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An enhanced methodology to monitor the EU's strategic dependencies and vulnerabilities

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The opinions expressed in this paper are the authors' alone and cannot be attributed to the European Commission.

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An enhanced methodology to monitor the EU's strategic dependencies and vulnerabilities

Román Arjona, William Connell and Cristina Herghelegiu[1 2 3]

Abstract

This article develops an enhanced bottom-up and data-driven methodology to detect EU strategic dependencies using highly disaggregated product-level trade data. It identifies 204 products in sensitive industrial ecosystems where the EU experiences an important level of foreign dependencies. A subset of these products are then identified as particularly problematic given that their world trade networks can experience Single Point of Failures (SPOF). Since dependent products bear important risks in the event of unexpected disruptions, identifying them is the first step towards building resilience. Consequently, this analysis provides evidence based solutions to the EU's open strategic autonomy agenda, including the efforts to diversify EU supply chains, to pursue partnerships with like-minded partners, and to strengthen the EU's internal industrial capacity.

Keywords: dependencies, supply chain disruptions, single points of failure, substitutability, trade networks, early warning.

JEL classification: L52, L60, F14, F61

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[1] **The opinions expressed are those of the authors only and should not be considered as representative of the European Commission's official position.**

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1. Introduction

Over the past decades, the EU has faced increasingly complex challenges in the social, environmental and economic spheres such as climate change, the ageing of its population, and a massive ongoing digitisation. While it is clear that some of these challenges can create several opportunities,[4] they also exercised some pressures on Europe's economy, industry and society. Moreover, these threats have been exacerbated over the recent past with the impact of an open-ended "permacrisis"[5] or "age of disorder",[6] characterised by continuous disruptions and persistent high degrees of uncertainty (European Commission, 2022b). Indeed, the previous challenges are magnified through the reinforcing effects of global events such as the COVID-19 pandemic, the Russian aggression of Ukraine, and the energy crisis. Consequently, a great share of contemporary disruptions risk having medium-term consequences in the form of increasing geopolitical tensions, including those linked to the scarce availability of energy sources and raw materials, as well as an underpinning and deep redefinition of the architecture and dynamics of global supply chains.

Some interrelated factors can simultaneously affect the world map of strategic dependencies and the ongoing reshape of global value chains in the long run. First, over the last decades, there has been a continuous process of de-industrialization that led to a loss of manufacturing capacity in the EU and other high-income economies, particularly for industries based on cost competitiveness and with low productive investments (Vu et al., 2021). Second, the ongoing "shoring" practices, with firms increasingly taking different strategies when it comes to localisation decisions, are driven by updated parameters. Among others, these parameters include the intensity of supply chain distress, the availability of raw materials, the probability of being hit by a logistics crunch, the availability of skills, R&D investments, and the generosity of the business environment (Fernández-Miguel et al., 2022; Alguacil et al., 2023). Third, a progressive shift in dependencies occurs as a result of the current energy transition. In this regard, the EU is moving away from fossil fuels, for which Eastern Europe has traditionally been a key EU provider, into raw materials, where EU demand has conventionally been met by supply from foreign markets.[7] In this respect, the International Energy Agency (IEA) (2021) forecasts an insufficient raw material supply to cover global demand in inputs such as cobalt, which is essential to develop batteries. Another example are permanent magnets, where China dominates global supply chains, from mining and refinement

[4] For example, in order to suppo the opportunities from digitalisation the Digital Decade Policy Programme 2030 was adopted, with objectives and targets in the area of skills and infrastructure, the digitalisation of businesses, online public services and EU's digital rights and principles. See https://eur-lex.europa.eu/eli/dec/2022/2481/oj.

[5] See statement of Thierry Breton, EU Commissioner for the Internal Market, 19 September 2022, Brussels: https://ec.europa.eu/commission/presscorner/detail/en/STATEMENT_22_5651

[6] Forthcoming book by Alex Stubb, former Finnish Prime Minister and Director of the School of Transnational Governance at the European University Institute.

[7] https://ec.europa.eu/commission/presscorner/detail/en/STATEMENT_22_5523

through to production (Gauß et al., 2021), which are critical for the production of e-vehicles and wind turbines.

Fourth, wide-ranging supply chain disruptions are inducing important changes in the structure of supply chains. Indeed, the EU benefits from an open and integrated participation in global value chains in terms of efficiency and resilience (Camarero et al., 2023), and this is particularly the case in years without disruptive events. However, recent developments revealed how supply distress, initially confined to the health ecosystem (e.g. personal protective equipment), later expanded onto most other ecosystems (e.g. electronics, mobility, renewable energy, construction, energy intensive industries) have affected global supply chains. Supply challenges, from energy products (e.g. gas), basic raw materials (e.g. magnesium) to high-tech products (e.g. semiconductors), risk delaying the EU's economic recovery and slowing down our pursuit of the twin transitions (green and digital). Such supply distress gets amplified by supply chain concentration, increases in global demand driven by structural shifts, logistics crunches or trade policy restrictions (Benoît et al., 2022; Amaral et al., 2022).[8] Fifth, skills mismatches, including labour shortages, arise as a key factor that limits industrial production, together with insufficient demand and material constraints (Kiss et al., 2022). Given that this factor is particularly worrisome in some country-sectors, it can have an impact on global supply chains if some of these shortages are not corrected.

