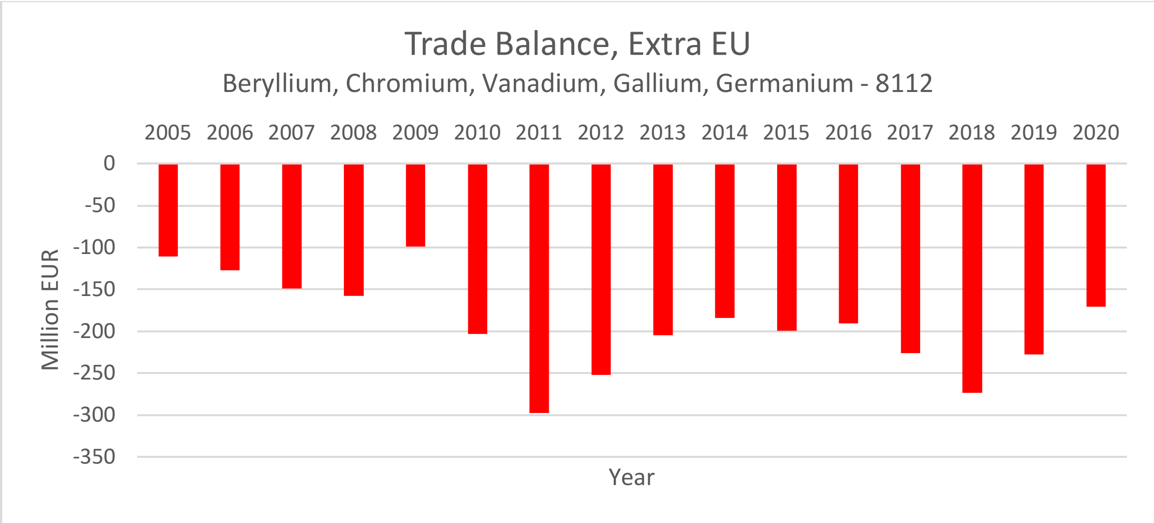
Averages: period 2017-2020	**1st**	**2nd**	**3rd**
1.Machines for semiconductors and integrated circuits	Taiwan	South Korea	China
2.Parts and accessories of machines for semiconductors	United States	South Korea	China
3.Other machines., note 9c to the chapter	Taiwan	China	United States
4.Machines for boules or wafers	China	United States	Taiwan
5.Machines for flat panel displays	China	Japan	South Korea

Note: Products have been selected based on the ranking of cumulated imports from extra-EU countries in the period 2017-2020. The ranking of source countries is obtained computing average import shares relative to total imports from extra-EU countries in the specific product category. 8-digits HS codes for selected product categories. Machines for semiconductors and integrated circuits "84862000", Parts and accessories of machines for semiconductors "84869000", Other machines (note 9c to the chapter) "84864000", Machines for boules or wafers "84861000", Machines for flat panel displays "84863000".

A second type of inputs in the SVC are metals, which, among other uses, are employed in the production of wafers containing chips. They correspond to the HS product category 8112, which includes beryllium, chromium, germanium, vanadium, gallium, hafnium, celtium, indium, niobium, columbium, rhenium and thallium, and articles of these metals. EU is a net importer of metals for the production of chips (Figure 10), even though the magnitude of the trade deficit for these goods is quite limited. This is due to the relatively small production of wafers in the EU.[35] The leading exporters of metals to the EU are China, Russia, and the United States, which jointly account for more than 68% of European imports in this product category in the period 2017-2020. Between 2009 and 2020, EU is also a net importer of silicon, HS 6-digit product "280461".[36] This product category includes relevant inputs for the production of silicon wafers.

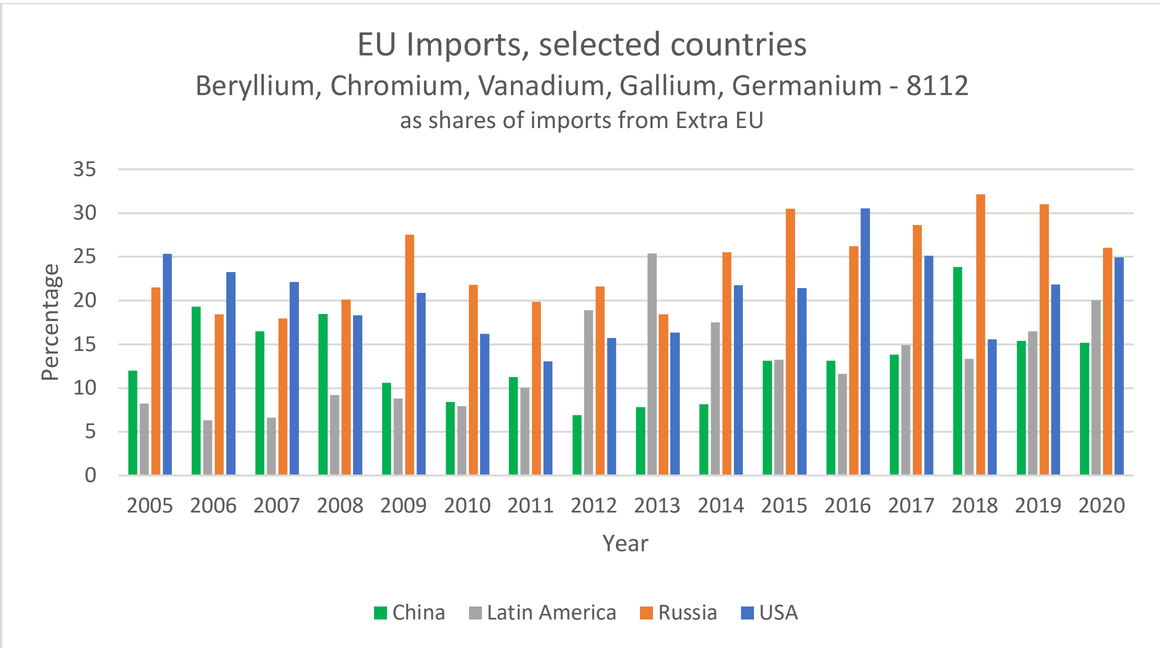
[35] As suggested by the evidence on the trade flows of electronic circuits, the production of wafers is mostly concentrated in China, Japan, South Korea, and Taiwan.
[36] Silicon containing >= 99,99% by weight of silicon.

