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EXternal Vulnerability Index (EXVI)

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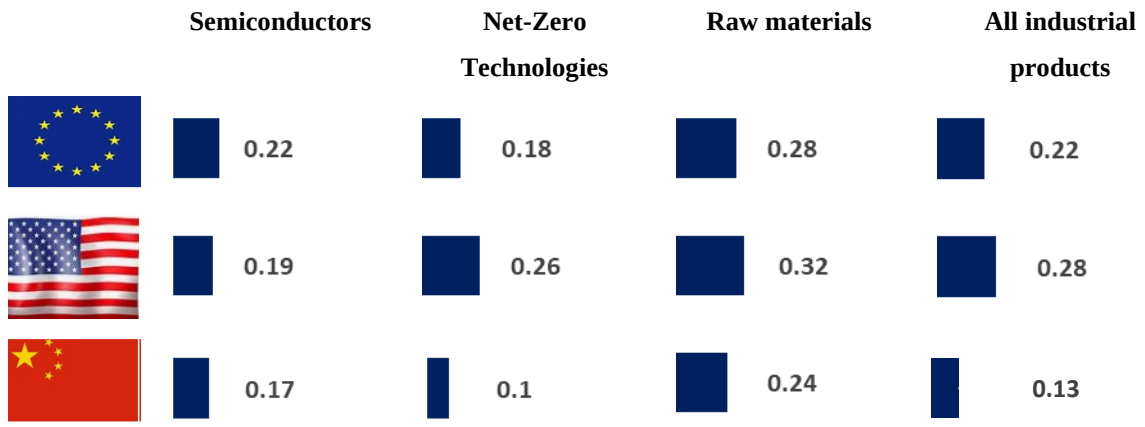
Summary of the External Vulnerability Index

In today's global economy, understanding EU supply chains is crucial for informing policies that enhance economic efficiency and resilience. As one of the most open regions, the EU benefits from global market access and well-integrated supply chains but also faces vulnerabilities that impact industries and aggregate economies, as seen with the COVID-19 pandemic, the energy crisis, and rising geopolitical tensions. A data-driven approach to identify vulnerabilities is essential to support an effective monitoring of EU supply chains over time. By tracking vulnerabilities, policymakers can develop timely, agile and responsive strategies, and navigate the complexities of a rapidly changing global market.

This brief introduces the EXternal Vulnerability Index (EXVI), a monitoring tool that uses trade data to identify and measure external vulnerabilities across various segments of the EU economy. As a composite indicator, the EXVI evaluates the vulnerability of products, sectors, and economies within the global trade system, analysing trade dependencies and competitive positions, and quantifying economic exposure to external shocks. It draws on highly granular data (HS6 product codes) and is anchored on a simple scoring system that ranges from 0 (lowest vulnerability) to 1 (highest vulnerability). The EXVI provides a framework to monitor supply chain risks, enabling policymakers to make informed, targeted and timely decisions to strengthen resilience.

External Vulnerability Index (EXVI) across strategic supply chains: EU, China and United States



Note: EXVI scores: 0= low vulnerability, 1=high vulnerability;
Source: European Commission, based on the latest BACI database (2022).

Based on the latest BACI data,[1] the obtained EXVIs show that the EU is more exposed to external trade vulnerabilities than China, but less so than the United States. A closer examination of critical areas such as raw materials, semiconductors, and net-zero technologies reveals that the EU is most vulnerable in raw materials. Furthermore, the index shows that the EU is more vulnerable than China in all three supply chains, while being more vulnerable than the United States only in semiconductors.

[1] Gaulier, G. and Zignago, S. (2010) BACI: International Trade Database at the Product-Level. The 1994-2007 Version. CEPII Working Paper, N°2010-23.

1. Overview

Over the last decades, supply chains have gained significant attention from policymakers, academics and business leaders by their capacity to enhance efficiency. Indeed, the EU as a whole benefits from world markets being open and integrated in internal supply chains in terms of efficiency, risk reduction or access to foreign inputs.

However, recently, there have been growing concerns about supply chain vulnerabilities that have highlighted potential risks of disruptions that can significantly impact businesses and national economies. These vulnerabilities have been partly exposed by events such as the COVID-19 crisis, as well as the intensification of geopolitical tensions. These incidents have highlighted weak points in global supply chains, emphasising the need for enhanced resilience and adaptability. A data-driven approach aiming at identifying and monitoring EU vulnerabilities could be the starting point to ensure that weaknesses are addressed effectively, maintaining competitiveness in a dynamic global landscape.

