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Applying the SCAN methodology to the Semiconductor Supply Chain

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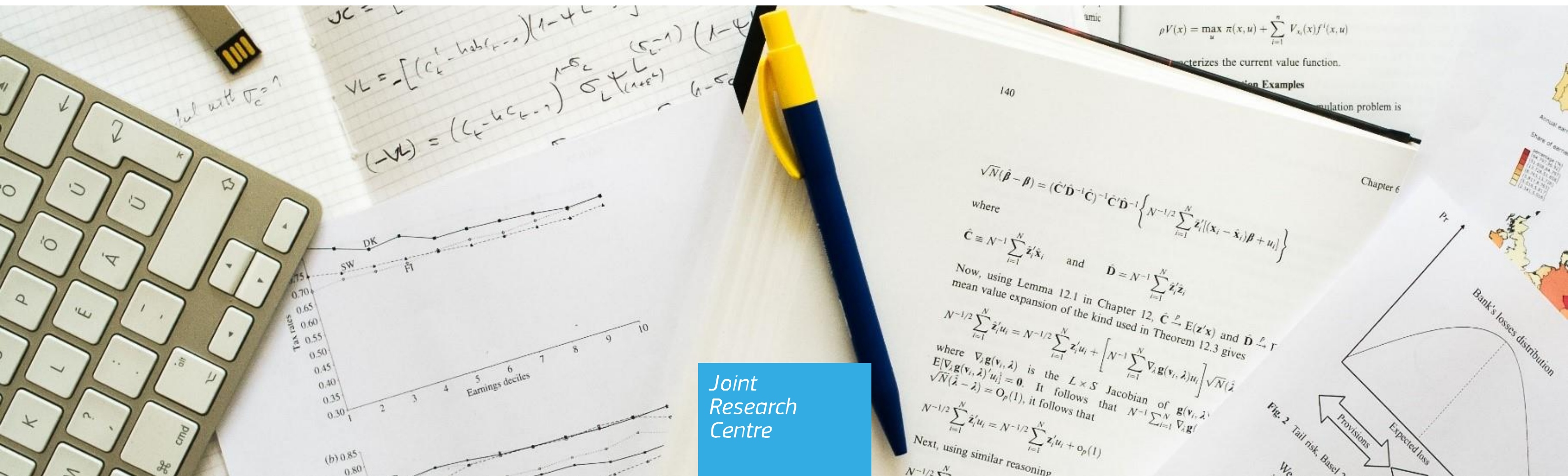

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Executive summary

The European Commission has proposed the "EU Chips Act", with the objective of increasing in the short-term the EU resilience to future shortages by avoiding supply chain disruptions, and becoming in the medium-term an industrial leader in this industrial sector. This legislative initiative also entails the creation of a monitoring system of this strategic value chain. The SCAN ("Supply Chain Alert Notification") methodology is an attempt to monitor the state of specific supply chains relying on trade data for products traded along these chains. This methodology relies on a set of structural indicators to assess the ex-ante systemic risk of import disruption and on high-frequency indicators to detect price increases and/or sizeable reductions in import quantities.

We apply the SCAN methodology to a set of 74 products in the semiconductors supply chain. Monitored products belong to different segments of the value chain: i. raw materials; ii. inputs for wafers; iii. silicon wafers; iv. foundry inputs; v. equipment; vi. final products. We find that ten products belonging to the semiconductor value chain can be considered in medium or high risk of import disruption due to high import concentration and low substitutability in 2021. Overall, we observe that EU import dependencies increased for the majority of these products in the period 2019-2021. These products belong to various segments of the value chain: raw materials, inputs for the production of wafers, equipment for the manufacture of semiconductors, and semiconductor devices, which are the final products of the chain. The EU27 sources these goods from a handful of countries: China, India, Japan, Taiwan, United Kingdom, and United States.

Six of these products are currently also in high distress due to observed reductions in import quantities accompanied by increases in import prices over the last available quarter. We then evaluate how relevant are imports of these products within their respective segments of the supply chain and discuss the evolution of structural and high-frequency indicators over time. Finally, we bring a case study on the D-RAM supply shortage from Taiwan, as a preliminary attempt to assess the performance of the SCAN methodology on past crises.

We conclude that the SCAN methodology can be helpful to monitor the functioning of the semiconductor supply chain in the EU. Nevertheless, to have a refined picture of the value chain, it should be complemented with additional information, possibly more granular. Moreover, we highlight that the list of products under analysis shall be updated over time as the relevant technologies and the corresponding products evolve over time.

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Abstract

The SCAN ("Supply Chain Alert Notification") methodology has been developed to report signs of distress in supply chains relying on trade data. This methodology is based on a set of structural indicators to assess the ex-ante systemic risk of disruptions, and on high-frequency indicators detecting price increases and/or sizeable reductions in traded volumes. The SCAN is here applied to a basket of 74 products traded in different segments of the semiconductor supply chain, from raw materials to the final products of the chain. We find that ten products belonging to the semiconductor supply chain can be considered in medium or high risk of import disruption due to high import concentration and low substitutability in year 2021. These products belong to various segments of the value chain: raw materials, inputs for the production of wafers, equipment for the manufacture of semiconductors, and semiconductor devices. According to the SCAN methodology, EU imports of six of these products can also be considered in high distress due to observed reductions in import quantities accompanied by increases in import prices in the last available quarter (Nov. 2022 – Jan. 2023).

Keywords: Semiconductors, Supply Chains, Trade Data.

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1. Introduction

The impact of the semiconductors' shortage recently experienced by the major industrial economies confirmed once more that companies operating in different parts of the globe are highly interconnected within global production networks.[1] The Covid-19 pandemic exacerbated the vulnerabilities of the chips supply chain, which is inherently characterized by bursts and booms, leading to a global shortage that caused a sizeable reduction of EU manufacturing output in different industrial sectors, from automotive and consumer electronics, to space and defence. Several companies in these industrial sectors were forced to cut or to temporarily stop production due to the lack of integrated circuits.[2] As a consequence, semiconductors are at the very heart of the geopolitical scene with tensions rising between US, China, and Taiwan.[3] In this context, the European Commission has proposed the "EU Chips Act", with the objective of increasing in the short-term the EU resilience to future shortages by avoiding supply chain disruptions, and becoming in the medium-term an industrial leader in this sector.[4] This legislative initiative also entails the creation of a monitoring system of this strategic value chain.

The SCAN ("Supply Chain Alert Notification") methodology proposed by the Chief Economist Team of DG Grow is an attempt to monitor the state of specific supply chains relying on trade data for products traded along these chains (Amaral et al., 2022; Benoit et al., 2022). This methodology relies on a set of structural indicators to assess the ex-ante systemic risk of disruption and on high-frequency indicators to detect price increases and/or shortages (i.e. sizeable reductions in import quantities). Structural indicators identify products vulnerable to import disruptions. Vulnerabilities at the product level arise due to strong EU foreign dependencies in terms of (1) high concentration of extra-EU imports; and (2) low substitution potential of extra-EU imports with EU total supply. On the other hand, high-frequency indicators capture short-run fluctuations in import prices and quantities that can materialize in cases of imbalances between demand and supply in the market. Factors driving these changes include, but are not limited to, sudden increases in demanded quantities, bottlenecks in supply chains, changes in shipping rates and conditions, difficulties in transport logistics, external disruptions related to production crashes or exogenous events such as natural disasters, or a combination of both supply and demand shocks.

The idea behind the SCAN is therefore to combine together the information obtained from structural and high-frequency indicators. While the first set of indicators identifies medium-run vulnerabilities that could exacerbate products' shortages, the use of up-to-date high-frequency indicators allows to assess, almost in real-time, if there is a distress in imports that may

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[1] https://www.gartner.com/en/articles/what-s-ahead-for-semiconductor-shortages
[2] https://europe.autonews.com/automakers/toyota-cut-full-year-production-target-chips-crunch
[3] https://www.globaltimes.cn/page/202112/1241579.shtml
[4] See the statement made by the President of the European Commission, Ursula von der Leyen, in 2022: https://ec.europa.eu/commission/presscorner/detail/en/statement_22_866

materialize in inflationary pressures along with a contraction of imported volumes. In addition, the comparison of subsequent updates of the SCAN can also help determining whether the distress observed in trade flows is a transitory or a persistent phenomenon. Having said this, exogenous shocks affecting the production of specific goods in a geographical area may manifest in trade data with a delay of several months due to buffer stocks and contingency plans which are always available, especially to large companies operating at a global scale.

We apply the SCAN methodology to a set of 74 products in the semiconductors supply chain following the list available in OECD (2019).[5] Monitored products belong to different segments of the value chain: i. raw materials; ii. inputs for wafers; iii. silicon wafers; iv. foundry inputs; v. equipment; vi. final products. The list of products taken under consideration might be extended in the future after a deeper review of the value chain thanks to the help of experts. Nevertheless, this study is a first attempt to monitor EU trade flows in the semiconductor value chain relying on a methodology which has already been applied to other value chains like solar panels and wind turbines (Amaral et al., 2022).

We find that ten products belonging to the semiconductor value chain can be considered in medium or high risk of import disruption due to high import concentration and low substitutability in year 2021.[6] These products belong to various segments of the value chain: raw materials, inputs for the production of wafers, equipment for the manufacture of semiconductors, and semiconductor devices, which are the final products of the chain. Six of these products are currently also in high distress due to observed reductions in import quantities accompanied by increases in import prices over the last available quarter (Nov. 2022 – Jan. 2023). Products traded along the semiconductor supply chain whose imports are in high-distress are: i) *Azidies, Silicides*; ii) *Photographic plates and film in the flat for monochrome photography*; iii) *Sheets and plates of polarising material*; iv) *Fans of a kind used principally for cooling microprocessors*; v) *Diodes*; vi) *Electronic integrated circuits as dynamic random access memories*.

We then evaluate how relevant are imports of these products within their respective segments of the supply chain and discuss the evolution of structural and high-frequency indicators over time. Finally, we bring a case study on the D-RAM supply shortage from Taiwan, as a preliminary attempt to evaluate the performance of the SCAN methodology on past crises. Even though the evidence presented is only descriptive and does not allow us to infer causal relations, we observe the effects of this specific crisis on our monthly trade variables as expected by the SCAN framework (i.e., rising import prices and falling imported quantities). However, there seems to be a relevant time lag in the response of trade variables, suggesting that, when monitoring

[5] OECD, 2019. "Measuring distortions in international markets: The semiconductor value chain", OECD Trade Policy Papers, No. 234, OECD Publishing, Paris.