It is against this backdrop that the EU is pursuing a new approach to industrial policy underpinned by the concept of "open strategic autonomy", which rests on two goals. The first one is the relevance of the EU as a geographical area open to international trade based on stable rules. Indeed, access to international trade and international supply chains have proven most effective in promoting the productivity of European firms (Shu and Steinwender, 2019), their innovation (Akcigit and Melitz, 2021; European Commission, 2022b), and resilience (Baldwin and Freeman, 2021). The second objective is to create internal domestic capacity there where needed, and notably in strategic areas such as in health related products, batteries, hydrogen, electronic chips or raw materials. In this respect, similar strategies have also been adopted by the EU's main trading partners.[9]

Based on these two objectives, the EU published its updated industrial strategy in 2021, European Commission (2021a), with a focus on curbing the EU's strategic dependencies where the EU faces excessive reliance on foreign sources combined

[8] Benoît et al. (2022) show that during the COVID-19 pandemic, concentrated global supply chains and structural global demand shifts were an important driver of import price pressures. More precisely, the most important price increases occurred for: (1) products that combine a strong reliance on foreign imports with a particularly high import concentration and (2) products experiencing a higher structural demand prior to the COVID-19 shock. In addition, Amaral et al. (2022) combined dynamic indicators on the evolution of import prices and quantities useful to alert policy makers on ongoing supply chain disruptions, with the concept of structural dependencies allowing to identify ex-ante risks of disruptions.

[9] For the US, see Executive Order on America's Supply Chains of 24 February 2021 and dedicated follow up reports (https://www.whitehouse.gov/wp-content/uploads/2022/02/Capstone-Report-Biden.pdf), as well as US Inflation Reduction Act (https://www.whitehouse.gov/cleanenergy/inflation-reduction-act-guidebook/).

with limited domestic production capacity, through a better understanding of both technological and industrial vulnerabilities.

Recent developments, including the COVID-19 pandemic, the Russian war of aggression against Ukraine and the energy price hike have reinforced the political objective of the EU to roll out its open strategic autonomy agenda to avoid risks associated with the "non-availability" of critical intermediate and final products. The European Chips Act,[10] the Single Market Emergency Instrument (SMEI)[11] and the European Critical Raw Materials Act, the latter announced by the European Commission President in her State of the Union speech of September 2022,[12] are clear steps in that direction. Given the rapidly evolving political and policy backdrop, it appears more relevant than ever before to regularly revisit and enhance the methodology introduced by the European Commission (2021b) to monitor and anticipate strategic dependencies in sensitive industrial ecosystems.

2. An overview of empirical analyses to detect strategic dependencies

Previous empirical analyses that detected strategic dependencies rest on five main types of methodological approaches.

The first type of empirical analyses focuses on the aggregate sectoral level and finds mostly EU dependencies in industrial ecosystems such as electronics or energy intensive industries. Relying on databases linking country-sector pairs in global supply chains, Dachs et al. (2022) investigate the strategic position of the EU27 in global value chains and production networks and find that the EU industrial ecosystems that show high dependencies on Chinese electronics include energy intensive industries, aerospace and defence. They also detect dependencies on energy intensive industries vis-à-vis Russia, and energy intensive industries and retail from the US.

The second category of analyses uses product level data capturing global trade flows and it offers the advantage of using higher data granularity in order to detect specific world-level vulnerabilities. In other words, these work strands aim at measuring risks in global supply chains by detecting potential global "single points of failures" (SPOFs), which are nodes in the global trade system that, due to their centrality and weight, can have a major impact on supply chains and even put a halt on their

[10] Proposal for a Regulation of the European Parliament and of the Council establishing a framework of measures for strengthening Europe's semiconductor ecosystem (Chips Act), COM/2022/46 final: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex:52022PC0046

[11] The Commission proposed to create a new Single Market Emergency Instrument (SMEI) which is a crisis governance framework that aims to preserve the free movement of goods, services and persons and the availability of essential goods and services in the event of future emergencies, to the benefit of citizens and businesses across the EU. (See https://ec.europa.eu/commission/presscorner/detail/en/ip_22_5443 for more details).

[12] https://ec.europa.eu/commission/presscorner/detail/en/speech_22_5493

operations. For example, Korniyenko et al. (2017) developed a methodology, based on indicators on global players that allowed them to determine products characterised by “choke points” in global trade networks. The authors conclude that most of these products fall under broad categories, such as machinery and mechanical appliances, transport equipment, pharmaceutical products, rubber articles and precision instruments. Reiter and Stehrer (2021) extended this analysis in order to compute a “product riskiness indicator” at global level. This was done by adding the Hirschmann-Herfindahl index (HHI) on world exports and an additional indicator identifying products targeted by non-tariff measures.