The objective of this note is to propose a monitoring tool based on trade data that would allow to identify and measure external trade vulnerabilities. This monitoring tool should also enable comparisons over time and across the EU's major global trading partners, providing a dynamic perspective on evolving trends of foreign vulnerabilities. To this end, the EXternal Vulnerability Index (EXVI) has been developed.

The EXVI is a composite indicator developed to assess the external vulnerability of traded products within a region, spanning various sectors and supply chains. It quantifies economic vulnerabilities to external shocks by analysing a region's trade dependencies and trade competitive positions. High scores, with a maximum of 1, signal a high risk of foreign vulnerability, while low scores, with a minimum of 0, indicate a lower risk of external vulnerability.[2]

[2] Other papers looking at EU's foreign dependencies include:

Arjona, R., Connell, W. and Herghelegiu, C. (2023), "An enhanced methodology to monitor the EU's strategic dependencies and vulnerabilities", Single Market Economy Papers WP2023/14, Publications Office of the European Union.

Jaravel, X. and Méjean, I. (2021), "Quelle stratégie de résilience dans la mondialisation?", Notes du conseil d'analyse économique, 2021/4 (n° 64), p. 1-12.

Reiter, O., and Stehrer, R. (2021). "Learning from tumultuous times: An analysis of vulnerable sectors in international trade in the context of the COVID-19 health crisis". The Vienna Institute for International Economic Studies (wiiw), Research Report No. 454, July 2021.

The index is based on two key pillars:

1. *Risks related to foreign dependencies*. This examines the concentration of trade flows and the reliance of imports on foreign markets. The aim is to shed light on the potential risks and vulnerabilities associated with an economy's dependence on external trade.

2. *Risks related to a weak global market position*. It assesses an economy's position in global trade markets, through the lens of differences in prices and revealed comparative disadvantages. This pillar provides information on a region's economic strengths and weaknesses relative to the world.

Each pillar aims to measure the relative external vulnerability of each HS6 product category where the results can then be aggregated to higher levels of analysis, including supply chains, by using predefined baskets of products. Once again, a high score indicates a strong risk of dependency on foreign markets combined with a relatively weak competitive position in those markets. On the other hand, a low score indicates a low dependency on foreign markets combined with a relatively strong competitive position in those markets.

2. Conceptual framework using two economic pillars

Pillar 1: Risks related to foreign dependencies

The first pillar is composed of two indicators, which aim at measuring the concentration of trade flows and the degree to which a country relies on imports relative to its exports. By doing so, it provides insights into an economy's exposure to external risks, such as supply chain disruptions or the emergence of new trade barriers. Economies that rely excessively on foreign inputs, which at the same time are highly concentrated on a limited number of trading partners, are more vulnerable to external shocks.

The first indicator used in this pillar is the Herfindahl-Hirschman Index (HHI). This aims at measuring the level of diversification of imports by analysing the diversity of trade partners for the country's imports. A high HHI indicates a higher dependency on fewer countries, making the economy more vulnerable to external shocks.

The first indicator for country *i* and product *k* in year *t* is calculated as follows:

$$HHI_{i,t}^{k} = \sum_{j=1}^{N} s_{j,t}^{2} \qquad (1)$$

where $s_{j,t}^2$ is the share of imports from the trading partner *j* in the total imports of country *i* for product *k.* A HHI closer to 1 indicates a higher concentration of imports, while a HHI close to 0 indicates more diversification of imports.

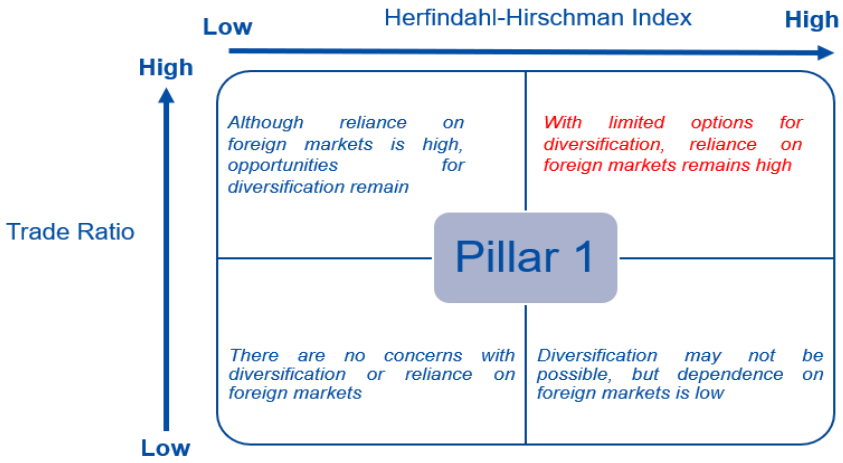
The second indicator used is the trade ratio (TR), which aims at showing the relative size of imports compared to exports for a given country. This ratio can be used to assess trade reliance in the economy. The second indicator for country *i* and product *k* in year *t* is calculated as follows:

$$TR_{i,t}^{k} = \frac{Total\ imports\ _{i,t}^{k}}{Total\ exports\ _{i,t}^{k}} \qquad (2)$$

A ratio higher than 1 indicates that a country is running a trade deficit, whereas a ratio lower than 1 indicates that the economy is running a trade surplus.