[6] If one of the concentration indexes and one of the substitutability indexes are above the respective thresholds, a product is considered as being in medium risk.

short-run supply chains distress, other factors such as firms' inventory capacity should be also taken into account as well.

Assessing the benefits and the functioning of integrated global supply chains is not a new concept in the economic literature. Trade liberalization and participation to international markets have typically benefitted firms in terms of efficiency and competitiveness, through improved access to foreign markets and inputs, economies of scale, productivity gains, or technology upgrading and innovation.[7] However, despite the overall pro-competitive effects of GVCs integration, recent supply disruptions driven by exogenous factors such as the Covid-19 pandemic, climate related events, natural disasters (like earthquakes) or geopolitical crises (as the Russia-Ukraine conflict) have changed the perception on international supply chains taking into account their strategic role. Accordingly, researchers and institutions are devoting a renovated interest on how global value chains can amplify negative natural or man-made shocks and on how to monitor their performances to anticipate crises.

Several contributions have focused on studying supply chains functioning and bottlenecks at macro level. For instance, in order to monitor global value chain conditions and capture pressures arising at the global level, Benigno et al. (2022) develop a novel indicator, the Global Supply Chain Pressure Index (GSCPI), that combines in a parsimonious way a wide range of publicly available high-frequency information on transportation costs, shipping rates and manufacturing PMI[8] indicators (such as delivery times, backlogs and inventories). By leveraging on maritime traffic data, other contributions have proposed alternative metrics based on port congestions and waiting times in ports in order to detect global supply chain bottlenecks (Komaroni, Cerdeiro and Liu, 2022). At sectoral level, the recent literature has focused on measuring how exposed are countries and sectors to foreign suppliers and GVC shocks. In order to take into account the global interlinkages in production at country-sector level, these measures of exposure and GVC participation are typically based on the use of inter-country input output tables (Borin and Mancini, 2019; Borin et al., 2021; Baldwin et al., 2022; Rueda Catuche et al., 2022).

When the focus is on monitoring strategic industrial sectors and specific value chains rather than global conditions or sectoral interlinkages, the analysis entails several challenges. The main ones refer to data limitations and to the level of aggregation required. Aggregated data used for macro and sectoral level analysis do not typically allow to disclose the dynamics of specific supply chains. Ideally, in order to have a targeted monitoring, the approach should focus on relevant classes of products/inputs traded along the different segments of the value chain. In this case, a first step is required to identify the specific basket of products that are particularly

[7] On trade liberalization and innovation, see for example Shu and Steinwender (2019); Akgicit and Melitz, (2021); Melitz and Redding, (2022); Coelli et al., (2022). On trade liberalization, access to foreign markets and productivity, see for example Melitz (2003); Melitz and Ottaviano (2008); Lieeva and Trefler (2010). For an extensive discussion on supply disruptions and risk in global supply chains see Baldwin and Freeman (2022).
[8] From IHS Markit's Purchase Manager Index (PMI) data.

relevant and representative of the value chain to be monitored. Moreover, to fully capture the occurrence of shocks and to track their real-time evolution, the analysis should also make use of frequently updated information. The SCAN monitoring system developed by Amaral et al. (2022) takes into account these considerations. The SCAN relies on detailed product level data on EU trade flows which are available with monthly updates. [9] In particular, the methodology uses high-frequency information [10] on EU trade flows to report signs of distress materializing in concurrent increases in import prices and reductions in imported quantities.[11] In parallel, the indication from structural indicators [12] on import concentration and substitution potential helps to narrow down the set of products where a risk of disruption is more likely to materialize. Amaral et al. (2022) also provide examples of the application of the SCAN methodology to a selection of raw materials particularly relevant in the context of the Russia-Ukraine conflict and to a basket of products necessary to produce solar panels.

The SCAN monitoring tool builds on the previous work conducted by the European Commission on mapping strategic dependencies at product level.[13] [14] [15] This methodology is also closely

[9] One should keep in mind that, in some cases, even the level of detail of trade flows may be still not sufficient for the analysis of very specific classes of products or inputs. Another limitation of trade data is that they are typically not available for services.

[10] For the computation of high-frequency monthly indicators, Amaral et al. (2022) rely on the European Commission customs database which allows an almost real time update of the trade data. COMEXT, the Eurostat's database for international trade statistics, provides monthly data on EU trade flows as well, but with a 2-3-months lag.

[11] The identification assumption that demand shocks lead quantities and prices to move in the same direction, whereas supply shocks drive them in opposite directions is well employed in the literature, especially for supply-demand shock decomposition in macroeconomic structural models (see for example, Fry and Pagan, 2011; Shapiro, 2022; Celasun et al., 2022; Kilian et al., 2023). However, regarding the SCAN methodology, Amaral el al., 2022 are very clear in specifying that the evolutions of the high-frequency indicators are only meant to proxy the extent of disruptive shocks, while they might be associated with many causes and factors including trade policies, exchange rates, shipping bottlenecks among others. One might also suspect significant heterogeneity in the effects across products. Thus, they recommend the use of the SCAN methodology shall be complemented with deeper analysis and expert assessment.

[12] For the computation of the annual structural indicators, they rely on trade statistics from COMEXT and on EU production statistics from PRODCOM.

[13] The European Commission document on strategic dependencies and capacities (2021) maps EU's strategic dependencies at the level of specific goods so as to identify potential risks related to the exposure to supply chain disruptions. Among the core indicators used, there are the concentration of foreign imports, the importance of extra EU imports in total demand and the substitutability of extra EU imports with EU supply. The Commission Staff Working Document SWD (2021) 352 on strategic dependencies and capacities is available at https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=SWD:2021:352:FIN

[14] More recently, Arjona et al. (2023) propose an enhanced methodology with respect to the European Commission's benchmark methodology (European Commission, 2021) with the aim of improving the data quality of the dataset, analysing dependencies in a multi-year framework, and complementing the "threshold" approach with a "ranking" approach to better identify foreign dependencies.

[15] According to the methodology developed for the EU assessment of Critical Raw Materials, the supply risk parameter takes into account the risk of disruption due to a high concentration of raw materials' supply and is calculated based on trade and production data (combined with other information, for example, on the governance performance of the sourcing country). The last report, titled "Study on the Critical Raw Materials for the EU 2023

related to the work of Benoit et al. (2022) on the relationship between import price fluctuations and structural dependency indicators. In particular, by analysing the universe of 6-digit-HS product-level trade data, Benoit et al. (2022) bring evidence that products with high levels of import concentration are those that experienced significant price pressures and shortages during the first phase of the COVID-19 pandemic.

This paper unfolds as follows. Section 2 describes the methodology behind the SCAN monitoring system and the data employed to develop this analysis. Section 3 reports our findings on the application of the SCAN to the semiconductor value chain. Section 4 concludes.

2. Methodology

2.1 Structural indicators

To measure EU foreign dependency, both the concentration of extra-EU imports and the substitution potential of extra-EU imports with EU domestic production are taken into account and measured using annual data. Indicators are computed relying on data on the last available year. Products that are classified as highly foreign dependent are characterized by both low levels of import diversification and low levels of potential substitutability with EU supply.

The concentration of extra-EU imports is identified by two complementary indexes that are computed for each product: (1) the extra-EU import concentration; (2) the share of the first source in extra-EU import. The first index is measured by the Herfindal-Hirshmann (HHI) index of market concentration and is computed as detailed below:

$$HHI = \sum_{c=1}^{N} (MS_c)^2$$

where MS_c is the market share of the extra EU supplying country c in EU's imports of a given product, and N is the total number of extra EU supplying countries. Higher values of the concentration index signal lower levels of diversification of EU imports from extra EU sources. More specifically, the index ranges from 0 to 1, moving from the case of no-concentration (i.e., large number of small suppliers) to a situation of a single monopolistic supplier. The HHI

– Final Report", is available at https://single-market-economy.ec.europa.eu/publications/study-critical-raw-materials-eu-2023-final-report_en threshold above which a product is considered as being in ex-ante risk is 0.4, which implies that the bulk of EU import values for a specific product originate in less than three countries.[16]

For concentration, the HHI indicator is complemented with a second indicator, the share of the first source in extra-EU imports:

$$MAX\_MS = max(MS_c)$$

where *MAX_MS* is the highest market share of an extra EU supplying country *c* in EU's imports. The threshold of 50% tells us that, for each product, imports originating from the first extra EU source account for the majority of extra EU imports.

The substitution potential of extra-EU imports with EU's domestic production is captured by two complementary indicators: (1) the ratio between extra-EU imports and total EU exports; (2) the exposure indicator. For each product, the first index is computed as detailed below:

$$Ratio_{IMP/EXP} = \frac{IMP_{extraEU}}{EXP_{EU}}$$

where $IMP_{extraEU}$ is the extra-EU import value for a specific product and EXP_{EU} is total EU export value (outside and within the Union) which is a proxy for domestic production. The chosen threshold is 1 indicating that alert levels of the indicator are reached when the value of extra-EU imports is higher than the value of total EU exports for a specific product. Intuitively, ratios higher than 1 identify cases where the EU is not fully capable to substitute extra-EU imports with domestic production in case of supply chains' disruptions. The second substitutability indicator, the exposure index, is defined as the share of extra-EU imports in total EU supply, as detailed below:

$$Exposure = \frac{IMP_{extraEU}}{(IMP_{extraEU} + Y_{EU})}$$

where total supply in the EU is the sum of extra-EU imports $IMP_{extraEU}$ and domestic production Y_{EU}. High exposure values identify products with low existing substitution potential in case of a crisis. The chosen threshold of 0.6 indicates cases for which imports account for more than 60% of total EU domestic supply.[17] The exposure index aims at complementing the indicator on the imports/exports ratio by providing a measure on the dependency of the domestic supply (which comprises products imported from abroad and products produced domestically) to imports from extra-EU countries.

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[16] The thresholds for import concentration, highest market share and for the ratio between extra-EU imports and total EU exports follow the definition of strategic dependencies presented in the Commission document SWD (2021) 352 on strategic dependencies and capacities.

[17] Regarding the choice of the threshold of the exposure index, it is worth noting that the European Critical Raw Materials Act sets that, by 2030, not more than 65% of the Union's annual consumption of each strategic raw material at any relevant stage of processing can rely on imports from a single third country.