Third, while these studies aim at detecting vulnerable products or trade nodes at the world level, the trade portfolio of each country appears rather heterogeneous. This supports the need for targeted studies that concentrate on particular world regions. Three examples of such work follow. In the context of the COVID-19 pandemic, Bonneau and Nakaa (2020) examined French extra-EU dependencies by looking at the import concentration level and centrality in product-level trade networks. Using six-digit level Harmonized System (HS6) data, they reduced the number of product categories from around 5,000 to 12 products where vulnerabilities were particularly present in France. Furthermore, European Commission (2021b), as part of its updated industrial strategy in 2021, presented a methodology to identify EU’s strategic dependencies and vulnerabilities. They depart from highly disaggregated trade data and encompass 5,200 HS6 products. Building indicators and corresponding criteria that look at import concentration, relevance of extra EU imports, and the possibility to replace with internal capacity, the European Commission identified 137 products in sensitive industrial ecosystems for which the EU shows foreign dependencies. In addition, they reduced the list to 34 vulnerable products with low capacity for further diversification and substitution. Finally, in a similar spirit, Guinea and Sharma (2022) classified EU traded products into four groups according to the degree of import dependency, relying on the more granular 8-digit Combined Nomenclature classification of products (CN8).[13]

Fourth, while the previous types of empirical analyses use trade in goods, confidential firm level data can be used to expand the level of granularity. In this regard, Jaravel and Méjean (2021) added the firm level dimension by looking at the import concentration on a few foreign firms. Out of around 9000 CN8 product categories analysed, they concluded that 122 products were particularly vulnerable to production concentration in a few country-firm pairs. The most predominant origins of dependencies were found to be the US and China.

Finally, additional studies use targeted information to explore specific products, areas, technologies or services. For example, European Commission (2020) identified 30 raw materials as critical by evaluating over 80 individual raw materials

[13] Note that trade flows at CN8 level can only be done using the EU as a reference point.

with two criteria, namely, the economic importance and the supply risk. In addition, given the complexity of analysing dependencies in service technologies in a systematic manner, the European Commission (2021b, 2022a) assessed vulnerabilities using qualitative and quantitative information in areas of strategic importance such as cloud and edge computing, solar panel technologies, cybersecurity and IT software, clean hydrogen among others.

3. A refined methodology to detect and monitor strategic dependencies

Using the latest data developments, this article builds on the identification strategy proposed by the European Commission (2021b) and improves it by introducing a number of changes that permit to enrich the data-driven approach to identify the EU's foreign dependencies.

3.1 The European Commission's benchmark methodology

The methodology proposed by the European Commission (2021b) used the BACI database,[14] which covers global bilateral trade flows for 200 countries at the product level.[15] BACI is an optimal source of trade information at it reconciles global trade flows and it allows to compare values of imports and exports of each country. Three core dependency indicators (CDIs) were used to identify products with low level of import diversification, for which foreign sources were particularly relevant for the EU, and where the substitutability potential with EU supply was limited.

The first indicator (CDI_1) captures products with a low level of import diversification. CDI_1 thus targets products for which EU imports (in values) are highly concentrated in a few extra EU countries using the well-known Herfindahl-Hirschman Index (HHI):[16]

$$CDI_1 = \sum_{i=1}^{n} (s_i^2)$$

The second indicator (CDI_2) identifies how important foreign sources are for the EU being a proxy for EU scarcity. By measuring the importance of extra-EU imports in total EU imports (i.e. extra- and intra-EU imports), CDI_2 helps to detect products where foreign sources are particularly important for the EU:

[14] See Gaulier, G. and Zignago, S. (2010) for more details.
[15] The BACI database relies on raw data from the UN statistical Division (COMTRADE dataset).
[16] s_i represents the market share of the extra EU supplying country *i* in EU's imports, and *n* is the total number of extra EU supplying countries.

$$CDI_2 = \frac{extra\ EU\ import\ value}{total\ EU\ import\ value}$$

The third indicator (CDI_3) explores to what degree extra-EU imports can be substituted by EU production. Using EU total exports as a proxy for the internal production capacity, CDI_3 captures whether EU production can cover the extra EU import needs in the event of trade disruptions.

$$CDI_3 = \frac{extra\ EU\ import\ value^{EU}}{total\ export\ value^{EU}}$$

Then, the identification of specific foreign dependencies was based on the application of pre-defined thresholds on the three indicators described. Each of the 5200 HS6 traded goods was evaluated based on the described indicators, and products that satisfied pre-defined specific thresholds were selected. For CDI_1, the chosen threshold was 0.4, indicating that the EU import value originates mainly from 2.5 foreign countries. For CDI_2, the threshold of 0.5 was selected, indicating that the value of extra EU imports accounts for more than 50% of the total EU import value. Finally, for CDI_3, the threshold was 1, indicating that the value of extra EU imports is higher than the value of total EU exports, which includes intra and extra EU exports.

Applying the three indicators and their respective thresholds to the sample of trade flows in 2018, allowed to identify around 390 products across all ecosystems where the EU faced foreign dependencies. Out of these, 137 products were located in sensitive ecosystems, identified as those related to: (1) security and safety, (2) health and (3) the green and digital transformation.

These 137 products represented around 6% of the EU's total import value of goods from extra-EU sources in 2018, with China accounting for more than 52% of the total import value of dependent products, followed by Vietnam and Brazil. Moreover, the majority of the identified dependencies were intermediate goods. In terms of sectors, the majority of these foreign dependencies belong to raw/processed materials and chemicals, some of which are extremely important for the green transition, such as lithium, cobalt, nickel or manganese among others. Then, the methodology reduced further the list to 34 HS6 products by using the world concentration of exports and the absolute difference of EU import and EU export prices. These 34 products are characterised by a limited global potential for diversification and substitution.