Figure 1 illustrates the four quadrants into which products can be categorised, offering a simplified view of the country's classification in terms of dependency risks for specific products. In this case, we are interested in identifying products with limited options for diversification, combined with a high reliance on foreign markets. In Figure 1, this situation is identified by the top-right corner scenario. Other options exist that highlight lower risks of foreign dependencies. For instance, the top-left quadrant identifies products with a high reliance on foreign markets but with a significant potential for diversification. The bottom-left quadrant indicates products with neither excess dependencies concerns nor diversification issues. Meanwhile, the bottom-right quadrant highlights products with a low trade ratio, which makes them less risky despite the observed high concentration on a specific origin.

Figure 1: Dependency risk in a 2x2 matrix



Pillar 2: Risks related to a weak global market position

The second pillar evaluates for each product traded, the risks arising from a weak standing in global trade. It focuses on two dimensions, namely the revealed comparative disadvantage and the price differences.

The first indicator of this pillar is the Revealed Comparative Disadvantage (RCD), which aims at identifying products where a country is less competitive in, relatively to other countries. A higher value indicates a comparative disadvantage, implying that a country is less competitive globally in exporting that product. The RCD indicator is calculated by taking 1 minus the Revealed Comparative Advantage (RCA) indicator, which measures what a country is "good at exporting" compared to the rest of the world. This indicator is calculated for each individual country *i* as follows:

$$\mathbf{1} - \boldsymbol{RCA}^{\boldsymbol{k}}_{\boldsymbol{i,t}} = \mathbf{1} - \frac{\boldsymbol{Exports}^{\boldsymbol{k}}_{\boldsymbol{i,t}} \Big/ \boldsymbol{Exports}_{\boldsymbol{i,t}}}{\boldsymbol{Exports}^{\boldsymbol{k}}_{\boldsymbol{w,t}} \Big/ \boldsymbol{Exports}_{\boldsymbol{w,t}}} \qquad (3)$$

where *k* means product, *w* is world and *t* is year. In terms of interpretation, a lower value suggests a stronger export specialisation, whereas a higher value implies the product is relatively less important in the export structure of the country.

The second indicator is the price competitiveness index (PCI). This indicator measures the price competitiveness of the traded goods of a country relative to its imports. A higher ratio can indicate a price disadvantage, which is important when evaluating the vulnerability to foreign markets, as it affects the capacity of the country to reduce its foreign dependencies. It is important to highlight that a price disadvantage can also be originated from a country producing higher quality products, which is not necessarily linked to a vulnerability. To understand the magnitude of the vulnerability, we need to combine it with the RCD indicator. This would enable us to identify products with higher risks of foreign vulnerabilities. The indicator for country *i* and product *k* in year *t* is calculated as follows:

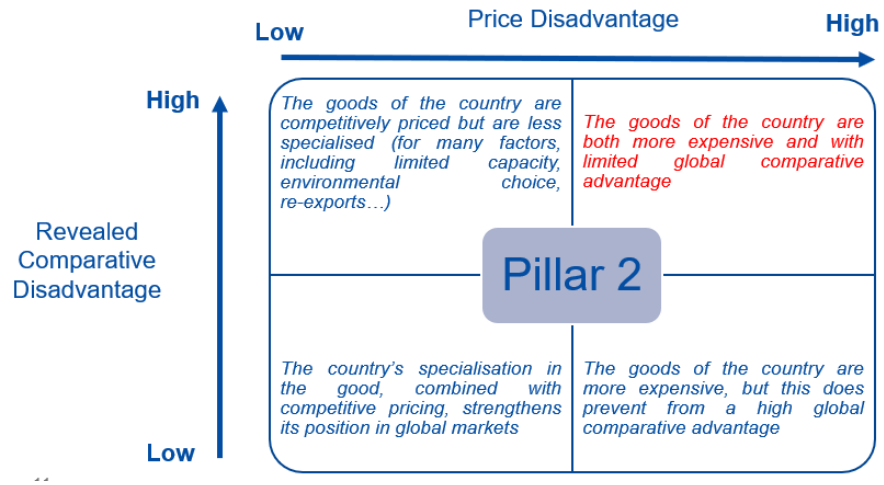
$$\boldsymbol{PCI}^{\boldsymbol{k}}_{\boldsymbol{i,t}} = \frac{\overline{\boldsymbol{P}^{\boldsymbol{k}}_{\boldsymbol{i,t}}}(\boldsymbol{exports})}{\overline{\boldsymbol{P}^{\boldsymbol{k}}_{\boldsymbol{i,t}}}(\boldsymbol{imports})} \qquad (4)$$

