Analysis

Global supply chains and European economic vulnerabilities

Dennis Bonam, Josien Demmers, Gavin Goy, Jos de Grip, Bas Heerma van Voss, Daan de Leeuw, Camille Mehlbaum, Andra Smadu & Rixt Swierstra

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Contents

Executive summary

Supply chain disruptions are an increasing source of inflationary pressure and macroeconomic volatility in Europe. Recent events, such as the COVID-19 pandemic and the wars in Ukraine and Iran, show how global disruptions can rapidly spill over into prices and output within the EU. Although supply chain disturbances are not new, the growing interconnectedness of production networks and the recent rise in geopolitical tensions have increased supply chain risk. Disruptions in specific intermediate inputs or critical raw materials can trigger large, persistent and unevenly spread inflationary effects. They can also create adverse and uneven effects on economic output, complicating macroeconomic stabilisation through monetary and government policy.

This study takes two complementary angles: it quantifies macroeconomic effects once global disruptions materialise, and it maps product-level vulnerabilities that indicate where future disruptions may arise. As firms do not internalise the broader economic costs of supply disruptions in their decisions, vulnerabilities in supply chains can persist even when they are socially inefficient. As a result, disruptions may be both more likely and more macroeconomically costly, calling for both structural policies to reduce vulnerabilities and macroeconomic stabilisation when shocks materialise. In this context, the study draws monetary policy lessons for an optimal response to supply chain disturbances from a theoretical model, and industrial and trade policy lessons for reducing vulnerability to such shocks in the future. How monetary policy should respond depends non-linearly on the size of the shock and the import dependence of the economy. Preventative industrial and trade policies can and should be targeted, as only 4% of goods produced across a variety of sectors are classified as vulnerable under our methodology. A small subset of EU member states appears best positioned to efficiently scale up domestic production to reduce these risks. Moreover, most vulnerabilities are short-lived, highlighting the importance of dynamism and technological innovation. Thus, policies that contribute to a competitive and innovative European economy help prevent future vulnerabilities.

Global supply chain disruptions and macroeconomic effects

The inflationary impact of supply disruptions is uneven and can rise sharply during episodes of severe disruption. Direct price effects are estimated to be stronger for goods than for services, reflecting that historical global supply chain disruptions have mainly affected the production and transport of physical goods. Price effects are strongest where production relies heavily on imported inputs and upstream components. As a result, disruptions originating in a narrow segment of the economy can become macro-relevant if they affect inputs that are widely used across production chains. Large shocks generate disproportionately stronger price effects than smaller shocks, implying that severe episodes create inflation risks materially larger than suggested by average historical effects.

There is no single, standard monetary policy response to supply-driven inflation in the euro area. For the ECB, the appropriate policy reaction depends on the nature of the disruption: whether it is temporary or persistent, and whether it mainly raises prices or also strongly hampers production. If the increase in inflation is temporary, a central bank may “look through” the shock and maintain its policy stance to avoid weakening output unnecessarily. When shocks are larger and more persistent, they are more likely to feed into wages and expectations. In such cases, policy tightening becomes warranted, even if it comes at the expense of output. The impact of a given disruption can differ across euro area economies. Countries that are more dependent on imported inputs, or where firms have limited scope to switch suppliers, are more exposed to supply-driven price pressures and production losses. As a result, a global supply chain disruption can call for different degrees of adjustment across member states. In a monetary union, this can complicate the calibration of a single monetary policy stance and increase the importance of national fiscal policy in cushioning asymmetric effects.

Europe’s supply chain vulnerabilities at the product level

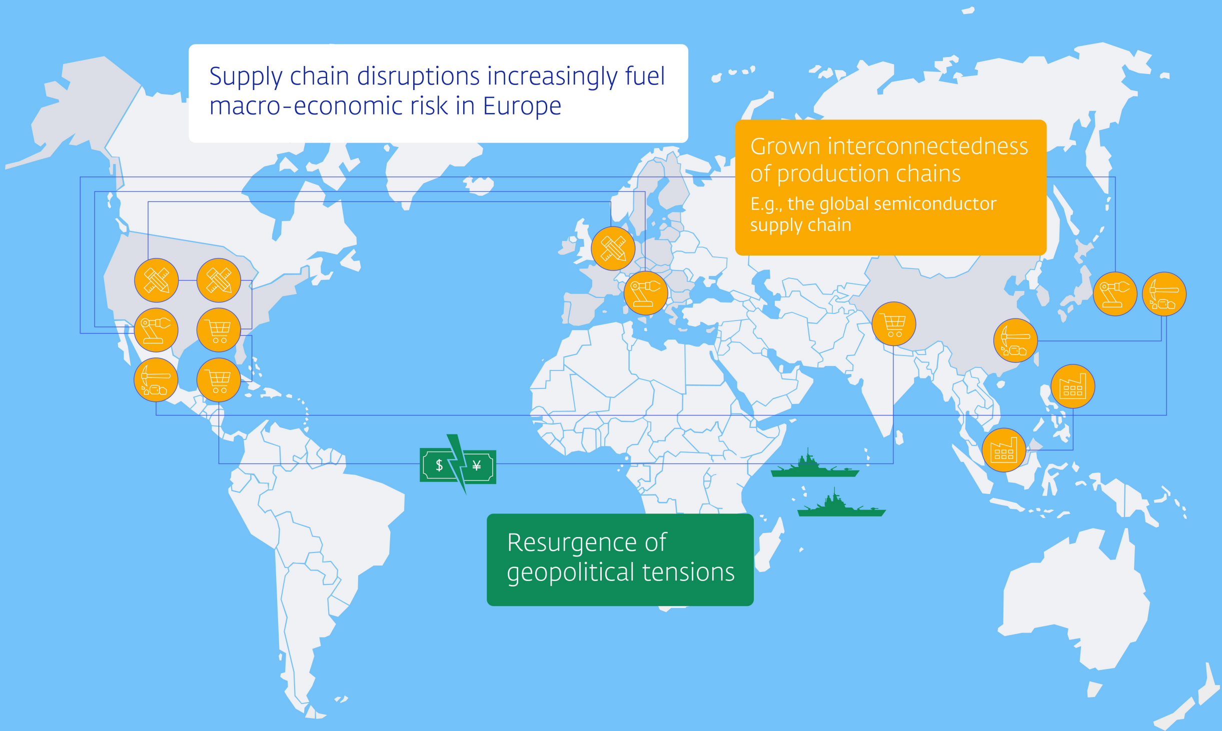
To complement the macro-perspective, this analysis uses a product-level approach to mapping supply chain risks. Using highly disaggregated trade data and information on production networks, the analysis identifies products for which supply is highly concentrated at a country level and that are part of supply chains of goods that serve critical functions such as defence, medical supply, the energy transition and digital infrastructure. By bringing these two perspectives together, the study helps identify not only how costly disruptions can be, but also where they are most likely to arise. The product-level analysis shows that Europe’s supply-chain vulnerabilities are concentrated in a relatively small set of products, often embedded within otherwise diversified sectors. Even in the sectors with the most vulnerabilities, vulnerabilities affect only a small share of products, peaking at 13% of all products (representing 4% of export value) in chemicals, followed by 11% of total products in mineral products. This limits the effectiveness of broad, sector-level policy interventions and points to a more targeted approach. A product-level perspective helps prioritise where government tools are most likely to reduce risk. Vulnerabilities to global supply chain disruptions occurring outside Europe are concentrated in China, and to a lesser extent the US.