Figure 10: Metals for the production of semiconductors, EU trade balance versus extra-EU partners.



Source: JRC elaboration on Comext Data.

Figure 11: Metals for the production of semiconductors, EU imports by trade partner.



Source: JRC elaboration on Comext Data.

3. Firm-level data: EU semiconductors through the lenses of the official NACE classification

As it is the case for all production chains, companies in semiconductors operate across several industrial sectors. Different industrial classifications can provide different degrees of detail in the description of a company's business. Moreover, it is important to stress that information on industrial classification is provided directly by companies, often when they are first incorporated, therefore this classification may be subject to the usual biases due to self-reporting and may not evolve with the evolution of the company's business.

Given the European focus of our analysis, we refer to the NACE rev.2 classification of industrial sectors, available from Eurostat.[37] The industrial sectors more closely related to the manufacture of semiconductors are 26.11, "manufacturers of electronic components", and 26.12, "manufacturers of printed circuit boards". We expect fabless companies, foundries, and IDMs in our mapping of the value chain to be mostly associated with these industrial sectors. Companies that adopted the fabless business structure, as well as IDMs, and OSATs, may also operate in sub-sectors of category 46.5, "wholesale of information and communication equipment".

Companies supplying the software for the design of chips (EDA), are found among those involved in "other software publishing", 58.29. The suppliers of machines for the manufacture of semiconductors are classified in either sector 26.11 itself, in 26.51 "manufacture of instruments and appliances for measuring, testing and navigation", in 26.70 "manufacture of optical instruments and photographic equipment ", in 27.90 "manufacture of other electrical equipment "or 28.89, "manufacture of other special-purpose machinery". Suppliers of chemicals and gases, and other materials to the manufacturers of chips can instead be found in sectors 20.11, "manufacture of industrial gases", and 20.59, "manufacture of chemical products".
Companies that are placed downstream in the value chain and demand semiconductors devices are in sectors 26.20 "manufacture of computers and peripheral equipment", 26.30 "manufacture of communication equipment", and 26.40 "manufacture of consumer electronics".

[37] Economic activities provided by the North American Classification System (NAICS) can be mapped into industrial sectors identified by the NACE classification. We highlight that the description of economic activities provided in NAICS is more detailed than the one provided by NACE, at least for sectors involved in this production chain. A concordance table is available upon request.

3.1 EU companies in the Nace rev.2 sector code 26.11

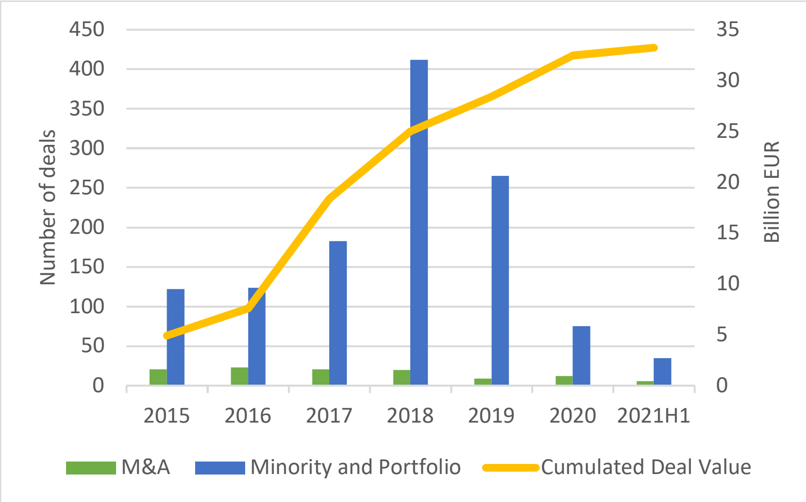
In this section, we report evidence on EU companies operating in semiconductors according to their NACE rev.2 classification and describe data on foreign acquisitions in this sector. Relying on Orbis-BvD data, we select all companies belonging to NACE sector 26.11, "manufacturers of electronic components". This enables us to observe all entities, both foreign-owned and controlled by EU investors, operating in Europe. Moody's Bureau van Dijk Zephyr Database provides information of investments.

Focusing on companies for which financial statements are available for both year 2019 and 2020, we are able to observe 4,406 companies in this sector. Among them, the 41% is foreign-owned, while 59% is controlled by EU investors. The total turnover obtained by these companies amounts to 110 bn EUR in 2020.[38] We observe that this amount is highly polarized as the top-10 companies in Europe account for over 53% of total turnover in this industrial sector. One single company, the Dutch ASML, which produces machines for EUV lithography used in the production of the most advanced chips, with almost 14 billion EUR accounts for more than 12% of total EU turnover in this sector in year 2020. Entities with a foreign global ultimate owner account for more than 18% of total turnover of EU entities operanting in this sector.

In Figure 12, we report evidence on investment transactions targeting EU companies belonging to the NACE sector 26.11, which includes the manufacturers of electronic components.[39] We show data on completed deals both for minority investments and for M&As in the period 2015-2021H1 for a total of 1,327 deals. The number of deals reached a peak in 2018 and then declined in the following years.
The vast majority of transactions, 91%, concerns portfolio investments: acquisitions where the acquirer, thanks to the deal, gains control over less than 10 % of the shares in the target company.[40] During the same period, we observe an average of 16 M&A deals per year. Over the last six years, non-EU investors invested a total of 33 Billion EUR on EU firms manufacturing electronic components. The largest amount, more than 10 bn EUR, was invested in 2017. [41]
With more than 54% of minority deals and almost 27% of M&A, US investors have a leading role for investments in this sector. Investors based in Norway (14%), the Caymans (11.4%), and United Kingdom (10%) follow in the ranking for minority and portfolio deals in the EU. On the other hand, investors whose ultimate owner is Chinese (21%), Japanese (12%) or Swiss (9%) follow US investors in the ranking of M&A deals.