where $\overline{P^{k}_{i,t}}$ is the average unit price. In terms of interpretation, $PCI^{k}_{i,t}$>1 suggests an economy that exports higher prices than it imports, indicating in principle a price disadvantage.

Figure 2 provides the interplay between these two indicators, which are shown in a 2X2 matrix. The most vulnerable quadrant is once again the top-right, where the country's goods are both more expensive than those of foreign competitors and are paired with a limited comparative advantage. All the other quadrants represent options characterised by relatively lower levels

of vulnerability. The top-left quadrant represents goods that are competitively priced but the country exhibits lower levels of specialisation. This may result from many factors such as limited production capacity, deliberate national policies prioritising safety or environmental considerations, or the nature of the goods being primarily re-exported. The bottom-left quadrant shows a favourable situation where the country has a high degree of specialisation, and this is combined with a competitive pricing. This combination of factors minimises the country's vulnerability. Finally, the bottom-right quadrant displays the situation where the goods of the country are more expensive, but this does not prevent the country from achieving a high global comparative advantage. This may not necessarily indicate vulnerability, as it could instead reflect differences in the quality of goods produced.

Figure 2: Global position risk in a 2x2 matrix



Obtaining the product, sectoral and national level External Vulnerability Index (EXVI)

To ensure a standardised analysis, the methodology addresses indicators that fall outside the 0 to 1 range. These indicators are adjusted using winsorisation at a 90% level, a statistical technique that minimises the influence of extremely outliers, consequently, minimising the effect caused by anomalous data points. Winsorisation is done on all HS6 product categories combining all three regions (EU, US and China) in a specific year.

After winsorisation, a min-max normalisation strategy is applied to rescale the data, standardising it to a common range between 0 and 1 to enable consistent comparisons across variables.

$$Indicator_{normalised} = \frac{X - X_{min}}{X_{max} - X_{min}}$$

where X_{max} , X_{min} will be determined by the regions we would like to include in the analysis. Initially, we will start with the EU, as well as with its main trading partners, the US and China.

In order to aggregate the two indicators in the two pillars, the methodology employs a geometric mean. This method captures the multiplicative interaction between the two indicators, which is useful in this application, as we want to ensure that both indicators are important for the overall risk of vulnerability. In our quadrant, this is shown by the top-right quadrant. In other words, the geometric mean emphasises balance, suggesting that if either indicator within a pillar is low, the composite score of the pillar will be low.

$$\boldsymbol{Pillar\ 1}_{i,t}^{k}= \left(\boldsymbol{TR}_{i,t}^{k\ w1} * \boldsymbol{HHI}_{i,t}^{k\ w2}\right)^{\left(\frac{1}{w_1+w_2}\right)} \quad \textbf{(5)}$$

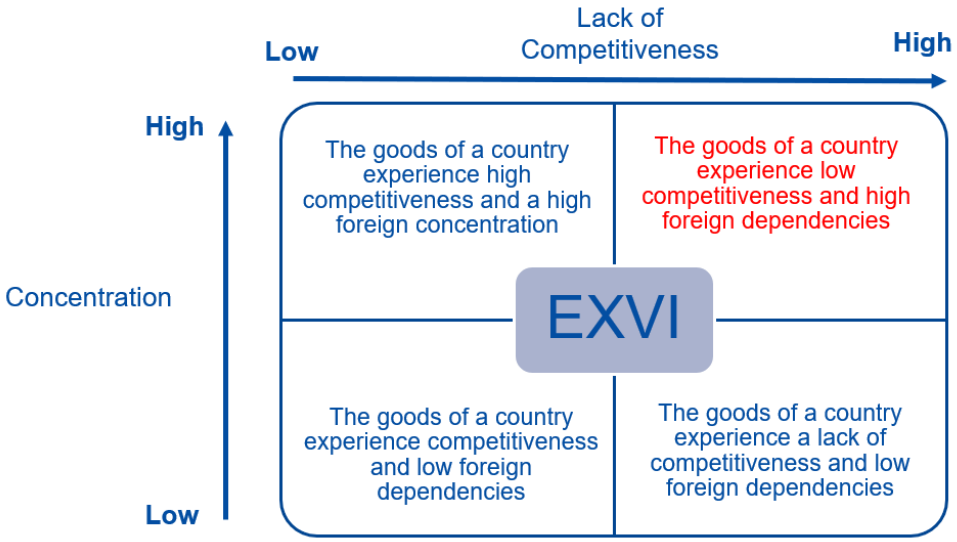
where $w_1 + w_2$ represent the relative importance of each indicator. This exercise assumes that both indicators are equally important, that is $w_1 = w_2 = 0.5$. The same approach is applied to the indicators in Pillar 2 and to the aggregation of the two pillars, resulting in the product-level External Vulnerability Index (EXVI).