A small set of European countries appears best positioned to scale up production to overcome vulnerabilities. This underscores the added value of European coordination to overcome these vulnerabilities. Vulnerabilities show limited durability, as they tend to be short-lived and change over time, with about a third of vulnerable goods remaining such over a decade. This indicates that vulnerabilities are not a static, binary characteristic, but instead evolve over time as production structures change. A high flux in vulnerabilities suggests industrial policy should also be aimed at maintaining an innovative and competitive economy, in addition to targeted interventions to overcome current vulnerabilities.

Balancing prevention and response

Supply chain disruptions necessitate both stabilising inflation and reducing vulnerability. Monetary policy can counteract price pressures once disruptions materialise, but this often comes at the cost of weaker output. How costly such disruptions become depends not only on the monetary policy response, but also on how easily adjustment takes place in the economy: on the demand side, through substitution by users, and on the supply side, through the ability of alternative producers to enter or scale up production. When such adjustment is limited, price pressures are more likely to persist and real economic costs tend to be larger, sharpening the trade-offs faced by policies that aim to stabilise inflation and support economic output. In a monetary union, targeted fiscal policy and automatic stabilisers can play a complementary role in addressing uneven effects across member states. Monetary policy is set for the euro area as a whole and focuses on stabilising average inflation in the euro area. National fiscal policy can play a complementary role by cushioning income losses and facilitating adjustment at the country level, including through automatic stabilisers. At the same time, these instruments cannot address the underlying sources of vulnerability. The costs of monetary policy ex post imply a high premium on reducing supply chain vulnerabilities ex ante. Such reduction of vulnerabilities lies beyond the reach of the demand-side instruments available to central banks. Incorporating the lessons from product-level analyses of vulnerabilities is key to reducing such risks of disruption efficiently.

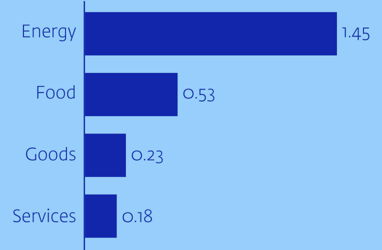
Global supply chains and European economic vulnerabilities



Global supply chains disruptions raise inflation

1 Impact is strongest for energy and food inflation

Peak YoY change in HICP components after 1-SD global supply-chain schock (p.p.)



2 Optimal monetary policy tightening response depends on specific factors

Low and high **Import dependence**: weaker policy response

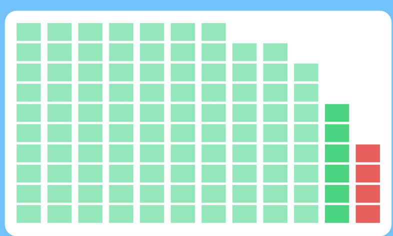
Opportunities for **subsititution** limit the shock's impact

Shock size matters non-linearly: large shocks have disproportionately large effects

Source: own calculations DNB

Supply chain risks tend to materialise at the product level, calling for targeted policy responses

Out of 5612 total traded products:

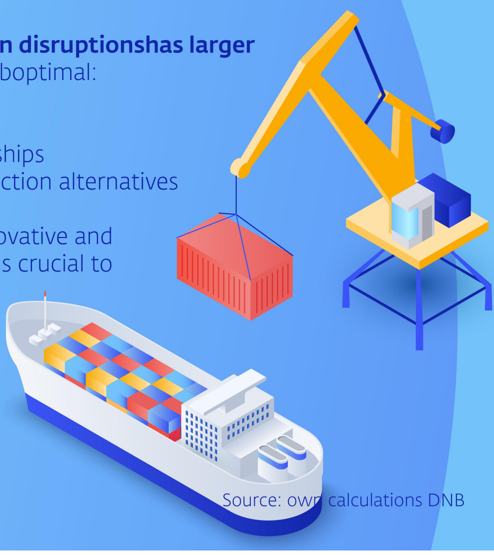


- 5034 do not have concentrated production
- 369 have concentrated production but no link to critical uses
- 209 have concentrated production and link to critical use

Resillience against supply chain disruptionshas larger social than private benefits, suboptimal:

- Stockpiling
- Alternative supplier relationships
- Building out domestic production alternatives

Targeted EU policy can help; innovative and competitive EU economy remains crucial to prevent future vulnerabilities



Source: own calculations DNB

1 Introduction

1.1 Supply chain disruptions in the 21st century: is this time different?

Supply chain disruptions are a longstanding feature of international trade.[1] Wars, natural disasters, trade restrictions and geopolitical conflicts have repeatedly disrupted the cross-border supply of goods, sometimes with large effects on prices and economic output. From drought-driven food shortages to oil embargoes, supply chain disruptions have long shaped inflation dynamics and macroeconomic outcomes. While disruptions themselves are not new, their relevance is increasing and their economic transmission has changed. Climate change is expected to intensify weather-related disruptions, and higher geopolitical tensions make strategic interference with trade and supply dependencies more likely, suggesting that adverse supply shocks may occur more frequently. This raises the question whether recent supply chain disruptions reflect a continuation of familiar patterns, or whether their reach, persistence and macroeconomic impact have been amplified by the structure of modern global supply chains. Recent experience suggests the latter: in advanced economies, the largest inflation surges in recent decades have typically been triggered or amplified by adverse supply shocks, often through energy, commodities, and global production bottlenecks (Celasun et al., 2022). In highly interconnected production networks, even small, local shocks can propagate widely across sectors and countries, resulting in much larger and more systemic macroeconomic effects than in earlier periods.