One reason why the SCAN methodology employs two complementary indicators on substitutability is that each indicator presents some limitations. Regarding the ratio between extra-EU imports and total EU exports, the EU exports variable is only a proxy of domestic production; it cannot capture, for example, the fraction of domestic production that is not exported. On the other hand, the exposure index relies on domestic production sourced from a separate database (PRODCOM) whose data quality suffers from data confidentiality issues. Moreover, matching PRODCOM data with detailed trade data from COMEXT might raise some aggregation concerns.[18]

The assessment on products' ex-ante risk of disruptions takes into account the joint outcomes obtained from the whole set of structural indicators, rather than being based on single indexes' values and thresholds. More specifically, if one of the concentration indicators and one of the substitutability indicators are above the thresholds, a product is considered as being in "medium-risk". If all four indicators are above the thresholds the product is considered in "high-risk", according to structural indicators of dependency.

2.2 High-frequency indicators

The high-frequency indicators rely on monthly data on extra-EU imports and measure the change in price and in quantity [19] for the average values of last available quarter with respect to the averages of the same quarter in the previous three years, in order to smooth-out yearly and seasonal shocks. These indicators are meant to capture the effects of a potential crisis in the short-run. However, it should be noted that high-frequency trade-related variables on prices and quantities might take some months to react. This might be due to, for example, pre-existing trade contracts and it might vary depending on firms' stock capacity. According to these indicators, distressed products are those reporting a sizeable increase in import price together with a reduction in imported quantities. The economic intuition behind considering together prices and quantities is that by looking at their contemporaneous movements it is possible to better grasp the type of the underlying distress. Demand shocks are expected to lead to significant positive changes in both quantities and prices, while opposite patterns (i.e., rising prices together with falling quantities) are expected to show up in case of supply shocks. Indeed, in the real world, it is more complicated to disentangle the effects of multiple concurrent and heterogeneous shocks from the impacts of other factors (e.g. exchange rates, trade policies, changes in buyers' preferences, or technology upgrading). For these reasons, it is highly recommended to complement the information obtained from the SCAN methodology with deeper analysis and with field-expert knowledge.

[18] See the Appendix for a detailed discussion.

[19] International trade datasets such as the United Nations Comtrade database or the Eurostat COMEXT provide statistics on trade flows in terms of values and quantities. Trade prices are typically not available from official statistical offices. To approximate trade prices, empirical trade and macro economists usually compute prices as "unit values" which correspond to the ratio of the value and the quantity of the traded products.

Finally, the evidence on short-run distress obtained from the high-frequency indicators is combined with the indication on product level structural vulnerabilities assessed by the structural indicators. A product is considered in high-distress when it is considered in medium or high-risk of import dependency according to structural indicators, *and* it is experiencing abnormal rises in prices and falls in quantities according to high-frequency indicators.

2.3 The Data

To develop our application of the SCAN to the semiconductor value chain, we first selected 74 CN 8-digits [20] products belonging to different segments of this production chain, following OECD (2019).[21]

The full list of products taken under consideration is reported in the Appendix to this manuscript.[22] The different segments to which we assign products in this list are: i. raw materials (R); ii. inputs for wafers (IW); iii. silicon wafers (SW); iv. foundry inputs (I); v. equipment (E); vi. final products (F).

Structural indicators of the SCAN are computed relying on data for year 2021. [23] Concentration indexes are obtained from the COMEXT database, which is the Eurostat's database for statistics on trade in goods among EU member states and between member states and third countries. Data for the two substitutability indicators also come from the COMEXT dataset, while the data on EU domestic production are obtained from the PRODCOM database. Both COMEXT and PRODCOM are available on the Eurostat Website.

High-frequency indicators for changes in prices and quantities are obtained using data on average import value and quantity from Extra-EU27 countries for the last available quarter: November 2022-January 2023. We then take the difference with respect to the average for the same quarter in the previous three years in order to take into account and smooth seasonal effects as well. This data is also available in COMEXT with a time-lag of three months.

[20] CN stands for Combined Nomenclature, which is the EU's eight-digit coding system for the classification of goods employed in EU trade statistics. It comprises the six digits of the HS code (i.e., the World Custom Organization's Harmonized System nomenclature) with further EU two digits subdivisions.

[21] OECD, 2019. "Measuring distortions in international markets: The semiconductor value chain", OECD Trade Policy Papers, No. 234, OECD Publishing, Paris.

[22] The list of products can be extended in the future, after a deeper review of the value chain.

[23] The most up-to-date data on domestic production (PRODCOM) refers to 2021. COMEXT annual data are available for 2022. To be time consistent across indicators, we use trade and production data for 2021. The reader could be interested in looking at the structural indicators calculated in the pre-Covid period in order to predate the effects of the shock itself. These results are available upon request.

3. Evidence on SCAN Indicators

Table 1 reports the scoreboard of products under medium or high risk according to structural indicators (columns 1 to 6), as well as the subset of products that are in high distress due to reductions in import quantity accompanied by increases in import prices observed over the last available quarter (columns 9 to 11).

Looking at the structural indicators displayed in Table 1, we observe that eight products belonging to this supply chain can be considered in medium risk of import disruption due to high import concentration and low substitutability in year 2021.[24] This group of products in medium risk includes raw materials, inputs for the production of wafers, equipment for the manufacture of semiconductors, and semiconductor devices, which are the final products of this supply chain. The name of the country accounting for the largest share of EU imports is displayed in column 1. The majority of these products is sourced from Asia: China is the main 1st source country of EU imports for these products. Ideally, the strategic role of the 1st source country for imports of products in this supply chain shall be pondered by taking under consideration the possible risks associated to import dependence on this country. Given this, we augment the information provided in column (1) by employing data on the geopolitical risk of the country accounting for the largest share of EU27 imports, relying on information from the World Governance Indicators (WGI).[25] These indicators, developed by the World Bank, inform on the traditions and institutions by which political power is exercised in each country. These include the procedures by which governments are monitored while in charge, how their powers are balanced, how they can be replaced, the respect of citizens and state for the institutions governing economic and social interactions. The WGI focus on six broad dimensions of governance: i. voice and accountability; ii. political stability and absence of violence/terrorism; iii. governance effectiveness; iv. regulatory quality; v. rule of law; vi. control of corruption.[26] Trade partners like China and India, which report an average of WGI for year 2021 between the first and the second quartile of the WGI distribution at the global level, are indicated in orange, while countries with a higher average WGI are indicated in green in column (1).

In addition, we find two products that can be considered under high risk of import disruption as all their structural indicators are above the respective thresholds. In column 6 these high risk products are highlighted with a double asterisk to distinguish them from medium risk products (single asterisk). Indeed, around 70% of EU27 imports for the product *"articles of niobium*

[24] If one of the two concentration indexes and one of the two substitutability indexes are above the respective thresholds, a product is considered as being in medium risk.

[25] The Worldwide Governance Indicators (WGI) project reports aggregate and individual governance indicators for over 200 countries and territories over the period 1996–2021 (see https://info.worldbank.org/governance/wgi/).

[26] The Worldwide Governance Indicators (WGI) are assembled by summarizing the views on the quality of governance provided by a large number of enterprise, citizen and expert survey respondents in industrial and developing countries. These data are gathered from a number of survey institutes, think tanks, non-governmental organizations, international organizations, and private sector firms.

columbium or rhenium" originate from the United States, while extra-EU imports more than double total EU exports. For *"photosensitive semiconductor devices"*, imports from China make up almost the entire extra-EU supply with a market share around 90%.

As discussed above, structural indicators provide a picture on medium-term dependencies of the EU, while observing their evolution over time provides insights on how dependencies varied over the last years. It is therefore important to stress that the EU reported sizeable increases in import concentration and/or reductions in substitutability (which are determined by either an increase in the import/export ratio or/and in the exposure index) for seven products out of ten in medium or high risk during the period 2019-2021 (columns 7 and 8). This evidence further confirms the need to closely monitor this strategic supply chain.

Results obtained from high-frequency data sheds light on changes in EU27 import prices and quantities over the last quarter (Nov. 2022 to Jan. 2023). A total of six products in medium or high risk of disruption according to structural indicators, are also in high distress due to observed reductions in import quantities accompanied by increases in import prices (columns 9 to 11) over the last observed quarter. Products traded along the semiconductor supply chain whose imports are in high-distress are: i) *Azidies, Silicides*; ii) *Photographic plates and film in the flat for monochrome photography*; iii) *Sheets and plates of polarising material*; iv) *Fans of a kind used principally for cooling microprocessors*; v) *Diodes*; vi) *Electronic integrated circuits as dynamic random access memories*. The majority of these products is currently subject to EU import restrictions from specific geographical areas. A subset of them is also subject to EU export authorizations due to their potential dual-use (e.g. *Photographic plates and film in the flat for monochrome photography, Diodes, Electronic integrated circuits as dynamic random access memories).*[27]

[27] The interested reader can refer to: https://www.tariffnumber.com.

Table 1: *Scoreboard of SCAN Indicators for products in the semiconductor value chain.*

		Structural Indicator (S)								High-frequency Indicators (H)		S + H
		Concentration indexes (2021)			Substitutability indexes (2021)			% change (2021 -2019)				
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Product	Segment	1st source	Share 1st source (%)	HHI index	Imp/Exp	Exposure Index (%)	Ex-ante risk	Conc.	Subst.	% change import p	% change import q	Level of distress
Germanium oxides and zirconium dioxide	R	China	50.9	0.30	1.6	64.5	*	7.8	7.2	26.0	12.6	
Azides, silicides, whether or not chemically defined	R	India	53.2	0.37	1.2	78.3	*	-1.2	-6.4	55.1	-58.3	High distress
Borides whether or not chemically defined	R	United Kingdom	48.3	0.40	2.4	87.5	*	-2.8	-1.8	-28.9	115.6	
Photographic plates and film in the flat for monochrome photography	IW	Japan	82.5	0.70	0.9	60.7	*	24.0	8.2	48.7	-20.5	High distress
Articles of niobium "columbium" or rhenium, n.e.s.	IW	United States	71.4	0.58	2.3	68.7	**	7.4	21.8	9.2	36.6	
Sheets and plates of polarising material	I	Japan	51.3	0.32	1.9	81.5	*	-4.3	-3.5	10.4	-8.0	High distress
Fans of a kind used solely or principally for cooling microprocessors	E	China	57.3	0.35	0.8	83.5	*	-3.6	28.6	152.5	-49.7	High distress
Diodes (excl. photosensitive or light emitting diodes "LED")	F	China	56.8	0.35	0.5	65.7	*	15.9	8.5	44.1	-0.8	High distress
Photosensitive semiconductor devices, incl. PV cells	F	China	88.6	0.79	1.3	88.3	**	34.2	1.1	22.6	148.4	
Electronic integrated circuits as dynamic random-access memories "D-RAMs", with a storage capacity of <= 512 Mbit	F	Taiwan	59.1	0.39	0.6	98.7	*	35.7	-19.0	51.5	-46.2	High distress

Source: JRC B.1 elaboration on COMEXT (trade statistics) and PRODCOM (production statistics) data (year 2021) for structural indicators (last extraction date: 21/03/2023), and on monthly trade data (COMEXT) for the period 2019-2023 for high-frequency indicators (last extraction date: 29/03/2023). Data on the quality of governance from the Worldwide Governance Indicators project are used for the heat-map in column 1. R: Raw materials, IW: Inputs for wafers, I: Foundry inputs, E: Equipment, F: Final products.