$$\boldsymbol{EXVI}_{i,t}^{k}= \left(\boldsymbol{Pillar1}_{i,t}^{k\ w1} * \boldsymbol{Pillar\ 2}_{i,t}^{k\ w2}\right)^{\left(\frac{1}{w_1+w_2}\right)} \quad \textbf{(6)}$$

where again this exercise assumes that $w_1 = w_2 = 0.5$.

The final matrix is displayed in Figure 3. As before, the greatest risk of external vulnerability is observed in the top-right quadrant, where a country's goods face both risky factors, namely low competitiveness and high foreign dependency.

Figure 3: EXternal Vulnerability Index (EXVI) in a 2X2 matrix



The calculation of the indicator using HS6-level products aggregated into broader baskets offers a practical framework for analysing vulnerabilities in strategic supply chains. This

approach is particularly relevant for assessing supply chains targeted by major policy initiatives such as the Chips Act, the Net Zero Industry Act (NZIA), and the Critical Raw Materials Act (CRMA), which will be detailed in the next section. To align with these policies, we have selected a specific set of products within each of these supply chains, based on the assumption that all components are equally essential. Given the low substitutability of these products, a simple average is applied to derive the EXVI. Cross-country comparisons, especially between the EU, the US and China, provide valuable insights for policymakers, highlighting potential areas of strategic vulnerability and informing the design of more resilient supply chain strategies. Furthermore, differences in EXVI scores across countries could serve as an indicator of relative vulnerability to supply chain disruptions in relation to our main trading partners.

Empirical application using three sensitive supply chains

This section focuses on three areas prioritised by EU policymakers since the release of the EU's 2021 trade and industrial strategies.

The first area concerns raw materials, which are central to the functioning of several global supply chains. In April 2024, the EU adopted the Critical Raw Materials Act,[3] defining a list of critical raw materials (CRMs), which are considered important for the wider EU economy, and a list of strategic raw materials (SRMs), which are relevant in support of EU green, digital, defence and space applications and which present risks of dependencies. The focus on raw materials by policymakers is justified by their extensive range of applications and the rising global demand for some of these products such as aluminium, copper, silicon, nickel, and manganese and the concentrated supply for many of these materials. Moreover, the Act aims, among other measures, to increase and diversify the EU's CRM supply, including by substituting the strategic raw materials. Specially, it sets a benchmark for 2030, stipulating that no more than 65% of the EU's annual consumption of any given strategic raw material should originate from any single third country. In practical terms, the Act targets to reduce the risks associated with these products by strengthening global supply chains. It also aims to continue to negotiate and implement Industrial Strategic Partnerships, as well as to develop sustainable trade and investment agreements.

[3] Regulation (EU) 2024/1252 of the European Parliament and of the Council of 11 April 2024 establishing a framework for ensuring a secure and sustainable supply of critical raw materials and amending Regulations (EU) No 168/2013, (EU) 2018/858, (EU) 2018/1724 and (EU) 2019/1020. Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=OJ:L_202401252.

A second sensitive area highlighted by EU policymakers refers to the supply chain of semiconductors.[4] In mid-2023, the EU adopted the Chips Act, which aims at reducing EU's vulnerabilities and dependencies on foreign actors. This is achieved by enhancing the EU's security of supply, resilience and technological sovereignty. As in the case of raw materials, microchips are pivotal for the manufacturing of current and future critical applications, including items related to work, education, entertainment, healthcare and mobility, among others. We map the supply chain of semiconductors in the EU based on the study conducted by Bonnet and Ciani (2023), who identify products spanning across different segments of the semiconductor value chain. Among these, we also include raw materials, but equally inputs for wafers, silicon wafers, foundry inputs, equipment, as well as final products.