Historically, supply disruptions most often affected basic goods, key raw materials or major trade routes. Recurrent harvest failures and wars repeatedly disrupted food supplies in pre-industrial economies, giving rise to major grain crises and sharp increases in food prices from medieval Europe through the early modern period. Control over trade routes and staple exports was frequently used as a strategic instrument, for example through naval blockades and export bans during early modern wars. In the nineteenth century, large geopolitical interventions in trade, for example the Napoleonic Continental System, restricted access to critical goods across Europe by disrupting established trading patterns. During the first half of the twentieth century, severe supply constraints arose through blockades, rationing and the redirection of industrial production during the World Wars, limiting access to energy, food and key raw materials. In the post-war period, disruptions to oil supply following geopolitical conflicts and embargoes, notably during the 1973–74 and 1979 oil crises, had pronounced inflationary and macroeconomic effects. Despite their severity, these shocks primarily operated through final goods or broadly used inputs, and their economic impact tended to remain concentrated in directly affected markets rather than propagating globally through complex production networks.

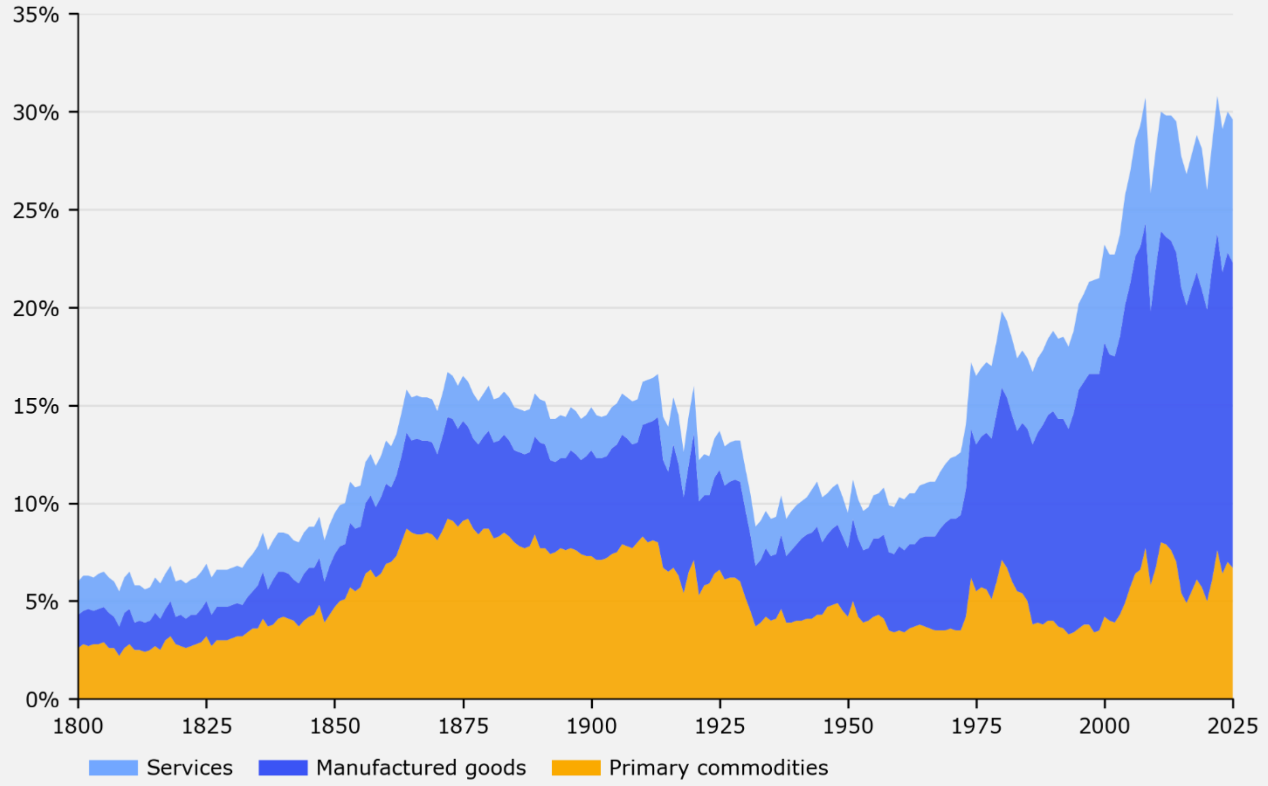
Since the 1970s, globalisation has increasingly taken the form of internationally dispersed production processes. Rather than trading primarily in final goods, production has been organised along long and specialised supply chains, with tasks and stages allocated across countries according to comparative advantage. This transformation is evident in the strong expansion of global trade relative to output and in the changing composition of trade flows. As illustrated in Figure 1.1, the share of manufactured goods in global trade has risen markedly since the 1970s, reflecting the growing international dispersion of production, while primary commodities and services play a smaller role in cross-border goods flows. This phase of "hyperglobalisation"

[1] We thank Bas ter Weel, Mark Mink, Sophie Steins Bisschop, Niels Gilbert, Peter van Els, Jip Italianer and Oscar Lemmers for their comments. All remaining errors are ours.

delivered substantial efficiency gains and lower production costs (Rodrik, 2011; Antràs, 2015), but also increased interdependence between firms, sectors and countries.

Figure 1.1 Manufacturing has become the dominant component of global trade

Magnitude and composition of global total exports (% of GDP), 1800-2025



Note: Primary commodities include agricultural products, fuels and mining products (SITC 0-4 + 68). Manufactured goods include all other goods. Services include transport/freight, travel/tourism and other services (insurance, banking, consulting, digital, etc.).

Source: World Inequality Lab

The increase in efficiency due to globalisation has come at the price of higher risk of disruptions of supply chains. In these dispersed production structures, supply disruptions propagate through dense input–output linkages within production networks. Intermediate inputs supplied by one firm or country often serve as essential inputs for multiple downstream producers, so shortages or delays can cascade through supply chains via indirect upstream and downstream connections (Carvalho & Tahbaz-Salehi, 2019). Such network propagation allows shocks originating in specific inputs or locations to generate rapid and persistent inflationary effects and broad macroeconomic consequences, particularly when shortages affect sectors deeply embedded in global trade networks (Cavallo & Kryvtsov, 2023). These dynamics are most pronounced when shocks affect upstream inputs that are widely used across sectors and for which substitution possibilities are limited in the short to medium run (Acemoglu & Tahbaz-Salehi, 2025). Recent disruptions - such as the semiconductor shortages during the pandemic and energy supply disruptions following Russia's invasion of Ukraine - illustrate this mechanism, as they have been characterised by an unusual combination of reach, persistence and macroeconomic impact, reflecting propagation and amplification through dense global supply chains rather than isolated sectoral shocks (Igan, Rungcharoenkitkul & Takahashi, 2022).