[38] Balance-sheet data for 2021 is not yet available for all companies.
[39] Completed M&A deals in NACE sector 26.12, manufacturers of printed circuit boards, are in the order of few units per year and report a cumulated value lower than 40 Million EUR between 2015 and 2021H1.
[40] Institutional investors like Blackrock, Norway SF, Marshall Wace, Goldman Sachs, MLM trust, JPMorgan Chase have a leading in role for portfolio deals observed in this sector.
[41] For this sector, we are able to observe the monetary amount of the invested for 93% of deals, therefore this can be considered as a reliable figure on the amount actually invested.

Figure 12: Foreign (non-EU) investments in the EU, targets in NACE sector 26.11.

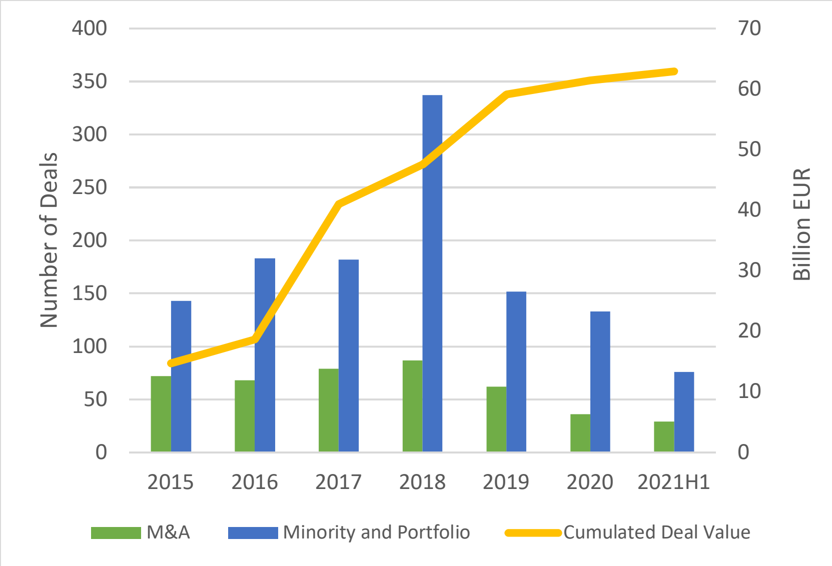


Source: JRC elaboration on Zephyr-BvD data.

A snapshot of the sector codes[42] hosting firms that are likely to be suppliers of machines and other inputs to chips manufacturers (i.e. upstream sectors in the SVC), shows a remarkable interest by foreign investors in EU firms in these sectors, with a total cumulated investment slightly above 60 bn EUR between 2015 and 2021H1. The average number of M&A deals in this segment of the chain is above 60 per year, while the vast majority of investments takes place via minority and portfolio acquisitions. This type of FDI reached a peak in 2018 with 337 deals and declined in the following years (Figure 13).

[42] NACE sectors: 26.51 (manufacture of instruments and appliances for measuring, testing and navigation), 26.70 (manufacture of optical instruments and photographic equipment), 27.90 (manufacture of other electrical equipment), 28.99 (manufacture of other special-purpose machinery n.e.c.). Companies reporting these NACE codes as primary industry classification represent 14% of companies in our mapping.

Figure 13: Foreign (non-EU) investments in the EU. Detail for NACE sectors 26.51, 26.70, 27.90, and 28.99.



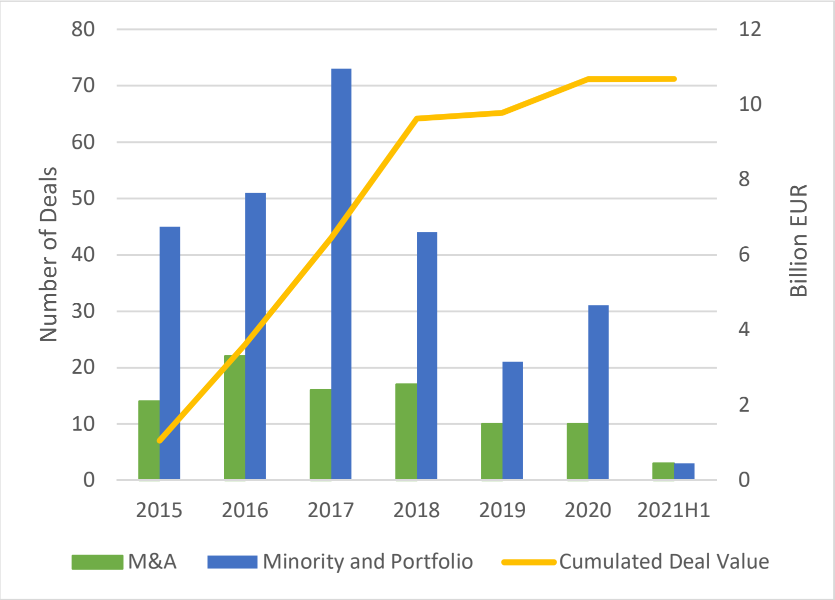
Source: JRC elaboration on Zephyr-BvD data.