3.2 The enhanced methodology in three steps

The analysis to identify EU foreign dependencies conducted by European Commission (2021b) in the context of the industrial strategy update was a first of its kind. However, there is now a need to enhance it in order to incorporate the latest data and developments in the methodology.

The *first step* in the enhanced methodology is the use of a more suitable dataset to control for product re-exports. Trade statistics record flows from an origin to a destination country for a specific HS6 product code, in values and volumes. There are however well-known “trade asymmetries” or mismatches between exports for a given origin-destination (country A to B) and imports of the mirror flow (country B from A). As previously mentioned, for this reason, the European Commission (2021b) used the BACI-CEPII database to identify EU foreign dependencies instead of relying on raw trade data such as COMTRADE. However, BACI also experiences some well-known limitations. In particular, there is a bias when identifying strategic dependencies if products get re-exported through different intermediate countries, before being imported to the final destination. This can affect the outcome of the dependencies analysis, as it can artificially reduce (or increase) dependency levels of some products. To circumvent this problem, we rely on the TRADE-FIGARO-EUROSTAT database that uses a methodology to identify trade flows categorised as re-exports (Ferreira, 2018; Remond-Tiedrez and Rueda-Cantuche, 2019).[17] The advantage of this database compared to BACI is that it permits to distinguish between products imported from a given location where the product is domestically produced and those destinations where the product goes in the form of transit.[18] However, despite its clear advantage, it has also a limitation compared to more regional trade databases (e.g. COMEXT), which contain more granular information on the traded products but do not include trade flows between third countries.[19]

The *second step* concerns the adoption of a dynamic perspective. In order to detect EU dependencies, the previous analysis relied on trade data from 2018. However, relying on a specific year risks hiding structural vulnerabilities that can be made more apparent over time. For this reason, this upgrade on the methodology will rely on a longer time window, namely 4 years.

[17] The FIGARO database is jointly compiled by Eurostat in collaboration with the European Commission’s Joint Research Centre and provides a consistent overview of national accounts with data on business, trade and jobs for EU Member States, 18 main EU trading partners and a rest of the world region. In this paper, we used the underlying (unpublished) version of a balanced view of trade in goods statistics, as described in Remond-Tiedrez and Rueda-Cantuche (2019, chapter 6), with thousands of products, for HS codes at 6 digit level and a correct treatment of re-exports combining UN Comtrade and EU Comext information.

[18] The treatment of re-exports is extensively performed for the EU and, to the extent possible, for other third countries. Given that there are some asymmetries in the treatment of re-exports across countries, the TRADE-FIGARO-EUROSTAT dataset is very well suited to study EU foreign dependencies and less suited to draw comparisons between the dependencies of the EU and those of third countries. To that end the BACI dataset, which ensures an even treatment of all countries, is more appropriate, even though it suffers from the drawback of not considering re-exports.

[19] While a high disaggregation (e.g. CN8 or TARIC 10 digits) would provide a much finer level of granularity, our analysis has to rely on HS6 product categories (HS 2017), for which total global trade flows are available.

The choice for a multi-year time frame is justified by the idea that while dependencies are normally structural in nature, they can vary as a result of multiple factors, which includes trade instruments, domestic subsidies or supply chain disruptions. For example, in a specific year, a trade measure on a product-origin pair could artificially affect the observed number of dependencies.

The analysis is thus performed individually on each of the four years considered and, to give higher informative value to the most updated information, a product is considered as foreign dependent if it is identified in the list of dependencies in: (1) 2020 (the most recent data point), and/or (2) two out the three years prior to 2020 (e.g. 2019 and 2017, 2018 and 2017).

The *third step* relates to the complementary use of two methods to identify foreign dependencies. The benchmark methodology used specific thresholds to identify dependent products. Their economic rationale is explained in European Commission (2021b) and in the previous sub-section. It has the main benefit of simplicity but it is affected by the arbitrary choice of thresholds. For this reason, we complement the threshold approach with an analysis using the whole distribution of the dependency indicators. Notably, the article uses the three indicators described in the benchmark methodology $(CDI_1, CDI_2, \text{and } CDI_3)$ in order to identify products that are "highly concentrated", "significantly imported" and "low substitutable". As in the benchmark methodology, we apply the pre-defined specific thresholds defined in the previous sub-section to each of the indicators. We then use a complementary approach, which relies on the top 10% products in the aggregate level of dependency, drawing on the ranks of all three described indicators.

More precisely, each of the three indicators is ranked based on their dependency risk, with the highest risk identified with the highest rank.[20] To obtain an overall dependency indicator, we aggregate the individual ranks of each indicator by using a simple average. Then, the most dependent products are those situated in the top 10% products in terms of aggregated rank, indicating a higher risk of dependency. EU dependencies are then identified for products that satisfy both approaches, namely, the "threshold" and the "rank".