Recent geopolitical developments have further altered the risk profile of highly integrated production networks by increasing the strategic value of control over specific supply relationships. Trade and supply dependencies are increasingly used as instruments of strategic and geopolitical leverage, alongside more traditional means of economic pressure such as energy goods and commodities (IMF, 2023). In tightly interconnected supply chains, control over narrowly defined production stages or inputs that are highly concentrated and difficult to substitute can create powerful ‘chokepoints’, allowing states or firms to exert outsized influence through disruptions at central nodes. The supply chain disruptions observed during the COVID-19 pandemic, as well as more recent energy and geopolitical shocks, illustrate how such chokepoints can translate quickly into economy-wide effects when production is organised around highly central and difficult-to-substitute nodes. Manufacturing supply chains, long viewed primarily as efficiency-driven economic structures, have therefore become a channel through which risks that were previously largely national or sector-specific can take on a global and systemic character. The combination of deep production interdependence and heightened geopolitical risk means that supply chain disruptions today can differ from earlier episodes in their scale, propagation and persistence.

For policymakers, the relevance of supply chain disruptions lies not only in their average size, but in how their effects depend on production structure, network centrality and the scope for adjustment through substitution or reallocation. Whether a disruption remains contained or gives rise to persistent, economy-wide inflationary pressures depends on where it occurs within production networks and how easily firms and households can adapt. Understanding these mechanisms is essential for assessing the real economic costs and macroeconomic relevance of supply shocks, including their implications for inflation dynamics and macroeconomic stabilisation (Carvalho, 2014). The resilience needed to limit these macroeconomic effects is not fully reflected in individual firms’ decisions, which can result in insufficient resilience and persistent vulnerabilities (Acemoglu & Tahbaz-Salehi, 2025).

1.2 A policy challenge for governments and central banks

Supply chain disruptions pose a complex challenge for economic policy by simultaneously affecting prices, quantities and the allocation of production. By constraining the availability of key inputs, such disruptions raise costs and prices, while also depressing output, delaying investment and forcing firms and households to adjust production and consumption decisions. These effects need not unfold uniformly across the economy: shocks that originate in specific inputs or locations propagate through production networks, generating heterogeneous macroeconomic effects and amplifying uncertainty. Inflation is often the most visible manifestation of such shocks, but it represents only one dimension of a broader adjustment process that also affects output, employment and investment. The macroeconomic impact of a given disruption therefore depends critically on production structures and adjustment capacity, including the centrality of affected inputs within supply chains and the scope for substitution. This heterogeneity is particularly relevant in a monetary union, where differences in import dependence, sectoral specialisation and production networks imply that common supply shocks can translate into uneven macroeconomic pressures across countries.

For monetary policy, supply-driven inflation is difficult to stabilise because it reflects constraints on production rather than excess demand. Monetary tightening mitigates second-round effects by containing inflation expectations and preventing spillovers into wages and margins, but it does so by restraining aggregate demand rather than by alleviating the underlying supply bottleneck. This creates a fundamental mismatch between the nature of the shock and the policy instrument: supply disruptions are typically specific, affecting inputs or production stages, while monetary policy operates on demand across the entire economy. As a result, bringing inflation back towards target requires dampening demand well beyond the affected sectors, implying additional output losses on top of those already caused by the supply shortfall itself. These costs are amplified when supply disruptions persist and propagate through production networks. Bottlenecks in upstream inputs can keep cost pressures elevated across a wide range of downstream activities even as aggregate demand weakens, causing inflation and output to move in opposite directions for extended periods. In such settings, supply shocks give rise to a particularly acute policy trade-off, increasing the risk of sustained inflation alongside weak output (Carvalho, 2014; Ascari, Bonam & Smadu, 2024).

Fiscal policy plays a complementary role in managing the macroeconomic consequences of supply chain disruptions, particularly at the national level. While monetary policy operates at the euro area level and primarily influences aggregate demand, fiscal policy is more targeted, either by cushioning income losses of affected households and firms or by supporting reallocation and adjustment in sectors facing persistent supply constraints. In a monetary union, where economic structures differ but monetary policy is uniform, common supply disruptions result in uneven national inflation and output dynamics. In this context, fiscal instruments play a complementary role by addressing country-specific demand and distributional effects alongside the common monetary response.

Policies aimed at reducing exposure to supply chain disruptions are essential to limit inflationary pressures and prevent real economic losses. It is important to address these vulnerabilities ex ante, as ex-post monetary policy negatively impacts aggregate demand and is thus a second-best instrument. Ex ante policies should aim to strengthen resilience through diversification, redundancy or capacity building. In particular, resilience in the production of critical products is key for ensuring the continuation of vital functions of society. These policies simultaneously increase EU strategic autonomy, leaving it less vulnerable to geopolitical pressures, and reduce the inflationary risk of supply chain disruptions.

At the same time, the policy framework for reducing ex-ante exposure to global supply chain disruptions is less established than that for monetary policy. While monetary policy operates within a clear mandate and benefits from decades of institutional development and a strong focus on price stability, policies aimed at strengthening supply-side resilience involve explicit trade-offs between efficiency, security and redundancy, and remain comparatively underdeveloped. This study focuses on one specific aspect of this ex-ante policy challenge: identifying product-level vulnerabilities in inputs with critical uses, where disruptions are most likely to propagate and where short-term adjustment by firms may be limited. While firms do respond to disruptions—by drawing down inventories, switching suppliers or adjusting production—these margins can be constrained, particularly when production is concentrated or inputs are highly specific. Because firms do not internalise the broader macroeconomic costs of supply disruptions, they may underinvest in supply chain resilience, allowing vulnerabilities to persist even when socially inefficient. This reflects coordination problems in diversifying supply chains, uncertainty about future disruptions, and high upfront costs relative to private returns. Effective resilience policy must also account for the macroeconomic impact of disruptions, geopolitical risks, strategic objectives and fiscal constraints. Taken together, this underscores the need for a more integrated framework for risk management, in which insights from product-level vulnerability analysis are combined with macroeconomic, geopolitical and institutional considerations, and in which reducing supply-side risks is treated as a core element of macroeconomic stabilisation rather than an ad hoc or purely strategic concern.

Taking a broader perspective, debates on macroeconomic stability, strategic autonomy and societal resilience often revolve around the same underlying supply-side vulnerabilities. Discussions framed in terms of security, resilience or strategic dependence typically focus on risks arising from concentrated production, limited substitutability and central positions within supply chains. From a macroeconomic perspective, these same characteristics determine whether supply disruptions translate into persistent inflation, large output losses or difficult stabilisation trade-offs. Recognising this common ground helps clarify why insights from the literature on supply-chain resilience and strategic dependencies are directly relevant for assessing future inflation risks, even when the policy objectives and conventional instruments differ.