NOTE: How to read this scoreboard: [pink box] for values of structural indicators above the thresholds; chosen thresholds for concentration indexes are 50% for the share of 1st source in extra-EU imports (column 2) and 0.4 for the HHI index (column 3). For substitutability indexes, the thresholds are equal to 1 for the ratio of extra-EU imports and total EU exports (column 4), and to 60% for the exposure index (column 5). The exposure indicator is computed as the share of extra-EU imports in EU total supply (sum of domestic production from PRODCOM and extra-EU imports).

Column 1 reports the country name that is the 1st source in supplying a given product to the EU market. Orange-coloured cells indicates countries with an average WGI between the first and the second quartile (i.e., low-medium score ranking); yellow-coloured cells indicates countries with an average WGI between the second and the third quartile (i.e., medium-high score ranking); green-coloured cells indicates countries with an average WGI (World Governance Indicators) above the third quartile (i.e., high score ranking).

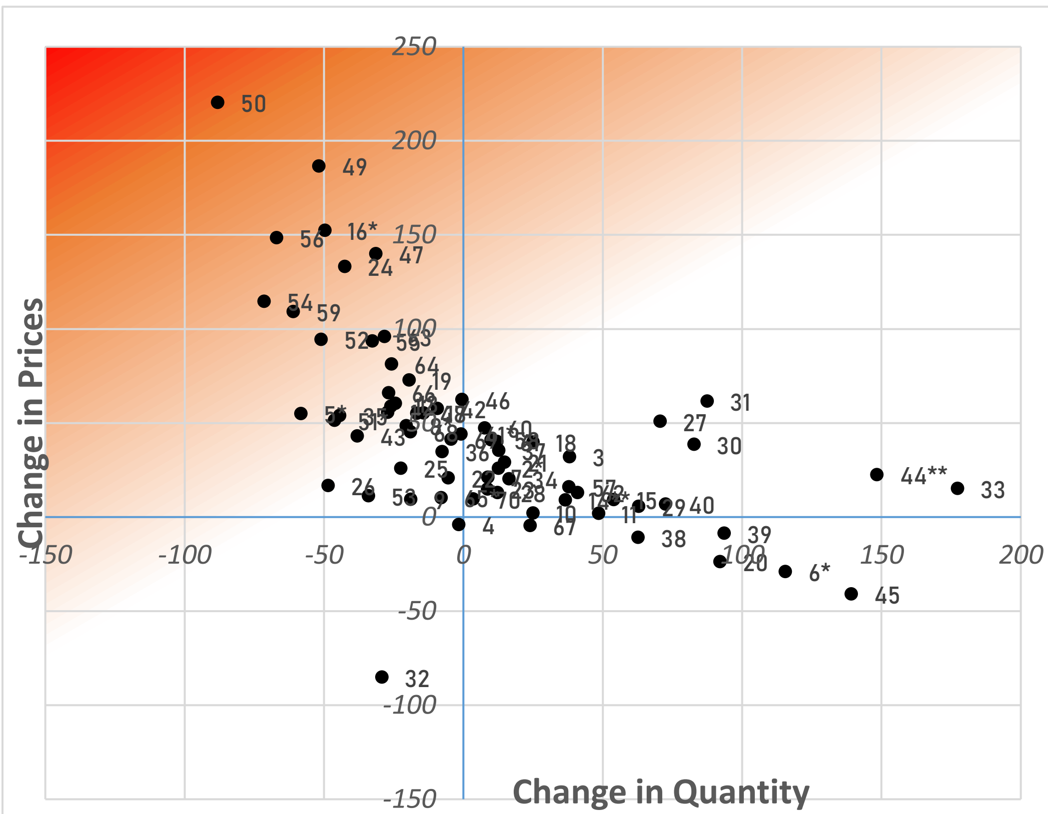
Column 7 reports the average of the percentage changes in the two concentration indexes over the period 2021 – 2019. Column 8 reports the average of the percentage changes in the two substitutability indexes over the period 2021 – 2019.

High-frequency indicators, i.e. changes in import prices (column 9) and changes in import quantities (column 10), are constructed by comparing the average for the quarter Nov. 2022 – Jan. 2023 with the average of the same period for 2021, 2020, and 2019.

Products under medium risk (in column 6) have at least one concentration index and one substitutability indicator above the relative thresholds, while high risk products (**) have values above the thresholds in all four structural indicators. Products in high distress (column 11) are those in ex ante medium or high risk of disruptions while also reporting increases in import prices and falls in quantities.*

Relying on data for the high-frequency indicators, we observe several products reporting increases in prices and reductions in import quantities (top-left quadrant of Figure 1) over the last observed quarter with respect to the same quarter in the previous three years. Some of these products, 13% of those in this quadrant, are also considered in medium risk (*) due to high foreign dependency according to the structural indicators for year 2021. Interestingly, the two products under high-risk (**) of import disruption do not appear in this quadrant of the graph as their imports in the EU did not report reductions in import quantities accompanied by increases in import prices. This currently leads us to discard the occurrence of import distress for these two products.

Figure 1: *Identification of products in high distress through the high-frequency indicators*



Source: JRC B.1 Elaboration on monthly data from Comext. Extraction date: 29/03/2023.

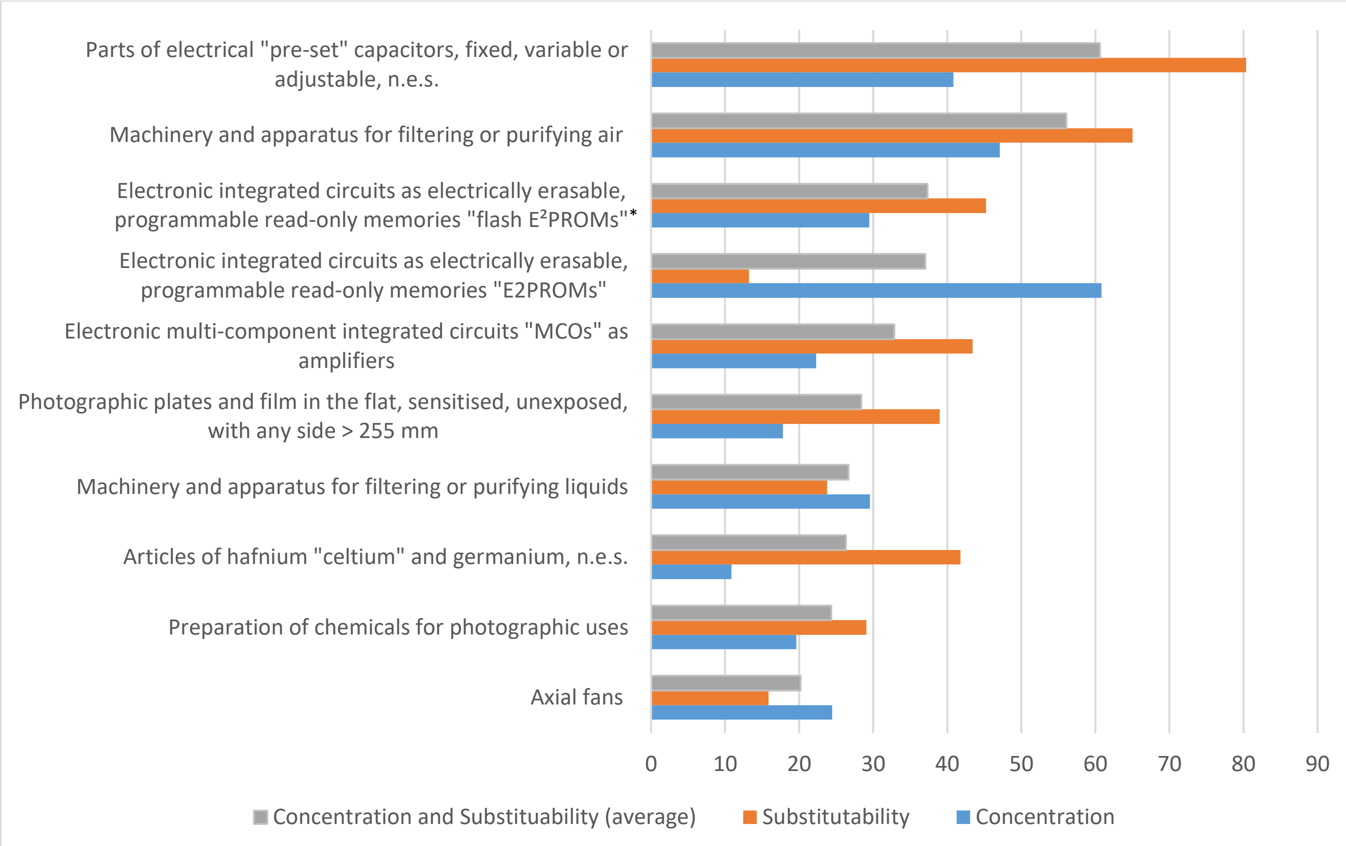
3.1 Variations over time of structural and high-frequency indicators

As discussed above, structural indicators identify those products for which the EU27 might have a risk of import disruption due to a high import dependence from specifing trade partners and a lower import-subsitutability potential.