Evidence for deals involving EU companies operating in sectors relying on semiconductors as inputs for their production chains, i.e. downstream sectors (Figure 14), points to smaller magnitude of foreign investment compared to other sectors of the EU economy.[43] We observe 44 minority and portfolio deals, and 14 M&As per year during the period 2015-2020. The total cumulated amount invested by foreign investors in EU companies over this period reached 10 bn EUR in 2020 and remained constant in 2021H1. Although narrowly defined, these sectors are those historically accounting for a large part of the EU demand for semiconductors.[44]

[43]We focus on NACE sectors 26.20 (manufacture of computers and peripheral equipment), 26.30 (manufacture of communication equipment), and 26.40 (manufacture of consumer electronics).

[44]We could also provide evidence on foreign investments in the EU automotive sector which is currently a crucial buyer of semiconductors, given the ongoing electrification of cars. Yet, by relying on data for FDIs on the entire automotive sector we would have captured investments on automotive companies which are not related to semiconductors. As a consequence, we report data only for sectors which, historically, are more directly linked to the semiconductors production chain. We acknowledge the strategic role of the EU automotive sector and plan to further investigate on its role.

Figure 14: Foreign (non-EU) investments in the EU, detail for NACE sectors 26.20, 26.30, and 26.40.



Source: JRC elaboration on Zephyr-BvD data.

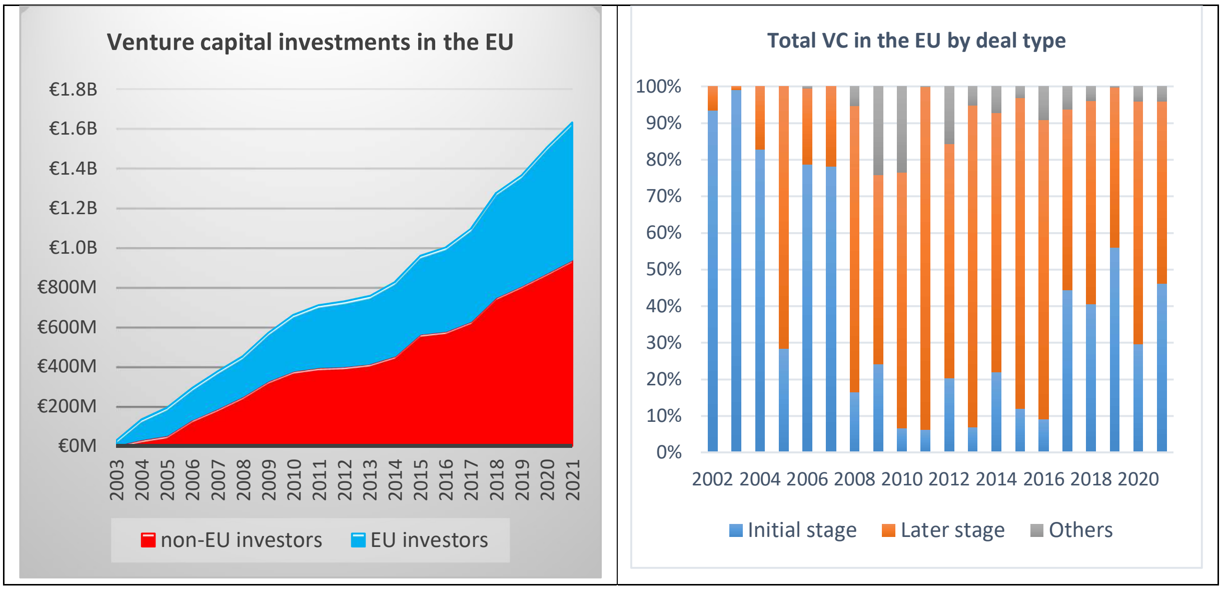
3.2.Venture capital investments in the EU

Besides the acquisition of equity stakes in EU companies, other forms of investments, such as venture capital, have been on the rise in latest years and therefore deserve specific attention. Target of venture capital investments (VC) since early years of the millennium, EU companies in semiconductors received as much as 1.63 bn EUR In the period 2003- 2021. Roughly, 60% of these VC investments originated outside Europe, principally in the US, with Asia (mainly Japan, South Korea and China) counting for 18% of the foreign originated VC capital. Since the start of the pandemic, China is substantially absent in the semiconductors VC ecosystem in the EU, at least as a direct origin of venture capital investments[45].

With an average increase of 10% per year in the last 5 years (up from 7% in the period 2012-2016), VC in semiconductors was principally directed to later stage financing (58%) rather than to early stage and seed financing (38%). The increased interest in the VC ecosystem is mostly due to the emerging role of non-traditional investors in the VC market such as private equity firms, hedge and pension funds, and sovereign wealth funds, among others.[46]

[45] Chinese VC investment rounded 110 Million EUR and was concentrated between 2016 and 2019.
[46] Pitchbook, European VC Valuations Report, February 16, 2022.

Figure 15: Venture capital investments in the EU. Detail on the investor's origin and type of deal.



Source: JRC elaboration on Pitchbook data, extraction February 2022. Initial stage includes Early stage, Pre/Accelerator/Incubator, Seed investments and Others includes Equity for Service and Grants.

3.3. Detecting supply chain linkages using firm-level data.

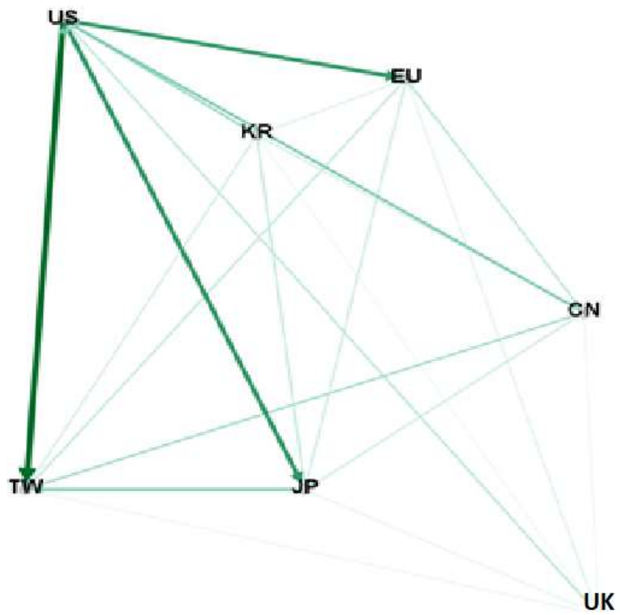
An alternative way to look at the semiconductors supply chain is to look at linkages between companies in a client-supplier relationship. Chip producers buy inputs and machines from suppliers and provide finished products or intermediates to customers.