1.3 Rest of this study

The second chapter of the study analyses how global supply chain disruptions affect inflation and other macroeconomic variables. Using a macro-economic framework, we identify global supply-chain pressure shocks and estimate their effects on prices, output, labour markets and expectations. Particular attention is paid to heterogeneity in effects across goods and services, the role of import content and upstreamness, and the conditions under which inflation effects become more persistent. The analysis also explores how optimal monetary policy responses depend on country characteristics such as import dependence.

The third chapter of the study focuses on identifying critical supply chain vulnerabilities in Europe at the product level. Using highly disaggregated trade data combined with information on production networks, we identify products for which supply is highly concentrated and that play a central role in supply chains linked to key public interests, including defence, medical supply, digital infrastructure and the energy transition. The product-level evidence is best interpreted as an ex-ante mapping exercise: it does not quantify economic losses or predict specific shocks, but it highlights where disruptions are more likely to occur and where adjustment may be slow.

The fourth chapter brings together the findings and discusses their policy relevance. It highlights the trade-offs between ex post macroeconomic stabilisation and ex ante supply-side resilience, and clarifies how supply chain vulnerabilities shape inflation–output trade-offs faced by monetary policy. The chapter also discusses the implications for coordination between monetary policy and fiscal, trade and industrial policies, given differences in exposure, adjustment capacity and mandates. Details on data sources and methodology are provided in the appendix.

2 Global supply chain disruptions and economic effects in Europe

2.1 Measuring global supply chain disruptions

Global supply chain disruptions take many forms and originate from very different events. At the aggregate level, such disruptions are reflected in indicators such as global transportation costs, supply delivery times, backlogs of orders and inventories. For example, a war in the Middle East disrupts the supply of oil and thereby raises global transportation costs. Natural disasters, like earthquakes, tsunamis and hurricanes, destroy infrastructure and production facilities, halting the production of intermediate goods and increasing order backlogs. A pandemic causes governments to restrict travel and close harbours, airports and other relevant nodes in global supply chains, causing delivery times to rise.

To study the broader macroeconomic effects of global supply chain disruptions, we use the Global Supply Chain Pressure Index (GSCPI) as a proxy. This index is developed by the Federal Reserve Bank of New York, which combines different indicators of supply chain disruptions into a single indicator. While the events that trigger movements in this indicator vary strongly in nature, the resulting dynamics are measured independently of the specific trigger and instead summarize the intensity of realized supply chain stress. Figure 2.1 plots the GSCPI for the period 2001m1 to 2026m3 (blue solid line). Positive changes in the index capture periods in which global supply chains were under elevated pressure. These periods often coincide with major historical events that disrupted the international flow of (intermediate) goods, such as the Tōhoku earthquake, the COVID-19 pandemic and the obstruction of the Suez Canal. Negative changes in the index correspond to favourable global supply chain developments, such as the widening of the Panama Canal in 2016, or an unwinding of existing supply chain disruptions, like the reopening of the Port of Shanghai following a two-month COVID-19 lockdown.

We use a statistical model to obtain changes in global supply chain disruptions that are unrelated to economic conditions. These ‘global supply chain pressure shocks’ are identified using a Bayesian VAR model that includes a set of macroeconomic aggregates for the euro area and the GSCPI, together with several sign, zero, and narrative restrictions. The sign restrictions impose that a positive global supply chain pressure shock, i.e. one that creates a disruption in global supply chains, must lead to an increase in euro area inflation, a reduction in euro area industrial production, and an increase in the GSCPI. We distinguish *global* supply chain pressure shocks from *domestic* supply shocks by imposing that the latter do not affect the GSCPI contemporaneously, an assumption that is based on the global nature of the GSCPI. The narrative restrictions impose that global supply chain pressure shocks must be positive and the most important driver of the GSCPI during historical events that are very likely to have been associated with global supply chain disruptions. For our narrative restrictions, we use some of the events shown in Figure 2.1, namely the Tōhoku earthquake in March 2011, the start of the COVID-19 pandemic in April 2020, the obstruction of the Suez Canal in March 2021 and the Shanghai Backlog in April 2022.[2]

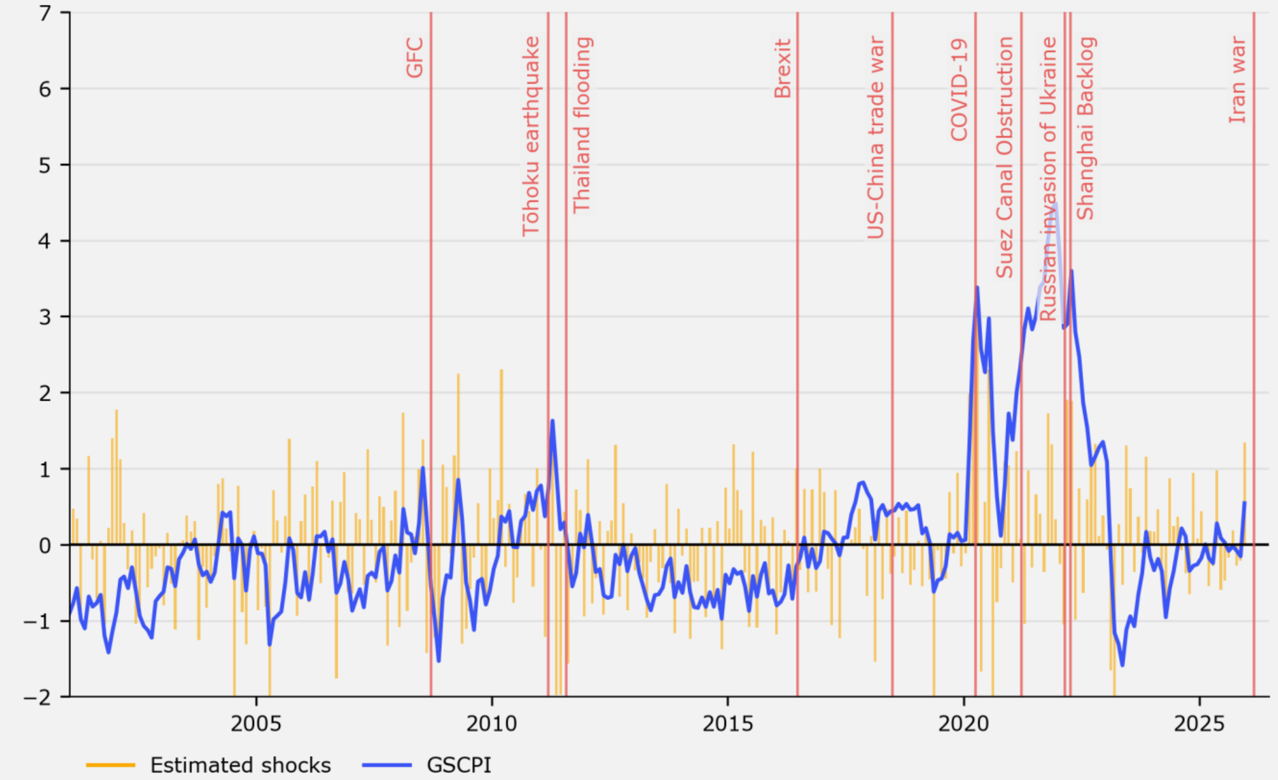
The effects of global supply chain pressure shocks on the euro area economy are estimated using local projection models. We take the global supply chain pressure shocks identified by our Bayesian VAR model and add them as a regressor in a series of local projection models. These models trace out the dynamic effects of the shocks on key variables of interest, such as inflation, unemployment and wage growth. A key underlying assumption is that the shocks are exogenous to these (and other) economic variables. This