The scoreboard discussed in this note is obtained computing structural indicators for year 2021. It is worthwhile to highlight that during the Covid pandemic and the following chip shortage, structural indicators of possible import discruption have deteriorated considerably for several products traded along this value chain (Figure 2), independently on whether these indicator were above the respective thresholds in year 2021, as done for the scroreboard reported in the previous section. In particular, we focus on those products experiencing simoultaneously a significant deterioration in both sets of concentration and substitutability indexes. [28] For example, structural indicators have significantly worsened for the EU27 imports of products like: *parts of electrical "pres-set" capacitors*, *machinery and apparatus for filtering and purifying air*, and *programable read-only memories*. This is confirmed either when looking separately at concentration indexes and susbtitubility indexes and when considering them jointly.

[28] For some products, we find a more mixed evidence, either a decrease in concentration combined with a deterioration in substitutability or vice-versa. For a smaller group of products, we find that structural indicators improved along both dimensions in the period 2021-2019. These results are available upon request.

Figure 2: *Structural indicators (% change 2021 - 2019), top ten products for deterioration in both the concentration and substitutability indexes*



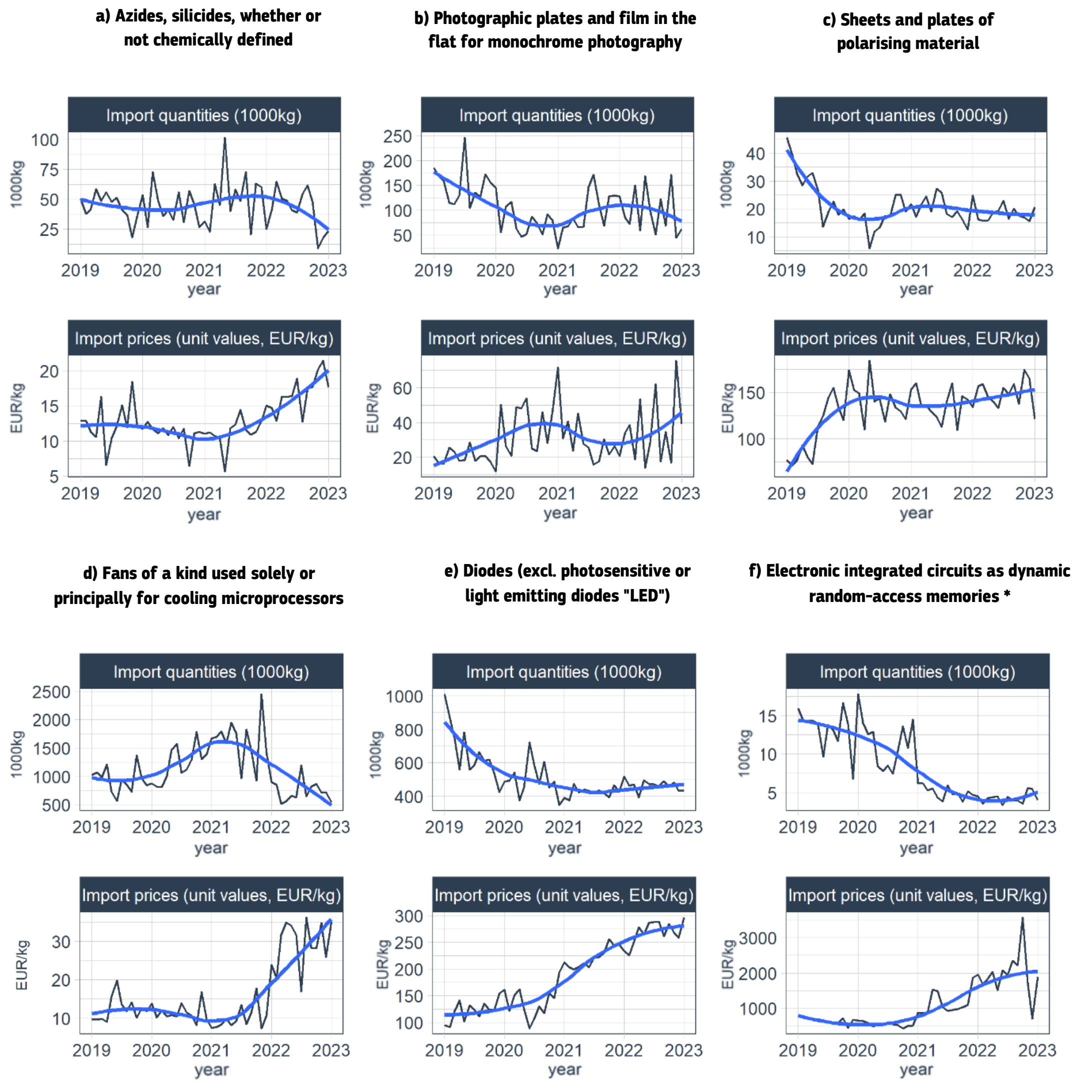
Source: JRC B.1 elaboration on COMEXT (trade statistics) and PRODCOM (production statistics) data (last extraction date: 21/03/2023).

NOTE: The % change in concentration over the period 2021-2019 is calculated as the average of the % changes (2021-2019) in the two concentration indexes (i.e., the HHI index and the share of the first source in extra-EU import). The % change in substitutability over the period 2021-2019 is calculated as the average of the % changes (2021-2019) in the two substitutability indexes (i.e., the ratio of extra-EU imports on total EU exports and the exposure index). Positive values indicates a deterioration of the structural indicators.

**The product labelled as "Electronic integrated circuits as electrically erasable, programmable read-only memories "flash E²PROMs"" refer to memories with a storage capacity of <= 512 Mbit*

Variations in unit values and import quantities for products in high distress over the last four years help us assessing whether changes in these variables observed over the last available quarter are consistent with medium-run trends observed for these variables (Figure 3). Importantly, we find sizeable reductions in import quantities for products in high distress starting from year 2022, while increases in import prices for these products are visible from 2021 onwards. The fast recovery of the global economy after the lockdowns of the Covid-19 pandemic is most likely behind the observed increases of EU import prices for these products.

Figure 3 *Monthly import prices and import quantities for products identified in high distress, Jan. 2019 – Jan. 2023.*



Source: JRC B.1 elaboration on COMEXT (trade statistics) data (last extraction date: 21/03/2023).
** This product refers to a subcategory of D-RAM products, i.e. "Electronic integrated circuits as dynamic random-access memories "D-RAMs", with a storage capacity of <= 512 Mbit"*

3.2 Structural indicators within segments of the value chain

Evidence for structural indicators at product level can be employed to draw inference for the different segments of the value chain. In this section, we discuss the relevance of products in medium or high risk of import dependency for their respective segments of the value chain. By doing this it is possible to grasp how relevant are these products for the proper functioning of the different segments of the value chain. Nevertheless, while pursuing such type of analysis, we should always keep in mind that products which are imported in small quantities and/or are traded at low commercial prices can have a strategic role, especially if their production is highly concentrated in a specific geographical location or in few companies.

First, we highlight that imports of products in the different segments account for remarkably different shares of imports along the whole semiconductors value chain (Table 2). In particular, the EU27 mostly imports the final products of this supply chain, like integrated circuits, memories, and amplifiers, followed by equipment for the manufacture of semiconductors (column 1). Results for year 2021 show that 50% of products belonging to the raw materials segment, accounting for 22.5% of imports, can be considered in "medium risk" according to the structural indicators for year 2021 (columns 2 and 3).[29] The same holds for 4.3% of the inputs for wafers, and 12.5% of foundry inputs, which account for 21% and 1.7% of EU imports in their segment, respectively.

Products in "high-risk" represent instead 14% of inputs for wafers and 3.3% of the final products in the value chain (column 4).[30] Interestingly, this last category accounts for 18% of imports in the segment of final products (column 5). The evolution over time of structural indicators shows that 33.3% of products in raw materials were in high-risk of import disruption in 2020, while they were considered in medium risk in 2019. Inputs for the production of wafers found in high-risk of import disruption in 2021, were in high-risk also in 2020 and 2019. This is the case also for the final products of this value chain under high-risk of import disruption. This last finding leads us to conclude that EU27 dependencies in this value chain tend to be quite persistent over time. These numbers highlight that dependencies and risks of import disruption have different relevance for the various segments of the value chain and that the risks of import disruption association seem not vary much over the recent years.

[29] These percentages are obtained considering the number of CN-8 products in each segment of the value chain. We stress once more that, especially for the case of raw materials, these products are traded also along other value chains. For this specific segment, evidence on dependencies should not only be ascribed to the semiconductor value chain.

[30] We find two CN-8 products in "high-risk": "articles of niobium or rhenium, n.e.s." (inputs for wafers), and "photosensitive semiconductor devices, incl. photovoltaic cells" (final products).

Table 2: *Results of structural indicators by segment and year*

Segment of the Value Chain	(1) % of Total Extra EU27 Imports in Value Chain	(2) % products "Medium Risk" in Segment	(3) % of Extra EU27 imports "Medium Risk" in Segment	(4) % products "High Risk" in Segment	(5) % of Extra EU27 imports "High Risk" in Segment
2019					
Raw materials	0.8	33.3	3.4	0.0	0.0
Inputs for wafers	1.5	0.0	0.0	14.3	5.6
Silicon wafers	2.0	0.0	0.0	0.0	0.0
Foundry inputs	3.0	12.5	1.9	0.0	0.0
Equipment	18.9	9.5	20.8	0.0	0.0
Final products	73.8	6.7	2.4	3.3	14.7
2020					
Raw materials	0.8	0.0	0.0	33.3	3.2
Inputs for wafers	1.2	14.3	4.5	14.3	6.0
Silicon wafers	1.9	0.0	0.0	0.0	0.0
Foundry inputs	2.7	0.0	0.0	0.0	0.0
Equipment	19.7	9.5	22.5	0.0	0.0
Final products	73.7	3.3	1.9	3.3	16.3
2021					
Raw materials	0.7	50.0	22.5	0.0	0.0
Inputs for wafers	1.0	14.3	4.3	14.3	5.6
Silicon wafers	1.7	0.0	0.0	0.0	0.0
Foundry inputs	2.7	12.5	1.7	0.0	0.0
Equipment	19.1	4.8	1.3	0.0	0.0
Final products	74.8	6.7	2.2	3.3	18.1

Source: JRC B.1 Elaboration on Comext and Prodcom Data for year 2019, 2020 and 2021. Extraction date: 21/03/2023.