Each of these three developments will affect the benchmark analysis carried out by the European Commission (2021b) in a different manner. The first enhancement related to the treatment of re-exports can either increase or decrease the number of dependencies on foreign sources. When it comes to the concentration of extra-EU imports, the bias induced by not treating re-exports can be two-fold. First, if a product is imported by the EU through different intermediate countries, despite the ultimate origin being the same, the concentration observed on EU imports can be artificially

[20] For the concentration indicator, products with the highest concentration levels are given a high rank. In second indicator, products where non-EU imports account for the highest share are identified as having the highest risk. Finally, for the third indicator, products where the EU exports account for a lower share of extra-EU imports are considered as experiencing higher risks and get assigned higher ranks.

underestimated. Second, if a product is imported by the EU from a single intermediate country, despite multiple sources being at the origin of the product in question, the concentration observed on EU imports can be artificially overestimated. Furthermore, treating re-exports is also important when computing the indicators referring to EU scarcity and production capacity. More precisely, if re-exports are not taken into account total EU imports and exports are overestimated. This would lead to an underestimation of the EU scarcity and an overestimation of the EU production capacity (proxied through total EU exports). To sum up, not treating re-exports would create a bias in the identification of EU foreign dependencies.[21]

The *second step* is also expected to increase the number of identified dependencies as we are expanding the time frame by taking into account the 2017-2020 period. The expansion of the time window under analysis leads to the identification of a higher number of dependencies, which will be then restricted by taking into account the more structural dependencies besides the most updated information. Finally, the *third and last step* is expected to decrease the number of identified dependencies as we are adding a new condition for the classification of foreign dependencies, which is based on the distribution of the overall level of dependency on top of economic thresholds.

4. Results

As a result of the three previous upgrades, out of approximately 5,400 HS6 products,[22] 564 are identified as those satisfying the above mentioned criteria.[23] They represent around 13% of total extra-EU imports, approximately 19% belong to “Chemicals and allied industries”, almost 17% to “Textiles”, 9% to “Animal products”, almost 8% to “Vegetable products” and 7% to “Mechanical appliances and electrical equipment”. As regards to the origin of these dependencies, China is the first source providing 211 products, which represent more than half of the import value of all dependent goods. The US is the second source with 62 products and 8% in terms of import values. Other important countries in terms of import value include Vietnam (6%), UK (3%), Norway (3%) and Russia (2%).

Next, as in the original methodology, we focus on products within critical ecosystems. In particular, we concentrate on HS6 products relevant for areas such as security and

[21] When replicating the European Commission (2021b) exercise based on the TRADE-FIGARO-EUROSTAT database, which takes into account re-exports, the number of EU foreign dependent products increases by approximately 27% compared with the benchmark exercise based on the BACI dataset, which identified 388 EU dependent products in all ecosystems. This suggests that, in the case of the EU, not considering re-exports leads to an underestimation of EU dependencies.

[22] The enhanced methodology exploits 5,400 HS6 products in the HS2017 classification. The benchmark methodology in European Commission (2021b) used the 5,200 HS6 products in the HS2012 classification.

[23] Slightly less than 50% of the 564 foreign dependencies are very persistent/structural, as they are identified in all years over the 2017-2020 period.

safety, health, and the green and digital transitions. As a result, 360 out of the 564 HS6 product categories were disregarded.[24] [25] [26] [27]

Following the previous steps, we obtain 204 HS6 product categories characterised as foreign dependent in strategic ecosystems.[28] Within the energy intensive industries, the list of dependent products cover raw materials, which are used as inputs across other industrial ecosystems. This includes manganese, nickel, aluminium, chromium, rare earth metals, molybdenum, borates, uranium, silicon, permanent magnets.[29] In addition, we also find dependencies in traditional energy inputs such as coal or petroleum coke and gases. Within the health ecosystem, we find products such as heterocyclic compounds, some medicines, vitamins, alkaloids, iodine, amino-acids, medical instruments (e.g. scintigraphic apparatus, mechano-therapy or orthopaedic appliances), as well as COVID-19 related goods such as surgical gloves or protective garments.[30]

Among goods within the renewable ecosystem, foreign dependencies include raw materials that are heavily used in this context and final products such as photovoltaic cells or LED lamps.[31] Within the digital ecosystem, we observe products such as laptops, mobile phones, monitors or projectors.[32] Among the products with defence applications, we identify products such as navigational instruments for aeronautical and space navigation, rough movement watches, inflatable rafts, radio broadcast receivers or electric generators. This ecosystem also includes more rudimentary inputs such as camping equipment, which can be particularly useful in catastrophic events or in terms of foreign aid.

Finally, while the agri-food ecosystem was left out of the analysis, some agri-related products can have a direct impact on the safety of European citizens. For this reason, we decided to keep those products used as important inputs in the

[24] While the agri-food ecosystem is strategic in nature, we consider individual products as non-strategic due to their substitutability potential. Within this ecosystem, products disregarded include different types of fishes, different parts of sheep, crustaceans, molluscs, nuts, fruits, spices, exotic vegetables such as manioc and sweet potatoes or whiskies.

[25] Among the HS6 product categories within textiles, we disregarded the following products: tanned and crust skins/hides, artificial fur, silk and silk products, different types of cotton yarn, fabrics made of woven, yarn, carpets, type of footwear, toilet and kitchen linen or small cases made of different materials among others.

[26] Among HS6 product categories related to construction, we disregarded types of (tropical) wood, various products made of bamboo, ceramic statuettes or products within the ceramic ecosystem such as feldspar or leucite.