[2] For more details about the estimation method and the sign and narrative restrictions, see Ascari et al. (2024).

assumption seems reasonable given that the Bayesian VAR model already imposes the shocks to be exogenous to aggregate euro area economic conditions, and because developments in the euro area are unlikely to substantially and systematically drive global supply chain disruptions. An important advantage of using local projections is that they are flexible, parsimonious and can easily allow for state dependence and other types of non-linearities that may be of interest.[3]

Figure 2.1 Global supply chain pressures arise from different types of global events

Global Supply Chain Pressure Index and estimated shocks in standard deviations from the historical mean



Note: The GSCPI is expressed in standard deviations from the historical mean. Positive values point at increased pressure on supply chains. The shocks are identified using a Bayesian VAR model and a combination of sign and narrative restrictions. For more information, see Ascari et al. (2024).

Source: NY Fed (2022) and own calculations.

Global supply chain pressure shocks have become larger, more persistent and more often disruptive in recent years. Figure 2.1 plots these shocks over the period 2001m1 to 2025m12 (yellow bars), while Figure 2.2 shows that the shocks have been more often positive (meaning global supply chains are more disrupted) since the COVID-19 pandemic and more often *negative* (meaning global supply chain disruptions are easing) on average in the period before the pandemic. Negative shocks capture favourable changes in global supply chains that could arise following, for example, the establishment of new supply chains, the improvement or expansion of existing supply chain infrastructure (such as the widening of the Panama Canal) or an increase in the number of international trade agreements that remove trade barriers. These negative shocks were particularly prevalent

[3] For more information about the data sources that we used, see Appendix A.1.

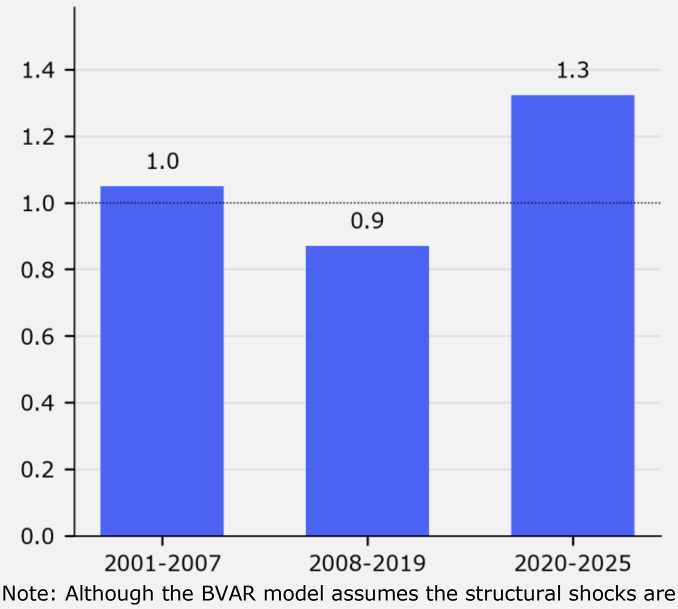
after the Global Financial Crisis of 2008/9, when weak global demand coincided with intact and highly developed global supply chains – scaled up during the preceding phase of rapid globalisation and largely preserved by limited protectionism – resulting in substantial spare capacity in production and logistics networks (Gawande, Hoekman & Cui, 2015). This trend came to an end in 2018 when the trade war between the US and China escalated. After the pandemic, shocks to global supply chains were more likely to be disruptive rather than favourable, were on average greater in magnitude and had a longer-lasting impact on global supply chains than before the pandemic. If such patterns were to persist, global supply chain shocks would pose a more recurrent challenge for policymakers.

2.2 The macroeconomic effects of global supply chain shocks

The response of euro area inflation to a global supply chain pressure shock is positive, statistically significant, persistent and hump-shaped. Figure 2.3 panel a plots the response to a one standard deviation global supply chain pressure shock of core inflation for the euro area.[4] To put the size of such a shock into context: during the COVID-19 pandemic, which disrupted global supply chains through port closures and lockdowns, the GSCPI was about 2.5 standard deviations above its mean. The inflationary impact builds up gradually, peaking only after around two years before fading. In the long term, the inflation response turns slightly negative. This may reflect several general equilibrium effects, such as adverse effects of the shock on production and labour market conditions, or the potential contractionary effect of a monetary policy tightening in response to the rise in inflation. The hump-shaped inflation response can be understood as the result of a gradual transmission of supply chain–related shocks through production networks. Price effects initially emerge in globally exposed and upstream sectors, but broaden as the shock propagates downstream. As transmission proceeds, even sectors with limited direct exposure to global supply chains may be affected through second-round mechanisms, including higher inflation expectations, wage growth, and price adjustments in other parts of the economy, particularly in labor-intensive services. The persistent nature of the effects on inflation is highly relevant for the design of the monetary policy response to the shock. In principle, a more persistent inflationary impact

Figure 2.2 Global supply chain disruption shocks have been more often positive than negative in recent years

Number of positive (greater supply pressures) shocks relative to number of negative shocks



Note: Although the BVAR model assumes the structural shocks are symmetric, the posterior distribution of the estimated shocks may be asymmetric due to the impact of the narrative and sign restrictions that we impose.