3.3 Case study: The D-RAM supply shortage

From early 2020, severe disruptions in supply chains and logistics caused by the Covid-19 pandemic combined with a surge in the global demand for PCs and smartphones, triggered an unprecendent global shortage in the chips industry. A constrained supply of semiconductors contributed to the global shortage as well. From the end of 2020 through the year 2021, the D-RAM chip market underwent significant pressures. Particularly, severe shortages and delays were registered in manufactuing plants in Asian countries, including Taiwan. Among the contributing factors, there were production disruptions, as the one caused by a power outage affecting D-RAM plants in Taiwan in December 2020. [31] Weather-related events, such as the unexpected drought that hit central Taiwan during summer 2021, stressed local factories as well, as massive quantities of clean water are needed to produce chips.[32]

The occurrence of this past crisis allows us to conduct a descriptive analysis on the performance of the SCAN methodology, to assess, for example, whether the trade variables of the high-frequency set of indicators reacted to the Taiwanese disruptive shock. In Figure 4, we report monthly EU import prices and quantities from Taiwan for three D-RAM memories product categories. It is worthwhile to note the discontinuity after the end of 2020 in prices and quantities trends reported for two products: "*Electronic integrated circuits as dynamic random-access memories "D-RAMs", with a storage capacity of <= 512 Mbit*" (panel a) and "*Electronic integrated circuits as dynamic random-access memories "D-RAMs", with a storage capacity of > 512 Mbit*" (panel b). [33] Since the beginning of 2021, there is evidence of rising import prices along with falling import quantities, which, as envisaged within the SCAN framework, are signals of short-run supply-side distress. Trade-related variables were then rather able to reflect the effects of this known past disruption, even though with some time delay. Indeed, larger spikes in prices and drops in quantities are observed only during the second half of 2021. The lag in the response could be explained by several factors, such as the presence of pre-existing trade contracts, the stocking capacity of the suppliers or the sourcing potential of EU importers. [34] [35]

[31] See https://www.reuters.com/technology/micron-forecasts-third-quarter-revenue-above-estimates-2021-03-31/ or BCG (2021). The power outage affected a Taiwanese fab of Micron, which is one of the largest worldwide supplier of DRAM or NAND technologies.

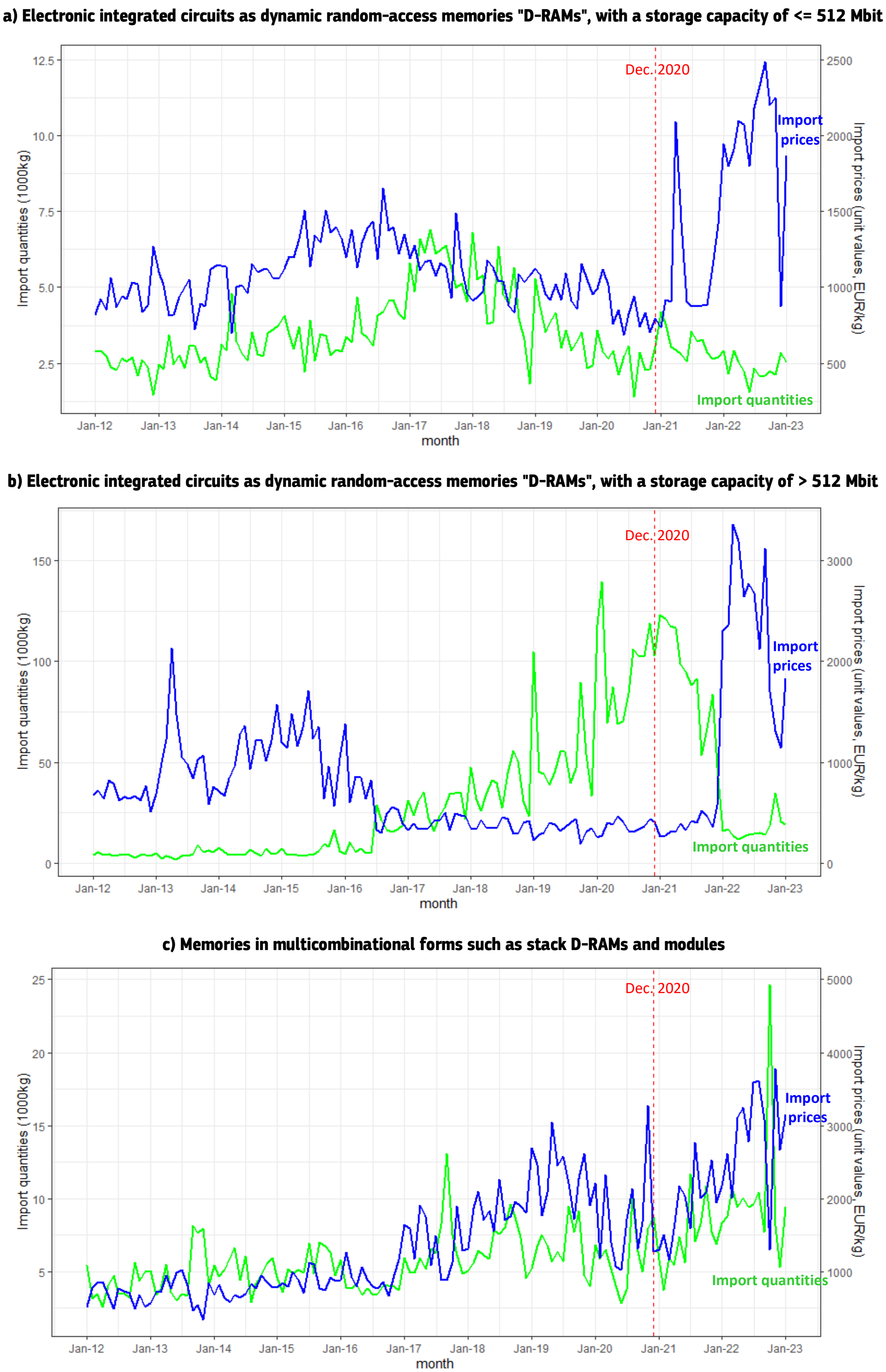
[32] See https://www.nytimes.com/2021/04/08/business/taiwan-is-facing-a-drought-and-it-has-prioritized-its-computer-chip-business-over-farmers.html

[33] The dynamics are less pronounced for the product "*Memories in multicombinational forms such as stack D-RAMs and modules*" (panel c) which records rising prices and stable levels of imported quantities.

[34] It could also be the case that immediately after a production crunch hit, downstream companies drain suppliers' stocks to prevent future shortages. This could cause a temporary rise in imported quantities followed by a decrease only once suppliers' inventory levels drop.

[35] It is important to note that the evidence provided so far is only intended to be descriptive. For a better understanding on the factors behind the dynamics, if applicable, an econometric and/or an event-study analysis should be considered.

Figure 4: *Monthly import prices and quantities, D-RAM chips sourced from Taiwan to the EU*



Source: JRC B.1 Elaboration on monthly data from Comext. EU imports from Taiwan. Extraction date: 04/05/2023.

4. Conclusion and future work

In this manuscript, we proposed the application of the SCAN monitoring tool to products in the semiconductor supply chain. We selected a group of products traded along the different segments of this supply chain, from raw materials to final products, and drew inference based on structural and high-frequency indicators. Structural indicators signal ex-ante vulnerabilities due to external dependencies and low import-substitutability potential. High-frequency indicators give an updated picture on trade volumes and import prices for the products under scrutiny. We find that ten products belonging to the semiconductor supply chain can be considered in medium or high risk of import disruption due to high import concentration and low substitutability in year 2021. According to this methodology, EU27 imports of six of these products are also in high distress due to reductions in import quantities accompanied by increases in import prices observed during the last available quarter (Nov'22 – Jan'23). We highlight that these fluctuations may be due to the interplay of supply and demand factors and are meant to capture imbalances in the market.
In addition, we discover that relevant structural vulnerabilities detected for year 2021 as well as trends in high-frequency indicators are persistent across the years.

The list of products taken under consideration to monitor this strategic supply chain shall be further extended and regularly updated after a deeper review done with the help of experts of this supply chain. Moreover, it should always be highlighted that, especially in the case of raw materials, monitored products might be traded along other supply chains. The role of re-exports should also be taken under consideration when working on this type of analysis.[36] The access to more recently updated high-frequency customs data would give the possibility to detect disruptions as they materialize in the market and to act consequentially. Nevertheless, a detailed analysis is needed to assess how past economic crisis affect the international trade of affected products, and on how to best treat this data from an econometric viewpoint to improve the robustness of the SCAN methodology. In this respect, future research could use econometric/event-study approaches and focus on the impact of known past disruptions on high frequency trade indicators to better assess the underlying mechanisms driving the observed dynamics and the timing of the response of the variables of interest.

[36] Refer to Rueda Catuche et al. (2022).

Another aspect which devotes additional considerations and study are the thresholds triggering a warning signal for the different indicators. Ideally, these thresholds shall be based on the previous literature, as currently done, and carefully tested.

Bearing this in mind, together with other frequently updated indicators on the functioning of dedicated logistics and on the prices of relevant services and materials, this methodology can provide to policy makers valuable, updated, insights on the functioning of strategic supply chain under the Open Strategic Autonomy framework pursued by EU institutions.[37]

[37] https://single-market-economy.ec.europa.eu/industry/strategy_en

References

Akcigit, U. and Melitz, M., 2022. International Trade and Innovation (No. w29611). National Bureau of Economic Research.

Amaral A., Connell W., Di-Comite F., and Herghelegiu C., 2022. "SCAN" (Supply Chain Alert Notification) monitoring system. Single Market Economics Papers. Publications Office of the European Union.

Arjona R., Connell W., and Herghelegiu C., 2023. An enhanced methodology to monitor the EU's strategic dependencies and vulnerabilities. Single Market Economics Papers. Publications Office of the European Union.

Baldwin R, Freeman R. 2022. Risks and Global Supply Chains: What We Know and What We Need to Know. Annu. Rev. Econ. 14: Submitted. DOI: 10.1146/annurev-economics-051420-113737

Baldwin R., Freeman R., and Theodorakopoulos A., 2022. Horses for courses: measuring foreign supply chain exposure (No. w30525). National Bureauof Economic Research.

BCG (2021): Varas, A., Varadarajan, R., Goodrich, J., & Yinug, F, "Strengthening the global semiconductor supply chain in an uncertain era," Boston Consulting Group and Semiconductor Industry Association, April, 35, 2021.

Benigno, G., di Giovanni, J., Groen, J.J.J., and Noble, A. I., 2022. The GSCPI: A New Barometer of Global Supply Chain Pressures. Liberty Street Economics 20220104, Federal Reserve Bank of New York.