The third sensitive area of products that we examine is the supply chain of technologies that play a central role in addressing climate change. As in previous sensitive areas, the market of these net-zero (NZ) technologies is set to triple by 2030. Recognising their significance, EU policymakers have designated them as critical technologies. On 16 March 2023, the Commission presented the Net-Zero Industry Act (NZIA) with the objective to build additional domestic manufacturing capacity within the EU.[5] In particular, NZIA aims to achieve 40% of the production necessary to fulfil the EU's needs for strategic technology products by 2030. The NZ technologies covered in the paper include solar photovoltaics, wind turbines, batteries, heat pumps, electrolysers and solar thermal technologies. In order to map CN products related to these technologies, we rely on final products and their first-tier components.

In order to calculate the pillars of the EXVI indicator, we will first identify HS6 products in each of the supply chains mentioned above. Using a simple average, which assumes that all the components are equally important, we obtain the two pillars explained above, which are summarised in Table 1 and Table 2. The final EXVI for each supply chain is obtained for the EU, US and China. The aggregated table with the EXVI for each sensitive supply chain and the aggregated industrial sector is shown in Table 3. Based on the latest BACI data, the obtained EXVIs show that the EU is more exposed to external trade vulnerabilities than China, but less so than the United States. A closer examination of critical areas such as raw materials, semiconductors, and net-zero technologies reveals that the EU is most vulnerable in raw

[4] Regulation (EU) 2023/1781 of the European Parliament and of the Council of 13 September 2023 establishing a framework of measures for strengthening Europe's semiconductor ecosystem and amending Regulation (EU) 2021/694 (Chips Act). Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32023R1781.

[5] Proposal for a REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on establishing a framework of measures for strengthening Europe's net-zero technology products manufacturing ecosystem (Net Zero Industry Act) COM/2023/161 final. Available at: https://eur-lex.europa.eu/resource.html?uri=cellar:6448c360-c4dd-11ed-a05c-01aa75ed71a1.0001.02/DOC_1&format=PDF.

materials. Furthermore, the index shows that the EU is more vulnerable than China in all three supply chains, while being more vulnerable than the United States only in semiconductors.

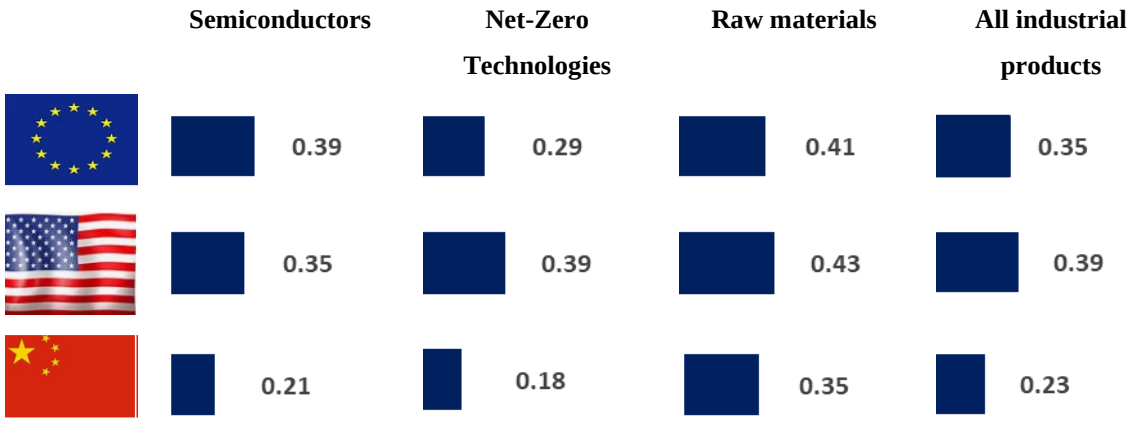
As previously highlighted, each EXVI number is composed of different product categories and for this reason, it is also important to look at the distribution of the product EXVIs. It is important to highlight that the vulnerability of a given supply chain is determined by its weakest spot. In other words, in the absence of a substitute, a critical component might affect the ability to produce of an entire supply chain. Figure 4 shows the distribution of the list of raw materials across the EU, China and the US. Among these regions, we observe that China has a lower aggregate EXVI value than the EU and the US. However, looking at individual products, we observe a low EXVI in some product categories (i.e. Aluminium ores, Boron, Palladium, magnesium…), while observing a high EXVI in some other raw materials (e.g. types of Nickel, Manganese, Lithium carbonates, unrefined copper). Looking at its distribution, China has many more products with low EXVI compared to the EU and the US but the 75th percentile of these products is higher than the EU. This means that although China has low vulnerability across a greater number of products, it also faces higher vulnerability in a larger range of products. In short, the distribution of the EU is more concentrated around the unweighted average than the distribution of China (see an illustration for a selected number of products in the Annex).