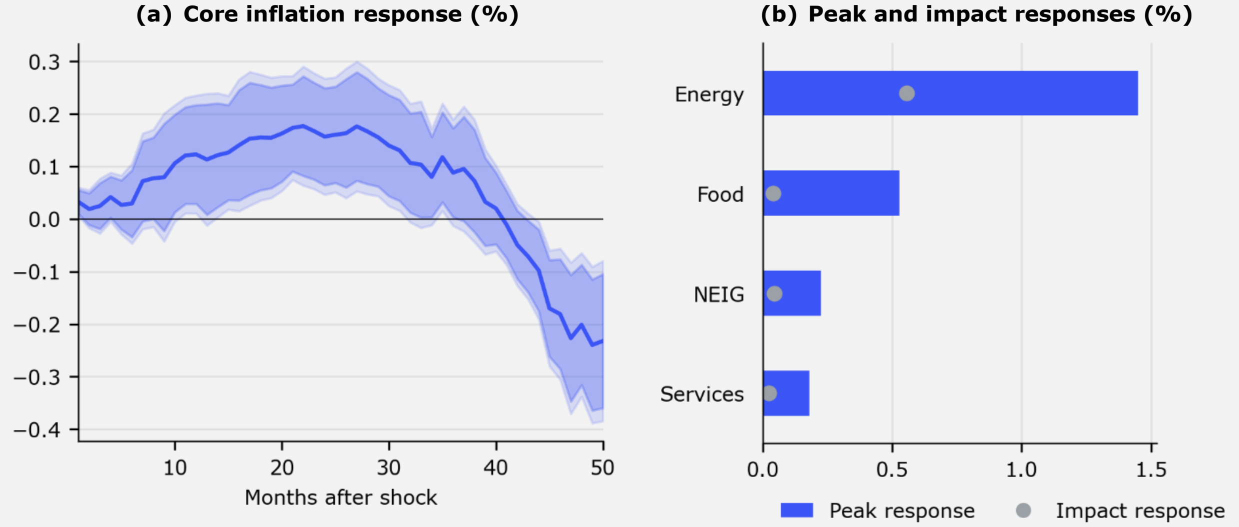
Source: own calculations

[4] Results for the Netherlands, which are reported in Appendix A.1, are very similar to those for the euro area. The persistent effect of global supply chain shocks on inflation has also been found by, among others, Finck and Tillmann (2022) and De Santis (2024) for the euro area, Liu and Nguyen (2023) for the US and Andriantomanga et al. (2022) for sub-Saharan countries.

warrants a more aggressive response, whereas a more transient impact would allow for a milder response or even for the central bank to 'look through' the shock. We discuss the optimal monetary policy response in more detail in Section 2.4.

Figure 2.3 Global supply chain shocks have a positive and persistent effect on inflation, with energy and food prices exhibiting the strongest responses

Inflation responses to a global supply chain shock



Note: Core inflation is measured as the year-on-year growth rate of HICP excluding energy and food. The size of the shock is one standard deviation. Light and dark blue shaded areas represent the 90% and 95% confidence level. The impact and peak responses are the year-on-year growth rate of different HICP sub-categories to a one-standard deviation global supply chain pressure shock. The impact response is the response occurring in the same month in which the shock occurs. The peak response is the greatest (positive) response over a horizon of 4 years.

Source: Eurostat and own calculations.

The inflationary effects are stronger for energy and food. Figure 2.3 panel b plots both the impact responses (grey dots) and peak responses (blue bars) of different HICP sub-components to the global supply chain pressure shock. All HICP sub-components show a positive response to such a shock, consistent with the fact that around 15% of the euro area consumption basket originates from outside the EU (Box 1). Compared with the United States, euro area households spend more on imports, with the corresponding share in the US at around 10%.[5] The strongest response to a global supply chain shock is found for HICP energy, reflecting the high reliance of euro area energy consumption on imports and global supply chains. At the other end of the spectrum, we find prices of services respond relatively mildly to the shock. Service categories are generally more oriented towards and reliant on domestic markets, and therefore less exposed to frictions in global supply chains. Nevertheless, even prices of such more domestically oriented products are to some extent sensitive to global supply chain disruption shocks, due to second-round effects triggered by the shock. In section 2.3, we focus on the responses of inflation expectations, wages and labour market conditions to global supply chain disruptions that are particularly relevant for second-round effects on price dynamics in the services sector.

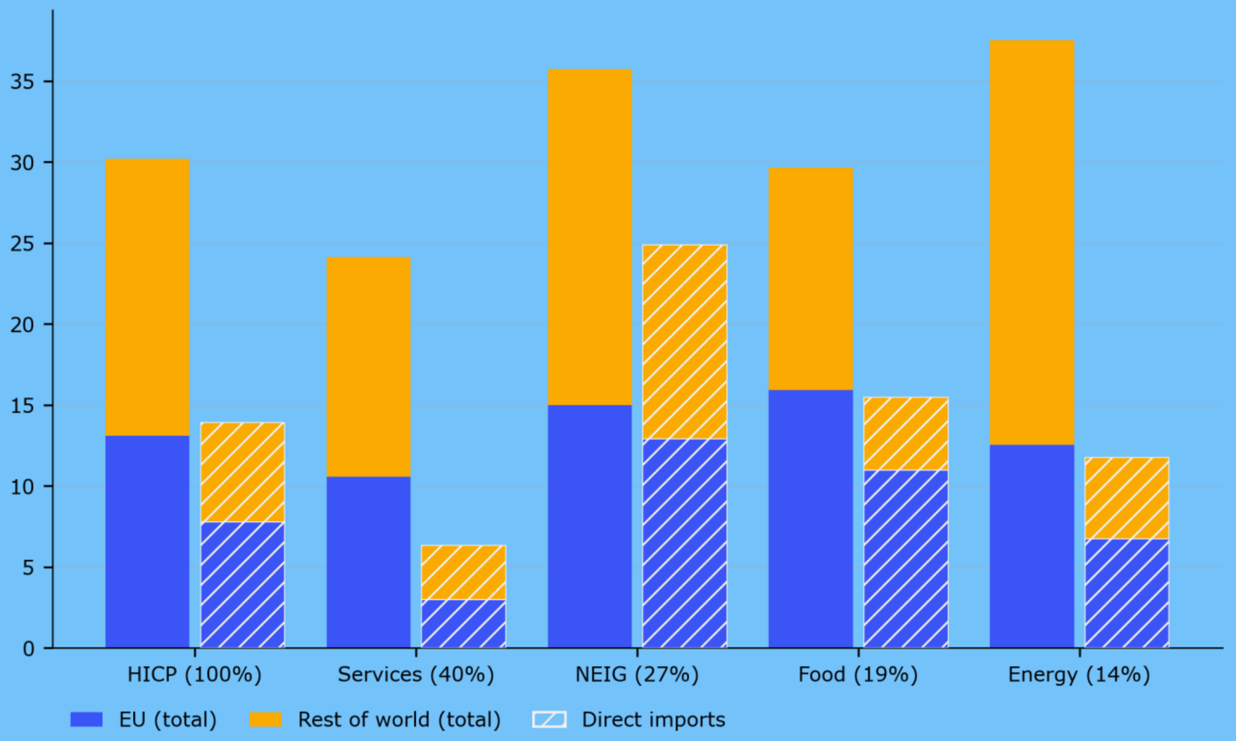
[5] See Hale et al. (2019). Note that the difference in import shares may partly reflect different data sources and methodological approaches.