[27] Other products include Christmas lights, umbrellas, sets of cutlery, hair dryers, music boxes, cooking appliances, weighing machines, photographic cameras, different types of design wrist-watches (non-defense related), sport's equipment (e.g. skates, tennis balls, athletics and gymnastics equipment, water sport equipment among others).

[28] While each of these products has applications in strategic ecosystems, assessing their level of strategic importance is beyond the scope of this data-driven exercise.

[29] Comprehensive exercises allow to have a comparison of dependent products across the whole economy. However, some targeted exercises can be potentially better equipped to capture the specificities of some sectors. In the case of raw materials, the European Commission conducted a more targeted exercise to identify a list of critical raw materials by looking at their economic importance and supply risk (https://single-market-economy.ec.europa.eu/sectors/raw-materials/areas-specific-interest/critical-raw-materials_en). Despite the methodological differences driven by different objectives, our comprehensive exercise also identifies more than half of the products included in the list of critical raw materials.

[30] The most updated trade data goes back to 2020. As a result of the EU industrial actions resulting from COVID-19 pandemic, some of the identified dependencies in COVID-19 related goods could have been reduced.

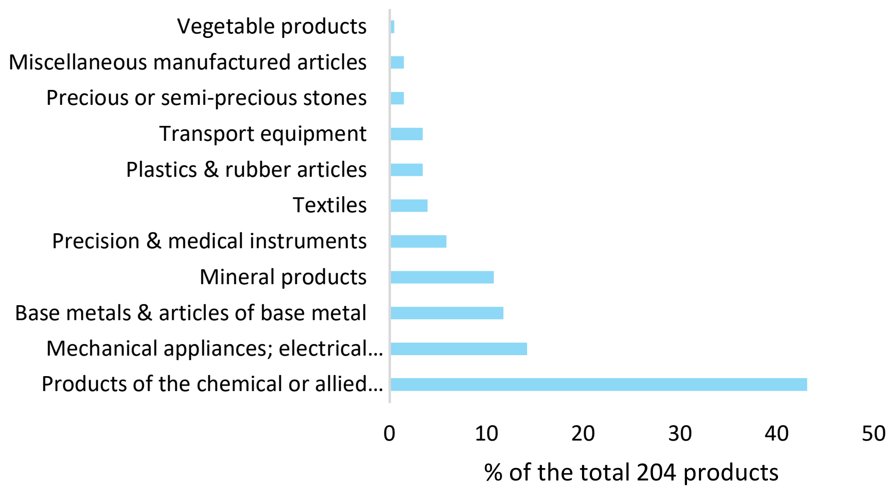
[31] Soya beans are also included in this category of products given their role in the production of biodiesel. See Soybeans for Biodiesel Production – Farm Energy (extension.org) for more details.

[32] Video games are kept in the list of products due to the vast "productive" applications of the attached human capital (transferable skills), as some of these applications might be being critical inputs across different ecosystems.

production of food. In this group, we identify a number of fertilizers, as well as critical inputs in farming and fishing with examples such as soya beans or fishing rods.

The 204 products get then distributed according to their geographical origin of dependency and the specific sector (i.e. HS section) they belong to taking into account that these products represent around 9.2% of total extra-EU imports. Approximately 43% belong to "Chemicals and allied industries", around 14% to "Mechanical Appliances and electrical equipment", almost 12% to "Base metals and its articles", 11% to "Mineral products" and 6% to "Precision and medical instruments" (see Figure 1).

Figure 1: Distribution of 204 dependent products across trade sections (%)



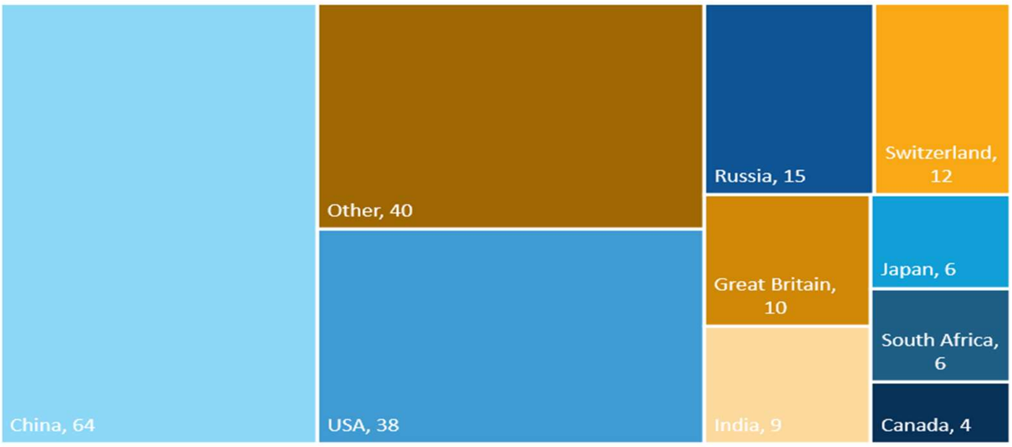
Source: GROW Chief Economist team' calculations based on the database - Trade-Figaro-Eurostat.