In this section, we look at the number of supplier-customer linkages for companies in NACE sector 26.11 headquartered in different parts of the globe in the FactSet database.[47] Data confirm the relevant role of companies headquartered in the United States (US), Taiwan (TW), Japan (JP), South Korea (KR), China (CN), and the EU (Figure 16). Interestingly, this network shows that US companies have a strategic role in the value chain, given the number of linkages they report with companies from Taiwan, Japan, Korea, and the European Union. European companies report the highest number of linkages with US companies,

[47] FactSet is one of the very few commercial databases providing this information. In particular, we use the FactSet module on supplier-customer relationships to retrieve information on supply chain relationships between companies operating across different industrial sectors worldwide. We underline that FacSet provides information on the headquarter and incorporation country of each company linked by a supplier-customer relationship. It does not provide information on which subsidiary is actually linked to a supplier or a customer. Moreover, the database over-represents large and listed firms. We show data only for those countries reporting a relevant number of linkages between companies.
The sector 26.11 includes the majority of companies operating in the SVC according to our evidence.

while linkages with companies headquartered in other countries are much less relevant. Chinese companies seem to be rather isolated given the relatively small number of reported linkages with all other countries in the network.

Figure 16: Supplier-customer linkages between companies in NACE sector 26.11



Source: JRC elaboration on FactSet data.

Relying on this rich data, we then focus on the following question: **Where do EU semiconductor companies obtain the inputs they use for their production?** Are they buying them from outside the EU or are they able to find the necessary input in Europe? In addition, are EU suppliers to the manufacturers of semiconductors supplying their products to companies headquartered outside or inside the EU?

To answer these questions, we identify as firms producing semiconductors those pertaining to the NACE rev. 2 sectors 26.11, *manufacture of electronic components*, and 26.12, *manufacture of loaded electronic boards*. Relying on information for year 2021, we count, for each EU company active in 26.11 and 26.12, the number of input suppliers of semiconductors that are headquartered in the EU or outside and then take the sample average.[48] Results (first row of Table 4) show that, on average, nearly 80% of the

[48] We are aware that the number of supplier-customer links is only a proxy of the links in a value chain, and detailed sales data by company and by product would be needed. Unfortunately, companies do not disclose this information.

suppliers to European firms operating in semiconductors (NACE sectors 26.11 and 26.12) are headquartered outside the EU.

Table 4: Manufacture of electronic components and loaded electronic boards, linkages with foreign customers/suppliers

Averages for year 2021	**Outside EU**	**Inside EU**
1.Suppliers to EU firms in 26.11 & 26.12	79,80%	20,20%
2.Customers in 26.11 & 26.12 for EU firms	63,64%	36,36%

Note: Information obtained from FactSet data, extraction date: 29/04/2021. Row 1, provides information on suppliers, operating in all possible industries, to EU firms operating in sectors 26.11 and 26.12. Companies are assigned to a given location using information on the location of their headquarters, available from FactSet. Row 2 reports information on the geographical composition of customers operating in NACE sectors 26.11 (Manufacture of electronic components) and 26.12 (Manufacture of loaded electronic boards), for EU companies operating in all possible industries.

Additionally, regardless of the sectors in which they operate, EU companies have 63% of their customers in 26.11 and 26.12 headquartered outside EU, while less than 37 % of them is actually located in the EU (Row 2 of Table 4).

Overall, this partial evidence suggests that EU firms involved in the semiconductors' production chain strongly rely on suppliers and customers headquartered outside the EU, confirming the interconnectedness of the semiconductors supply chain shown by the GVC integration index displayed in Figure 1.

Looking at the geographical location of foreign suppliers to EU firms manufacturing electronic components and loaded electronic boards (NACE codes 26.11 and 26.12), Table 5 shows that more than 35% of these foreign suppliers are headquartered in the United States, 12.4% in Taiwan, 11.7% in China or Hong Kong, 10% in South Korea, and nearly 9% in Japan. These are the countries playing a leading role in the value chain for semiconductors and in the electronics' sector, as confirmed by the trade data discussed in Section 2.

Data reported on the right-hand side of the same Table shows that EU manufacturers of semiconductors linked to foreign suppliers are mainly headquartered in Germany, France, Belgium, and the Netherlands.

Table 5: Suppliers to EU semiconductors (left) and EU customers using semiconductors (right), 2021.

Third countries, suppliers to EU firms operating in sectors 26.11 and 26.12		EU countries, customer firms operating in sectors 26.11 and 26.12	
Australia	1,38%	*Austria*	4,76%
Canada	2,76%	*Belgium*	7,94%
China	10,69%	*Finland*	6,35%
Hong Kong	1,03%	*France*	17,46%
India	2,76%	*Germany*	36,5%
Israel	1,05%	*Ireland*	1,59%
Japan	8,97%	*Italy*	6,35%
Malaysia	0,34%	*Luxembourg*	1,59%
Mexico	0,34%	*Netherlands*	7,94%
Norway	2,41%	*Spain*	6,35%
Singapore	2,07%	*Sweden*	3,17%
South Korea	10,00%		
Switzerland	2,41%		
Taiwan	12,41%		
United Kingdom	5,52%		
United States	35,86%		

Note: JRC elaboration on FactSet data, extraction date: 29/04/2021. Left: data on suppliers operating in all possible sectors of firms headquartered in the EU and operating in sectors 26.11 and 26.12. Right: data from suppliers, operating in all possible industries, of firms headquartered in EU countries operating in sectors 26.11 and 26.12.