Table 1: Pillar 1 (Dependencies risk) of the External Vulnerability Index across strategic supply chains (i.e. semiconductors, net zero technologies and raw materials) for the European Union, China and United States

	Semiconductors	Net Zero Technologies	Raw materials	All industrial products
	0.13	0.14	0.24	0.17
	0.12	0.21	0.29	0.39
	0.18	0.09	0.23	0.10

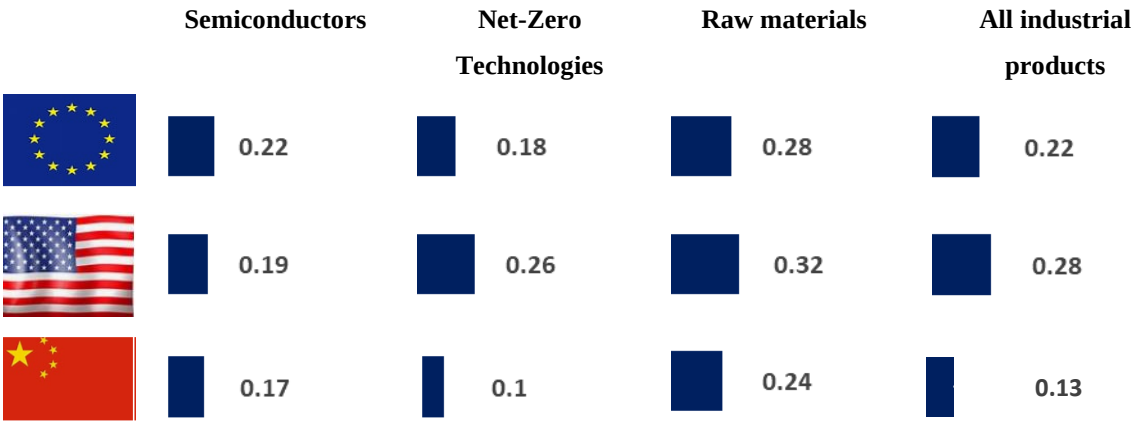
Note: EXVI scores: 0= low vulnerability, 1=high vulnerability;
Source: European Commission, based on the latest BACI database (2022).

Table 2: Pillar 2 (Global Position risk) of the External Vulnerability Index across strategic supply chains (i.e. semiconductors, net zero technologies and raw materials) for the European Union, China and United States



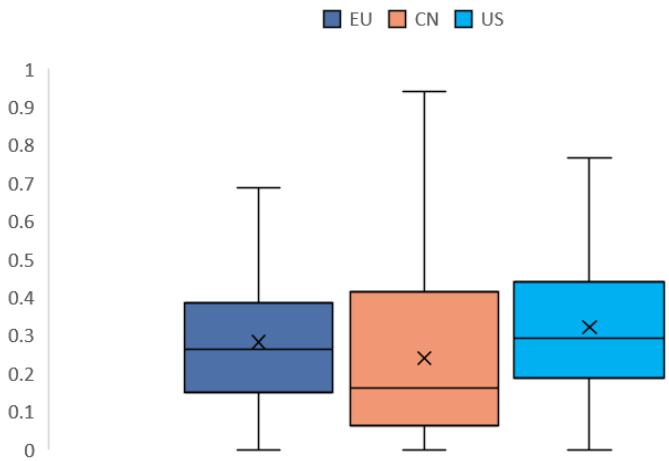
Note: EXVI scores: 0= low vulnerability, 1=high vulnerability;
Source: European Commission, based on the latest BACI database (2022).

Table 3: External Vulnerability Index (EXVI) across strategic supply chains (i.e. semiconductors, net zero technologies and raw materials) for the European Union, China and United States



Note: EXVI scores: 0= low vulnerability, 1=high vulnerability;
Source: European Commission, based on the latest BACI database (2022).

Figure 4: Distribution of product EXVIs within the raw materials list



Note: EXVI scores: 0= low vulnerability, 1=high vulnerability;
Source: European Commission, based on the latest BACI database (2022).