Benoit, F., Connell-Garcia, W. Herghelegiu, C., Pasimeni, P., 2022. "Detecting and analysing supply chain disruptions". GROW Economic Paper Series.

Borin A. and Mancini M., 2019. Measuring what matters in Global Value Chains and Value-Added Trade. Policy Research Working Paper No. 8804. World Bank, Washington, DC.

Borin, A., Mancini, M., & Taglioni, D., 2021. Measuring exposure to risk in global value chains. Policy Research Working Paper No. 978. World Bank, Washington, DC.

Celasun O., Hansen N. J., Mineshima A., Spector M., and Zhou J., 2022. Supply Bottlenecks: Where, Why, How Much, and What Next? Working Paper No. 2022/031, International Monetary Fund.

Coelli, F., Moxnes, A., and Ulltveit-Moe, K. H., 2022. Better, Faster, Stronger: Global Innovation and Trade Liberalization. The Review of Economics and Statistics.

European Commission (2021), Strategic dependencies and capacities, Brussels, Staff Working Document SWD(2021)352 final, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=SWD:2021:352:FIN

Fry R. and Pagan A., 2011. Sign Restrictions in Structural Vector Autoregressions: A Critical Review, Journal of Economic Literature, 49:4, 938–960

Kaufmann D., Kraay A., and Mastruzzi M., 2010. The Worldwide Governance Indicators : A Summary of Methodology, Data and Analytical Issues. World Bank Policy Research Working Paper No. 5430

Kilian L., Nomikos N. and Zhou X., 2023. "Container Trade and the U.S. Recovery," International Journal of Central Banking, vol. 19(1):417-450.

Komaroni, A., Cerdeiro D. A., and Liu, Y., 2022. Supply Chains and Port Congestion Around the World, Working Paper No. 2022/059, International Monetary Fund.

Lileeva, A. and Trefler, D., 2010. Improved access to foreign markets raises plant-level productivity… for some plants. The Quarterly Journal of Economics, 125(3):1051–1099.

Melitz, M. J. and Ottaviano, G. I., 2008. Market Size, Trade, and Productivity. The Review of Economic Studies, 75:295 – 316.

Melitz, M. J. and Redding, S. J., 2022. Trade and Innovation (No. w28945). National Bureau of Economic Research.

Melitz, M., 2003. The impact of trade on intra-industry reallocations and aggregate industry productivity. Econometrica, 71(6):1695–1725.

OECD, 2019. “Measuring distortions in international markets: The semiconductor value chain”, OECD Trade Policy Papers, No. 234, OECD Publishing, Paris.

Rueda Catuche J., Pedagua, L., and Mandras, G., 2022. "The relevance of re-exports for identifying strategic dependencies," JRC Research Reports JRC128381, Joint Research Centre.

Shapiro, A. H., 2022. “Decomposing Supply and Demand Driven Inflation,” Federal Reserve Bank of San Francisco Working Paper 2022-18.

Shu, P. and Steinwender, C., 2019. The impact of trade liberalization on firm productivity and innovation. Innovation Policy and the Economy, 19:39–68.

APPENDIX

Methodological appendix: building the indicators

To perform the analysis, we need (1) a consistent concordance between PRODCOM and COMEXT classifications (2) internal consistency over time within each classification. Related to point (1), for the purpose of constructing the fourth structural indicator (i.e., the exposure index), our analysis requires matching the CN classification on international trade at the 8-digit level (used in Eurostat's COMEXT), with the classification on production data (PRODCOM). In order to facilitate the comparison between statistics on production and on international trade in goods, the PRODCOM classification was developed by Eurostat with a close relationship with the Combined Nomenclature (CN) which is used for foreign trade statistics. However, even if the two classification systems are designed to be similar, there are differences between the two in a given year or across years. Differences mostly occur because the CN classification is too detailed in breaking down specific product categories. [38] As a result, for about 38 CN8-digits codes belonging to the list of the monitored products in the semiconductor value chain, there is a perfect match with the PRODCOM nomenclature.

For the remaining products, there are instead many CN codes associated to one PRODCOM code implying that the production data is only available at a more aggregated than the trade data. For these cases, using the more aggregated production information together with a detailed trade figure would inflate the indicator's denominator and underestimate the exposure risk. In order to mitigate this type of measurement error, we artificially disaggregated the production variable to match the same CN level by using weights computed on the base of the available export data. We compute the shares of exports corresponding to each CN 8-digit product code over the total exports in the more aggregated CN code that perfectly matches the PRODCOM classification. Then, we apply these shares to the aggregated PRODCOM data to obtain disaggregated production variable at the CN-8digit level. The underlying assumption of this procedure is that EU exports is a reasonably good proxy of domestic production, such that the distribution of production/exports levels within sub-categories of products is similar.

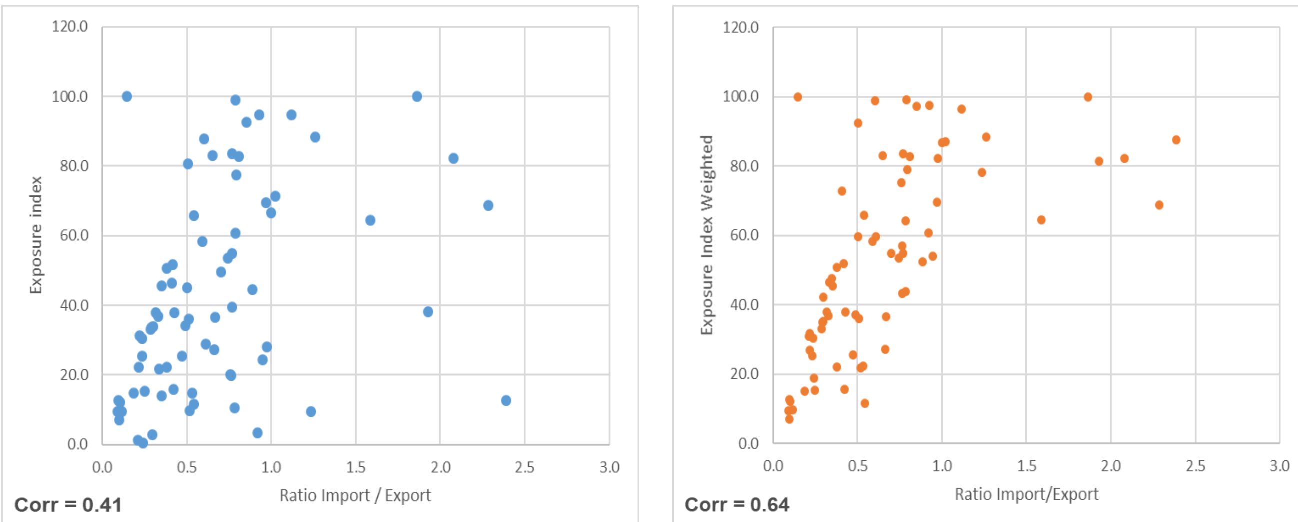
We show the results of the procedure described above in two scatterplots where we report on the x-axis the values of the first substitutability indicator (the ratio of extra-EU import and total EU exports) and on the y-axis the values of the exposure index for the list of 74 products and for the year 2021 (Figure A.1). In the graph in the left (panel a) we report the scatterplot between the two substitutability indicators before treating those cases of n-to-one match (several CN codes corresponding to one PRODCOM code), while panel b shows the results after applying the procedure. The overall correlation between the two indexes improves after using the exposure

[38] Differences between the two classifications can also emerge due to changes in the product coverage of the PRODCOM list.

index calculated with the "weighted" production. Moreover, there are no longer observations characterized by inconsistent indexes (i.e., the ratio import/export has very high values and the exposure indicator has very low values).

Figure A.1: *Scatterplot Ratio Import/Export index vs Exposure index -* ***panel a.*** *- and Ratio Import/Export Exposure index "Weighted" -* ***panel b.***

Panel a. **Panel b.**



Related to point (2) (i.e., internal consistency over time of the classifications), we proceed by harmonizing product codes through time. In particular, we need harmonized codes (CN and PRODCOM) from 2019-2021 for the computation of structural indicators and harmonized CN codes from 2019 to 2023 for the computation of high-frequency indicators. The CN and the PRODCOM classifications are regularly revised over time due to, for example, the elimination of obsolete product codes or to the emergence of new products. Thus, for the scope of the exercise, we need a consistent match not only between the PRODCOM and COMEXT classification systems in a given year but also through time, to have observations and product codes comparable across different years. Related to PRODCOM, there were not significant changes in the classification from 2019 to 2021 in our list of products (the last available year for production data is 2021). The CN classification, instead, undertook minor revisions from 2019 to 2021, and a major revision in 2022. The product codes related to the list of monitored products have been harmonized by considering 2021 as the reference year and by taking into account the recent revisions in the classification.

Table A.1: List of monitored products

#	CN 2021	Segment	Product description
1	28046100	Raw materials	Silicon containing >= 99,99% by weight of silicon
2	28256000	Raw materials	Germanium oxides and zirconium dioxide
3	28492000	Raw materials	Carbides of silicon, whether or not chemically defined
4	28500020	Raw materials	Hydrides and nitrides, whether or not chemically defined (excl. compounds which are also carbides of heading 2849, and inorganic or organic compounds of mercury)
5	28500060	Raw materials	Azides, silicides, whether or not chemically defined (excl. compounds which are also carbides of heading 2849, and inorganic or organic compounds of mercury)
6	28500090	Raw materials	Borides, whether or not chemically defined (excl. compounds which are also carbides of heading 2849, and inorganic or organic compounds of mercury)
7	37013000	Inputs for wafers	Photographic plates and film in the flat, sensitised, unexposed, with any side > 255 mm
8	37019900	Inputs for wafers	Photographic plates and film in the flat for monochrome photography, sensitised, unexposed, of any material other than paper, paperboard or textiles (excl. X-ray film and photographic plates, film in the flat with any side > 255 mm, and instant print film)
9	37079020	Inputs for wafers	Developers and fixers in the form of chemical preparations for photographic use, incl. unmixed products, in measured doses or put up for retail sale ready for use (excl. salts and compounds of heading 2843 to 2846)
10	37079090	Inputs for wafers	Preparation of chemicals for photographic uses, incl. unmixed products put up in measured portions or put up for retail sale in a form ready for use (excl. varnishes, glues, adhesives and similar preparations, sensitising emulsions, developers and fixers and salts and precious-metal compounds etc. of heading 2843 to 2846)
11	38180010	Silicon wafers	Silicon doped for use in electronics, in the form of discs, wafers, cylinders, rods or similar forms, whether or not polished or with a uniform epitaxial coating (excl. elements that have been further processed, e.g. by selective diffusion)
12	38180090	Silicon wafers	Chemical elements and compounds doped for use in electronics, in the form of discs, wafers, cylinders, rods or similar forms, or cut into discs, wafers or similar forms, whether or not polished or with a uniform epitaxial coating (excl. elements that have been further processed, e.g. by selective diffusion, and doped silicon)
13	81129920	Inputs for wafers	Articles of hafnium "celtium" and germanium, n.e.s.
14	81129930	Inputs for wafers	Articles of niobium "columbium" or rhenium, n.e.s.