4. Towards a mapping of companies in the semiconductor value chain

To draw the mapping of companies in the different segments of the semiconductor value chain, we employed several sources. First, we relied on studies by Kleinhans and Baisakova (2020), European Commission (2016), and Deloitte (2019) to obtain information on the organization of the supply chain as well as on the main players in the different segments composing it.

As already illustrated in Section 1, we divided the value chain in five segments: (1) suppliers of electronic design automation software (EDA); (2) suppliers of inputs as chemicals, materials, and equipment (SME); (3) fabless companies; (4) foundries; (5) integrated device manufacturers (IDMs); (5) outsourced semiconductor assembly and test (OSAT) companies.[49] We used the Refinitiv-Eikon database available from Thompson Reuters to obtain a list of publicly listed companies involved in the production of integrated circuits, memory chips, processors, as well as in the manufacture of machines for semiconductors and apportioned manually to each segment of the supply chain. We further increased the number of firms included in the list by using both the available specialized literature and FactSet data on supplier-customer linkages between companies operating in semiconductors and in all other

[49] A description of the different segments of the value chain is included in Section 2 of the present document.

industrial sectors. Finally, we added to this list companies that applied for EU funding under the ECSEL partnership programme.[50]

After checking manually each company's website, we assigned the company to a specific segment of the value chain. The final list at our disposal includes 1,084 companies worldwide. Since several multinational companies and industrial conglomerates operate in this value chain, we assigned each company to a specific segment of the chain by looking at its core operations. Moreover, subsidiaries are not included in this list, which only contains parent companies.

Among the 1,084 companies, 47% are suppliers of inputs as they produce either software, materials, chemicals, or equipment to the manufacturers of semiconductors. Fabless companies account for 15% of firms, while foundries represent the 10% of the companies in the list. The group of integrated device manufacturers is well represented with 24% of companies, while only 4% of companies in our list is classified as OSATs.

4.1 Evidence on turnover and ownership in the different segment of the value chain

4.1.1. Data construction

The first step to construct reliable data for turnover is to obtain data on the ownership of each company included in our mapping. We use firm-level information available from Orbis Bureau Van Dijk (BvD). A BvD identifier is assigned to each company and information on the global ultimate owner (GUO) is extracted.[51] Using information on the geographical location of their GUO, companies are assigned to seven geographical locations: EU27, United States (US), Japan (JP), South Korea (KR), Taiwan (TW), China (CN), and Others.[52]

Relying on the same data source, we retrieve information on the consolidated turnover reported by the companies in our list in year 2020. Unfortunately, this source does not provide information on turnover for all companies: we observe this variable for 886 companies, representing the 82% of all entities included in our list.

It should be highlighted that, among these entities, we can observe large MNEs, which control specific niches of the market for semiconductors but are also active across a variety of other industrial sectors.

[50] ECSEL is a public-private partnership for electronic components and systems. It manages a research and innovation programme for the development of a strong and globally competitive electronics components and systems industry in the EU. https://european-union.europa.eu/institutions-law-budget/institutions-and-bodies/institutions-and-bodies-profiles/ecsel_en

[51] Using the definition provided by BvD, the Global Ultimate Owner is "the individual or the entity at the top of the corporate ownership structure."

[52] We in include in "Others" countries accounting for a limited number of companies operating in the different segments of the chain. The composition of countries in this group is different for the various segments under consideration.
We rely on the ISO 3166-1 alpha-2 classification, provided by the International Organization for Standardization to obtain 2-digit country codes, https://www.iso.org/iso-3166-country-codes.html. Data for China include data from Hong Kong (HK).

For this reason, we relied on the financial reports for the largest companies operating in the production chain to obtain information on the share of revenue deriving from the business lines closely linked to the semiconductors' industry.[53]

Summing the turnover for all companies operating in the different segments of the chain, we observe a total turnover of 1.15 Trillion EUR for year 2020, which seems a representative picture of the whole production chain at the global level if compared to the total revenue for manufacturers of semiconductors, which is equal to 410 bn EUR.[54]

4.1.2. Turnover by segment of the value chain

Equipment suppliers controlled by EU ultimate owners report a turnover of 39 billion EUR in year 2020 (Figure 17, left), representing the 27% of the total turnover reported by companies in this segment of the supply chain. The EU ranks second after the US, which accounts for 31% of the turnover in this segment (45 bn EUR). Japanese companies follow with 35 bn EUR.

Interestingly, investors from jurisdictions having a prominent role more downstream stages of the production chain (i.e. the manufacture of chips) as Taiwan and South Korea, control a relatively small share of the turnover of companies producing equipment for the manufacture of semiconductors. This result reinforces the evidence of a disperse supply chain where no jurisdiction is actually autonomous in all phases of the production chain.[55]

Companies operating in the segment *materials for semiconductors* are an heterogeneous group. They produce e.g. ceramic and other composite materials, silicon or gallium nitride wafers, or machine-control software employed in the facilities manufacturing chips. EU-owned companies in this segment of the chain report a turnover slightly higher than 35 bn EUR (Figure 17, right), roughly 33% of total turnover at the global level in this segment. Japanese companies, with 46% of total turnover have the leadership in this segment. Companies from South Korea, US, Taiwan, and China, all account for shares below 10% of total turnover.