3. Conclusion

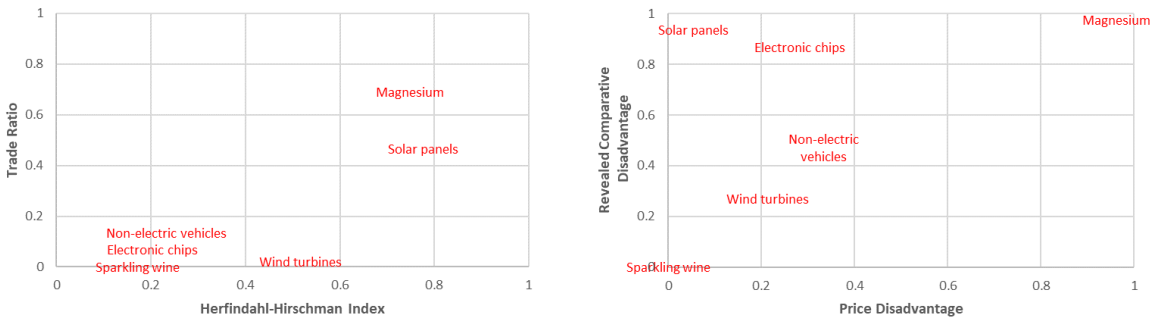
The increasing interconnectedness of global trade highlights the need for indicators to assess external vulnerabilities of regions in different products, sectors and supply chains. Accurately identifying and quantifying these vulnerabilities is essential for policymakers to design effective strategies that mitigate risks and enhance economic resilience. The External Vulnerability Index (EXVI) developed in this economic brief provides a tool in this regard. By integrating key dimensions such as trade dependencies and global market positioning, the EXVI offers a framework to evaluate external risks across products, sectors, and countries. As the global trade landscape continues to evolve, tools like the EXVI are useful for informed decision-making and long-term reduction in supply chain risks.

Annex: Empirical application at HS6 product codes (most granular information)

As a matter of illustration at the most granular level, we are going to use six different HS6 products. Namely, solar panels (854140), wind turbines (850231), electronic chips (final product) (854160), internal combustion engine (ICE) cars (870321), magnesium (851712) and sparkling wine (220410).

Figure 5 displays the values for each variable within the two pillars, based on the products selected as examples. The graph on the left-hand side shows a matrix combining the trade ratio and the Herfindahl-Hirschman Index (HHI). The closer the products are to the upper-right quadrant the higher their vulnerability, as they score high on both indicators, pointing to a significant external dependency. On the other hand, the graph on the right-hand side shows a matrix combining revealed comparative disadvantage and price disadvantage. Once again, products located closer to the top-right quadrant are seen as vulnerable, as they score high on both indicators, highlighting a significant competitive weakness in external markets. Among our example products, we see that vulnerability is relatively higher for magnesium.

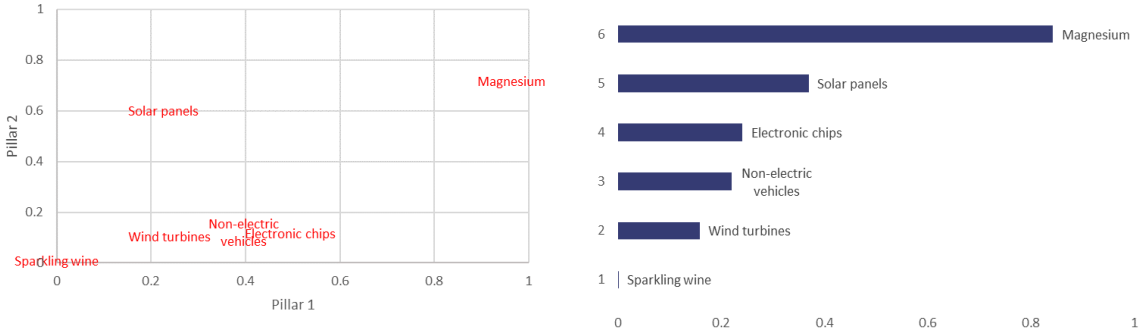
Figure 5: Pillar 1 and Pillar 2 for a selected number of products



Note: EXVI scores: 0= low vulnerability, 1=high vulnerability;
Source: European Commission, based on the latest BACI database (2022).

Figure 6 illustrates the values for each of the two pillars across the products selected as examples. The left-hand side graph shows a matrix combining the scores for Pillar 1 and Pillar 2. The closer the products are to the upper-right quadrant, the higher their vulnerability, as they score high on both pillars, pointing to a significant external vulnerability. In terms of ranking the selected products, the graph on the right-hand side highlights that magnesium is the most vulnerable product, followed by solar panels and electronic chips. On the other side of the ranking is sparkling wine, where the EU has a relatively high strength, as well as in wind turbines and non-electric vehicles.

Figure 6: EXVI indicator in matrix and absolute for a selected number of products



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