#	CN 2021	Segment	Product description
15	81129970	Inputs for wafers	Articles of gallium, indium and vanadium, n.e.s.
16	84145915	Equipment	Fans of a kind used solely or principally for cooling microprocessors, telecommunication apparatus, automatic data processing machines or units of automatic data processing machines
17	84145925	Equipment	Axial fans (excl. table, floor, wall, window, ceiling or roof fans, with a self-contained electric motor of an output <= 125 W, and fans for cooling IT equipment of 8414 59 15)
18	84145935	Equipment	Centrifugal fans (excl. table, floor, wall, window, ceiling or roof fans, with a self-contained electric motor of an output <= 125 W, and fans for cooling IT equipment of 8414 59 15)
19	84145995	Equipment	Fans (excl. table, floor, wall, window, ceiling or roof fans, with a self-contained electric motor of an output <= 125 W, axial and centrifugal fans, and fans for cooling IT equipment of 8414 59 15)
20	84195020	Equipment	Heat exchange units made of fluoropolymers and with inlet and outlet tube bores with inside diameters measuring <=3 cm
21	84195080	Equipment	Heat-exchange units (excl. those used with boilers and those made of fluoropolymers with inlet and outlet tube bores with inside diameters measuring <=3 cm)
22	84212920	Equipment	Machinery and apparatus for filtering or purifying liquids, made of fluoropolymers and with filter or purifier membrane thickness <= 140 µm (excl. those for water and other beverages, and artificial kidneys)
23	84212980	Equipment	Machinery and apparatus for filtering or purifying liquids (excl. such machinery and apparatus for water and other beverages, oil or petrol filters for internal combustion engines, artificial kidneys, and those made of fluoropolymers with filter or purifier membrane thickness <= 140 µm)
24	84213915	Equipment	Machinery and apparatus for filtering or purifying gases, with stainless steel housing and with inlet and outlet tube bores with inside diameters <= 1,3 cm
25	84213925	Equipment	Machinery and apparatus for filtering or purifying air (excl. intake air filters for internal combustion engines, and those with stainless steel housing and with inlet and outlet tube bores with inside diameters <= 1,3 cm)
26	84213935	Equipment	Machinery and apparatus for filtering or purifying gases other than air by a catalytic process (excl. those with stainless steel housing and with inlet and outlet tube bores with inside diameters <= 1,3 cm)
27	84213985	Equipment	Machinery and apparatus for filtering or purifying gases other than air (excl. isotope separators, those using a catalytic process, and those with stainless steel housing and with inlet and outlet tube bores with inside diameters <= 1,3 cm)
28	84219910	Equipment	Parts of machinery and apparatus of subheadings 84212920 or 84213915, n.e.s.
29	84219990	Equipment	Parts of machinery and apparatus for filtering or purifying liquids or gases, n.e.s.
30	84861000	Equipment	Machines and apparatus for the manufacture of boules or wafers
31	84862000	Equipment	Machines and apparatus for the manufacture of semiconductor devices or of electronic integrated circuits

#	CN 2021	Segment	Product description
32	84863000	Equipment	Machines and apparatus for the manufacture of flat panel displays
33	84864000	Equipment	Machines and apparatus specified in Note 9 C to chapter 84
34	84869000	Equipment	Parts and accessories for machines and apparatus of a kind used solely or principally for the manufacture of semiconductor boules or wafers, semiconductor devices, electronic integrated circuits or flat panel displays, and for machines and apparatus specified in note 9 C to chapter 84, n.e.s.
35	85235110	Final product	Solid-state, non-volatile data storage devices for recording data from an external source [flash memory cards or flash electronic storage cards], unrecorded
36	85235190	Final product	Solid-state, non-volatile data storage devices [flash memory cards or flash electronic storage cards], recorded
37	85235200	Final product	Cards incorporating one or more electronic integrated circuits "smart cards"
38	85235910	Final product	Semiconductor media, unrecorded, for the recording of sound or of other phenomena (excl. solid-state non-volatile data storage devices and smart cards)
39	85235990	Final product	Semiconductor media, recorded (excl. solid-state non-volatile data storage devices and smart cards)
40	85329000	Final product	Parts of electrical "pre-set" capacitors, fixed, variable or adjustable, n.e.s.
41	85411000	Final product	Diodes (excl. photosensitive or light emitting diodes "LED")
42	85412900	Final product	Transistors with a dissipation rate >= 1 W (excl. photosensitive transistors)
43	85414010	Final product	Light-emitting diodes, incl. laser diodes
44	85414090	Final product	Photosensitive semiconductor devices, incl. photovoltaic cells
45	85416000	Final product	Mounted piezoelectric crystals
46	85423111	Final product	Electronic multi-component integrated circuits "MCOs" as processors and controllers as specified in note 12 (b) (4) to chapter 85, whether or not combined with memories, converters, logic circuits, amplifiers, clock and timing circuits, or other circuits
47	85423119	Final product	Electronic integrated circuits as processors and controllers, whether or not combined with memories, converters, logic circuits, amplifiers, clock and timing circuits, or other circuits in the form of multichip integrated circuits consisting of two or more interconnected monolithic integrated circuits as specified in note 12 (b) (3) to chapter 85

#	CN 2021	Segment	Product description
48	85423190	Final product	Electronic integrated circuits as processors and controllers, whether or not combined with memories, converters, logic circuits, amplifiers, clock and timing circuits, or other circuits (excl. in the form of multichip or multi-component integrated circuits)
49	85423211	Final product	Electronic multi-component integrated circuits "MCOs" as memories as specified in note 12 (b) (4) to chapter 85
50	85423219	Final product	Electronic integrated circuits as memories in the form of multichip integrated circuits consisting of two or more interconnected monolithic integrated circuits as specified in note 12 (b) (3) to chapter 85
51	85423231	Final product	Electronic integrated circuits as dynamic random-access memories "D-RAMs", with a storage capacity of <= 512 Mbit (excl. in the form of multichip or multi-component integrated circuits)
52	85423239	Final product	Electronic integrated circuits as dynamic random-access memories "D-RAMs", with a storage capacity of > 512 Mbit (excl. in the form of multichip or multi-component integrated circuits)
53	85423245	Final product	Electronic integrated circuits as static random access memories "static RAMs", incl. cache random-access memories "cache-RAMs" (excl. in the form of multichip or multi-component integrated circuits)
54	85423255	Final product	Electronic integrated circuits as UV erasable, programmable read-only memories "EPROMs" (excl. in the form of multichip or multi-component integrated circuits)
55	85423261	Final product	Electronic integrated circuits as electrically erasable, programmable read-only memories "flash E^2PROMs", with a storage capacity of <= 512 Mbit (excl. in the form of multichip or multi-component integrated circuits)
56	85423269	Final product	Electronic integrated circuits as electrically erasable, programmable read-only memories "flash E^2PROMs", with a storage capacity of > 512 Mbit (excl. in the form of multichip or multi-component integrated circuits)
57	85423275	Final product	Electronic integrated circuits as electrically erasable, programmable read-only memories "E2PROMs" (excl. flash E^2PROMs and in the form of multichip or multi-component integrated circuits)
58	85423290	Final product	Memories in multicombinational forms such as stack D-RAMs and modules (excl. in the form of multichip or multi-component integrated circuits, and D-RAMs, S-Rams, cache-RAMs, EPROMs and flash E^2PROMs)
59	85423310	Final product	Electronic multi-component integrated circuits "MCOs" as amplifiers as specified in note 12 (b) (4) to chapter 85
60	85423390	Final product	Electronic integrated circuits as amplifiers (excl. multi-component integrated circuits)
61	85423911	Final product	Electronic multi-component integrated circuits "MCOs" as specified in note 12 (b) (4) to chapter 85 (excl. such as processors, controllers, memories and amplifiers)
62	85423919	Final product	Electronic integrated circuits in the form of multichip integrated circuits consisting of two or more interconnected monolithic integrated circuits as specified in note 12 (b) (3) to chapter 85 (excl. such as processors, controllers, memories and amplifiers)
63	85423990	Final product	Electronic integrated circuits (excl. in the form of multichip or multi-component integrated circuits and such as processors, controllers, memories and amplifiers)
64	85429000	Final product	Parts of electronic integrated circuits, n.e.s.

#	CN 2021	Segment	Product description
65	90012000	Foundry inputs	Sheets and plates of polarising material
66	90019000	Foundry inputs	Lenses, prisms, mirrors and other optical elements, of any material, unmounted (excl. such elements of glass not optically worked, contact lenses and spectacle lenses)
67	90021900	Foundry inputs	Objective lenses (excl. for cameras, projectors or photographic enlargers or reducers)
68	90022000	Foundry inputs	Filters, optical, being parts of or fittings for instruments, apparatus and appliances, framed or mounted
69	90029000	Foundry inputs	Lenses, prisms, mirrors and other optical elements, mounted, of any material, being parts of or fittings for instruments or apparatus (excl. objective lenses for cameras, projectors or photographic enlargers or reducers, such elements of glass not optically worked, and filters)
70	90121000	Foundry inputs	Electron microscopes, proton microscopes and diffraction apparatus
71	90129000	Foundry inputs	Parts and accessories for electron microscopes, proton microscopes and diffraction apparatus, n.e.s.
72	90308200	Equipment	Instruments and apparatus for measuring or checking semiconductor wafers or devices
73	90308400	Equipment	Instruments and apparatus for measuring or checking electrical quantities, with recording device (excl. appliances specially designed for telecommunications, multimeters, oscilloscopes and oscillographs, and apparatus for measuring or checking semiconductor wafers or devices)
74	90314100	Foundry inputs	Optical instruments and appliances for inspecting semiconductor wafers or devices or for inspecting photomasks or reticles used in manufacturing semiconductor devices

Science for policy

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