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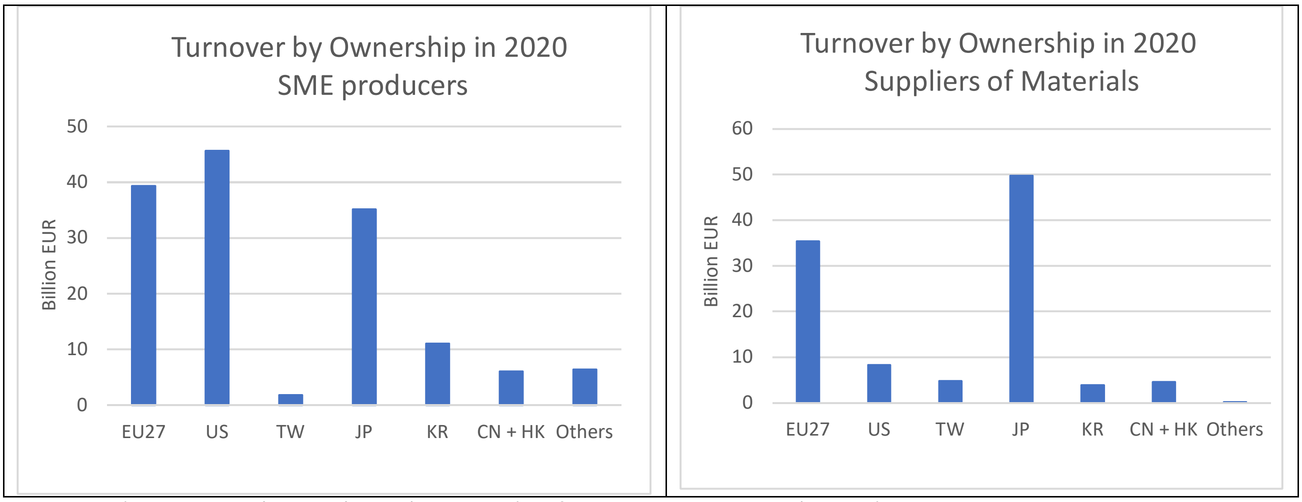
[53] According to information available from financial reports, the following share of total revenue can be assigned to business lines pertaining to the Semiconductors production chain. Company (share): Samsung Electronics Co. (28%), Robert Bosch GmbH (66%), Henkel AG (45%), Compagnie Saint Gobain (16%), Unimcore (7.5%), BASF SE (6%), Air Liquide (10%), Linde Inc. (10%), Heraeus (30%), Sumitomo Chemical Company (57%), Fujifilm Holdings Corp. (21%).

[54] Gartner (2021) in https://www.asml.com/en/news/press-releases/2022/asml-position-paper-on-eu-chips-act.

[55] This is also coherent with trade surplus data reported by the EU27 in the product category which includes the machines employed for the production of chips, which are mainly exported to Asia (Section 3).

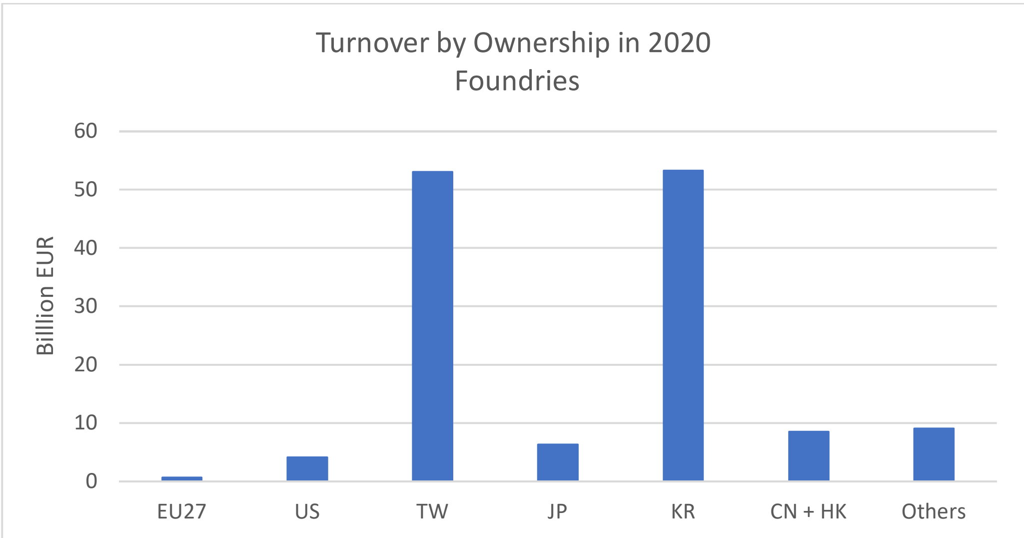
Figure 17: Suppliers of equipment (left) and suppliers of materials for semiconductors (right). Turnover by location of the ultimate owner in 2020.



Source: JRC Elaboration based on BvD data and on the JRC list of companies in the Semiconductor Value Chain.

Looking at firms producing semiconductors as contractors for other companies (i.e. foundries), we find that EU investors control an irrelevant share of turnover in this segment, dominated by Asian corporations.

Figure 18: Manufacturers of semiconductors (foundries). Turnover by location of the ultimate owner.



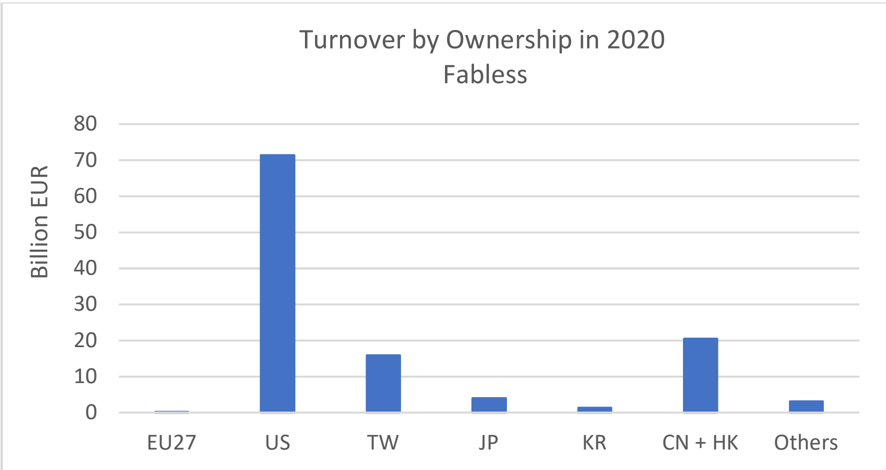
Source: JRC Elaboration based on BvD data and on the JRC list of companies in the Semiconductor Value Chain.