In terms of the origin of these dependencies, China is the first source for approximately 31% of all 204 products (i.e. 64 goods), accounting for more than half of the value of these products.[33] The US represents the main source for almost 19% of the 204 dependent products in sensitive ecosystems (i.e. 38 products) and amounts to 9% of the import value. Russia accounts for 7% of the 204 products (i.e. 15 goods) and 3% in terms of import value (see Figure 2 and Figure 3).[34]

[33] For simplicity of illustration, Figure 2 distributes products based on the main source of EU imports. However, second origins can be particularly important in some cases. Note that all origins are entirely accounted for in Figure 3, which considers the value of imports.

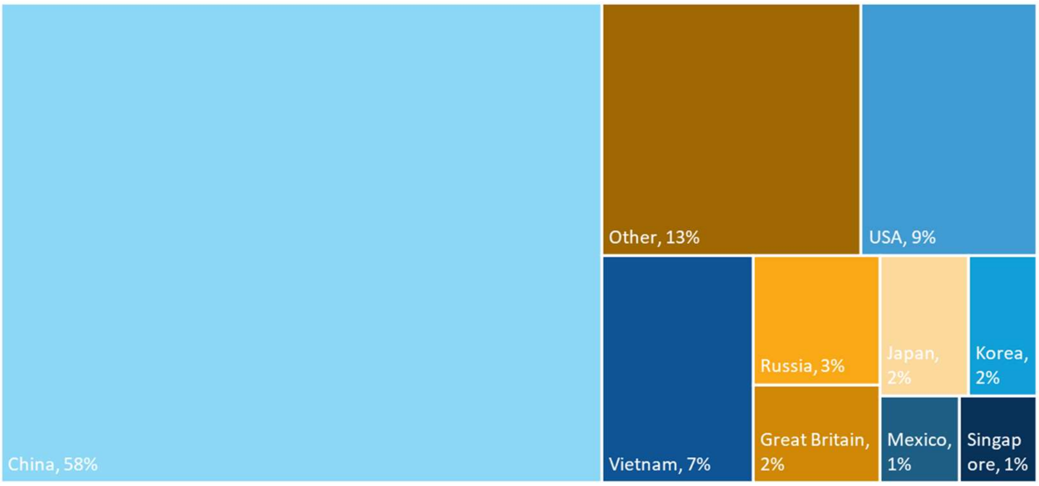
[34] In the analysis of the European Commission (2021b), China represented around 52% of the total value of imports of the most foreign dependent products, which is broadly consistent with our new results. However, the other two main sources are different. While the current study points to the US and Russia as main sources of dependencies after China, the previous study highlighted Vietnam and Brazil.

Figure 2: Distribution of 204 dependent products across origins (number of products)



Source: GROW Chief Economist team' calculations based on the database - Trade-Figaro-Eurostat.

Figure 3: Distribution of 204 dependent products across origins (% value of total imports)



Source: GROW Chief Economist team' calculations based on the database - Trade-Figaro-Eurostat.

5. Introducing the concept of global single points of failures (SPOFs)

The list of EU dependencies in strategic ecosystems can be complemented with the characteristics of the global network for each of the 204 identified products. This will allow to detect those goods whose production is highly concentrated at a world level, and which can be considered as highly vulnerable in case of supply chain disruptions. To address this concern, previous economic literature has pointed to the need to identify global SPOFs when analysing the risk of global disruptions. The trade data used in this analysis contains a level of disaggregation (i.e. HS6 product categories) which makes it possible to analyse global trade flows, including exchanges between non-EU countries. Hence, it is possible to assess the risk of SPOFs by targeting products with two features: (1) a central node in world trade networks, and (2) high concentration of world exports. To do so, two indicators have to be defined.

First, to assess the ex-ante risk of experiencing a SPOF for a particular product, we use an indicator, which is widely exploited in network analysis, in order to capture the risk of centrality.[35] It allows to identify situations where an exporter is central to a large number of countries in a trade network on the assumption that it might be problematic to global trade if there is a trade disruption that affects a central node in the trade network. The higher the value of this indicator, the higher the risk of centrality.

Second, a certain number of identified dependencies can be considered as more vulnerable given their risk of experiencing excessive production concentration in a given country. To evaluate this risk, we define a measure for concentration of world exports using the HHI index and relying on the total export flows of each country for a given product. A high level of concentration of world exports for a given product can indicate that its production is more likely to be concentrated in a single country, generating negative spillover effects across the globe in case of a supply shock.

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[35] Based on Korniyenko et al. (2017) and Reiter and Stehrer (2021), the indicator computes the standard deviation of the weighted outdegree centrality of each product and measures the risk of centrality in a network or, in other words, the presence of weighty central players, which might create risk in case of a trade disruption. A measure of outdegree centrality is obtained first as the sum of ties that a country directs outwards, to other countries, as a share of the total number of other countries. This measure is weighted to take into account the value of the trade flows. In formal terms, the weighted centrality of each country and for each product network is as follows:

$$C_{ik}^{out} = \sum_{j=1}^{n-1} \frac{w_{ijk}}{\overline{w_{jk}}}$$

where C_{ik}^{out} is the weighted outdegree centrality of country *i* in product *k*, *n* is the total number of countries in the trade network, w_{ij} is the value of the exports of country *i* to country *j* in product *k*, and $\overline{w_{jk}}$ is the average value of j's imports for each product *k*. Next, we use the standard deviation of outdegree centrality to measure the risk of each product, which arises from having very few central exporters.

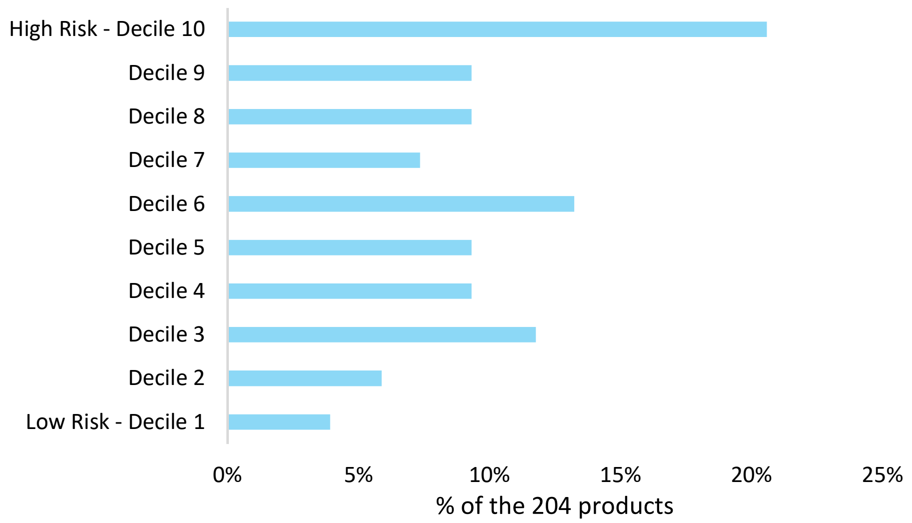
$$C_k^{out} = \sqrt{\frac{\sum_{i=1}^{n-1}\left(C_{ik}^{out} - \overline{C_k^{out}}\right)^2}{n-1}}$$

where $\overline{C_k^{out}}$ is the average centrality of countries for product *k*.

The calculated risk of global SPOF is obtained by combining these two indicators. First, we obtain the rank for each individual product and each of the two indicators. Second, we combine these ranks into a single average rank, which determines the level of risk of SPOF. Finally, we group products into deciles (i.e. 10 groups) based on the aggregate risk of SPOF.[36]

Products with the highest aggregate risk of SPOF are situated in the upper decile (i.e. decile 10) of all HS6 products, while products with the lowest risk of SPOF are in the lowest deciles. Figure 4 shows that out of the 204 dependent products around 19% are in the category of the highest risk of global SPOF, whereas only 6% are in the category of the lowest risk. Within the highest risk, we find products across different industrial ecosystems, including health (antibiotics, vitamins, medical apparatus and COVID-19 goods), digital (laptops and parts, radio-broadcast receivers or mobile phones), or renewables (LED lights or part of cycles). Risks of SPOF are also detected in humanitarian emergency-related goods such as tents or travelling blankets.

Figure 4: Distribution of the 204 products according to the risk of global SPOF



Source: GROW Chief Economist team' calculations based on the database - Trade-Figaro-Eurostat.

[36] The aggregate risk of SPOF is a relative concept, where each traded product is compared with all the others, with the objective of identifying different levels of risk.

6. Conclusion

Against the backdrop of the effects stemming from the “permacrisis” dynamics, triggered by events such as the COVID pandemics, the Russian aggression of Ukraine, and the energy crisis, this article provides an enhanced methodology in support of an improved understanding and monitoring of EU strategic dependencies, drawing on European Commission (2021b).

Enhancing this monitoring capacity is particularly timely given the ongoing process of redefinition of the architecture and dynamics of global supply chains influenced by the ongoing de-industrialization in the EU and other high-income economies, the emergence of updated shoring practices, a progressive shift in dependencies from fossil fuels into raw materials, disruptions in global supply chains, as well as skills mismatches and labour shortages.

The article proposes an enhanced methodology that uses the latest disaggregated data at product level to identify 204 products in sensitive industrial ecosystems where the EU faces foreign dependencies. We detect that around 70% of the products identified by European Commission (2021b) are present in the results from this enhanced methodology, suggesting that factors such as the EU economic and industrial structure, as well as historical trade relations underlie these dependencies.

Two findings derive from this exercise. First, mapping vulnerabilities across EU supply chains, including the risks of non-availability of critical goods, can prove valuable to develop early warning systems to monitor supply chain distress. The enhanced methodology permits to differentiate between products with potential for diversification (i.e. low risk of single points of failure or SPOFs) and those where further trade diversification might be limited (i.e. high risk of SPOF). It thus helps to detect ex-ante vulnerabilities stemming from structural dependencies associated with higher risks of supply distress.

Finally, the methodology allows to identify products for which substitutability can only happen through the increase of the EU’s internal capacity. As previously shown, some of the detected and persistent EU dependencies experience high risk of SPOFs at a global scale. Consequently, disruptions in these products are particularly prone to bear an impact on the EU’s resilience, resulting in non-availability in the event of idiosyncratic shocks. The development of internal EU capacity around those products (e.g. within the electronics ecosystem), including through strong investments and R&D deployment, can contribute to increase substitutability. Policy initiatives such as the European Chips Act, the Single Market Emergency Instrument (SMEI) or the European Critical Raw Materials Act are all steps in that direction.

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