As confirmed by the data on international trade flows of chips, the manufacturing heart of the semiconductors' global value chain is in Asia. Companies from Taiwan and South Korea account each for 39% of total turnover of in the foundry segment (Figure 18), with a total cumulated turnover higher than

100 bn EUR.[56] The share of turnover that can be attributed to companies owned by Japanese, American, and Chinese investors is significantly below 10%. The reason behind a low turnover assigned to US firms in this segment is that US companies operate either as fabless companies or as integrated device manufacturers, designing and manufacturing chips internally, rather than working as contractors for others.

EU investors hold a residual share of turnover also in the segment chip design, i.e. the fabless segment (Figure 19).[57] This relatively recent segment of the production chain, which according to the literature is characterized by a high profitability and high investments in R&D, is dominated by US-owned companies, which report a turnover higher than 70 bn Euro, equal to 61% of total turnover. The share of turnover of fabless companies owned by Taiwanese and Chinese investors is equal to 13%, and 17%, respectively. Japanese and South Korean investors hold control below 4% of turnover in this segment.

Figure 19: Fabless companies. Turnover by location of the ultimate owner.



Source: JRC Elaboration based on BvD data and on the JRC list of companies in the Semiconductor Value Chain.

The segment of integrated device manufacturers (IDMs), which includes companies involved in the design, manufacture, testing, and packaging of chips, appears as less polarized. As shown by the data (Figure 20), while companies owned by US investors account for over 33% of turnover in this segment, Japanese and EU companies follow with 28% and 17%, reporting a turnover of 126 bn EUR and 73 bn EUR, respectively.

[56] The Taiwanese TSMC with a turnover in 2020 of 39 Billion EUR is responsible for the result of Taiwan in this segment. The same holds in South Korea for Samsung Electronics, with a turnover of 49 Billion EUR. We assigned Samsung Electronics to the foundry segment and not to the IDMs as the company offers its services as a contractor to external companies designing chips, without focusing exclusively on its business lines as IDM.

[57] Large multinational companies like Alibaba (CN), Alphabet (US), Amazon (US), Apple (US), IBM (US), Meta (US), and Tesla (US), operate as fabless companies in semiconductors. In particular, they are active in the design of application-specific chips (ASIC). Given that it is not possible to disentangle from the consolidated turnover the fraction related to the semiconductor business, we excluded data from these companies in Figure 18. We considered only companies with design of chips as their core business.

Figure 20: Integrated device manufacturers (IDMs). Turnover by location of the ultimate owner.

Source: JRC Elaboration based on BvD data and on the JRC list of companies in the Semiconductor Value Chain.

Table 6: Semiconductors, turnover by ownership of companies in the different segments of the value chain, location of Global Ultimate Owner.

	EQUIPMENT (SME)	CHEMICALS AND GAS SUPPLIERS	MATERIAL SUPPLIERS	FABLESS	FOUNDRIES	IDMS	OSATS
EU	27.02%	34.19%	33.08%	0.17%	0.48%	16.83%	0.00%
USA	31.35%	17.19%	7.80%	61.17%	3.09%	33.75%	13.77%
TAIWAN	1.27%	0.08%	4.43%	13.67%	39.28%	2.99%	37.43%
JAPAN	24.15%	32.73%	46.58%	3.47%	4.70%	28.96%	11.02%
SOUTH KOREA	7.62%	15.80%	3.64%	1.24%	39.42%	7.62%	3.66%
CHINA	4.18%	0.00%	4.27%	17.59%	6.34%	8.30%	27.62%
OTHERS	4.40%	0.01%	0.20%	2.68%	6.70%	1.54%	6.50%

Source: JRC Elaboration based on BvD data and on the JRC list of companies in the Semiconductor Value Chain.

The share of total turnover for each segment of the value chain (a summary is provided in Table 6) includes data for chemicals and gas suppliers, as well as for companies operating in outsourced assembling and testing (i.e. OSATs). According to data at our disposal, investors based in the EU own the largest companies supplying chemicals and gases used in semiconductors manufacturing. Finally, Taiwanese companies are leaders in the OSAT segment. Chinese companies rank second in this segment of the chain controlling a sizeable share of total turnover (27.6%).

5. Ongoing and future lines of work

The objective of this document was to report preliminary evidence on the position of Europe in the semiconductor value chain (SVC) and to describe the exercise undertaken to map the companies operating in this complex ecosystem. This is a draft document as additional streams of research are ongoing.

- We are collecting detailed product-level information from companies in the foundry, fabless and IDM segments, in order to relate the supply chain to the demand needs of the EU industry.
- Additionally we will analyse in more detail chips production, to further increase the granularity of the information provided on companies operating in this mapping. The strategic role of specific companies for the supply of particular categories of chips will be investigated using this data.
- We are currently retrieving data on subsidiaries based in the EU operating in the NACE sectors pertaining to the SVC. This information will provide further insights on EU companies belonging to this production chain and, hopefully, on their specialization, knowing whether EU or foreign investors control them.

For the medium term, we plan to address the demand-side of the SVC, focusing on EU companies that buy semiconductor devices. This data would enable us to have firm-level information on the dependencies of crucial ecosystems for the EU economy, like Automotive, Space and Defence, and Health.

Finally, a closer look to the patents filed by EU companies in the value chain will be used to assess investment dynamics on the specific technologies employed in the different segments of the chain.

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