Box 1 – The import content of euro area consumer prices (HICP)

This box quantifies the extent to which euro area consumer prices depend on foreign inputs by decomposing the consumption basket into domestic and imported components. We estimate the implied share of the import content of the HICP and its main sub-categories, distinguishing between direct and total imports. Direct imports consist of final goods and services purchased by households in the form in which they are imported, such as clothing or electronic devices. Total imports consist of all imports consumed by households, thus also considering indirect imports, such as raw materials and machinery, used in the production of goods and services which are consumed by households.

Figure B.1 Around 30% of euro area HICP originates from abroad, half of which from outside the EU

A comparison of total- and direct import shares in the EA HICP-consumption basket to region of origin



Note: HICP weights (in brackets). Intra-EU trade is classified as 'EU' (blue) and trade outside the EU as 'rest of world' (yellow). Import values are derived from 2023 FIGARO input-output tables at CPA-classification based on both intermediate inputs and primary factors. Values are converted from basic prices to purchaser prices by adding 'trade and transport margins' and 'taxes minus subsidies', which is assumed to accrue domestically. Import shares are converted to COICOP-classification via a bridge matrix (Cai and Rueda-Cantuche, 2019).

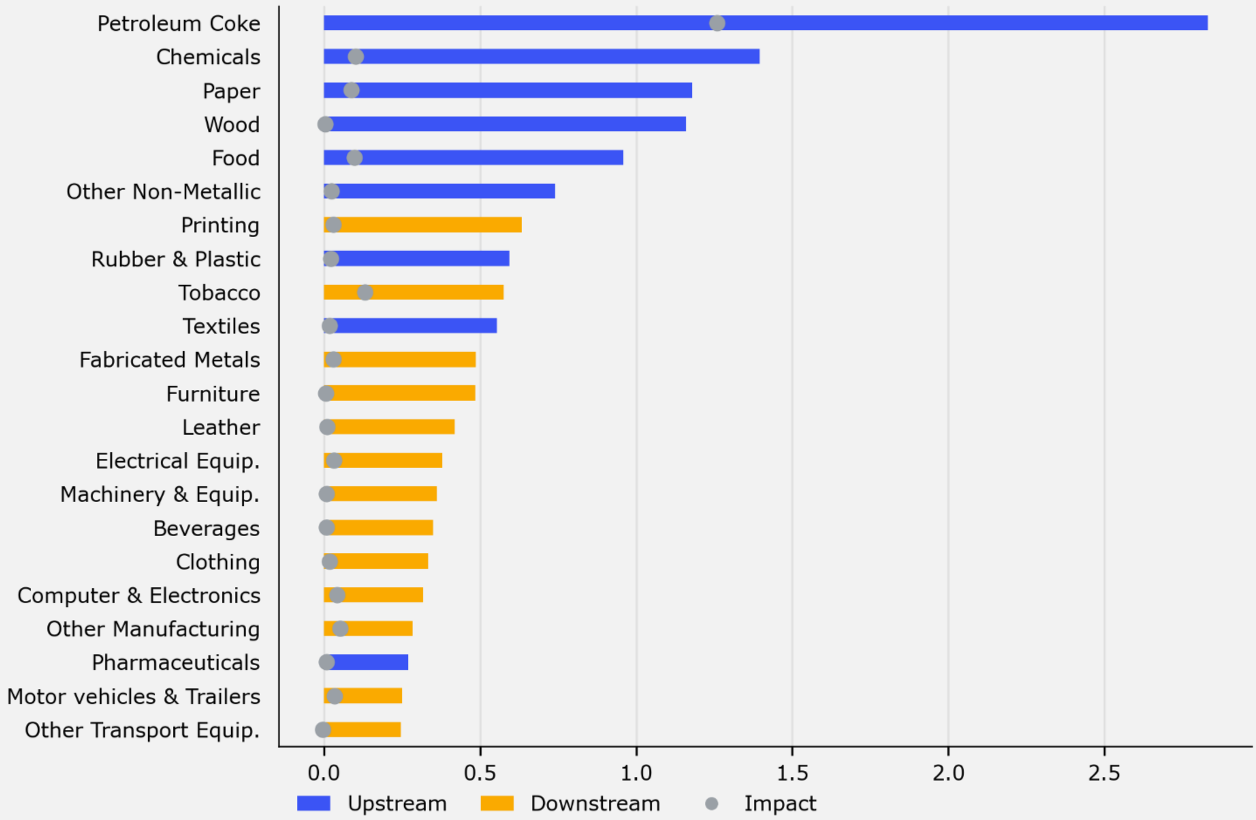
Source: Eurostat and own calculations

Around 30% of the euro area HICP-consumption basket originates from abroad, of which half from outside the EU, exposing euro area inflation to global supply chain disruptions. The first bar in the graph shows the total import share per HICP-subcomponent. The import share is highest for energy and non-energy industrial goods and lowest for services. The second bar shows the import share considering only direct imports. The graph also shows the country of origin of the imported goods. As the imports originating from outside the EU increase significantly going from direct imports to total imports for all HICP-subcomponents, this suggests imports from outside the EU used in the production of consumer goods constitute an important part of goods and services consumed by EA households.

Import shares are only one determinant of the pass-through of foreign price shocks to HICP inflation. While the peak responses to global supply chain shocks (Figure 2.3 panel b) are broadly in line with the import shares shown in this box, they also reflect other factors, including the origin of the shock, substitution possibilities, firms' pricing behaviour, and second-round effects through inflation expectations and wages.

Figure 2.4 Prices of upstream manufacturing goods are most sensitive to global supply chain disruptions

Responses of manufacturing prices to a global supply chain shock in percentage points



Note: The upstream/downstream classification is derived from ISIC Rev.4 activity descriptions (UN Statistics Division). NACE Rev.2 divisions C10–C33 were grouped based on whether output predominantly serves as intermediate input to other industries (upstream) or final consumption and investment (downstream), consistent with UN supply-use logic.

Source: Eurostat and own calculations

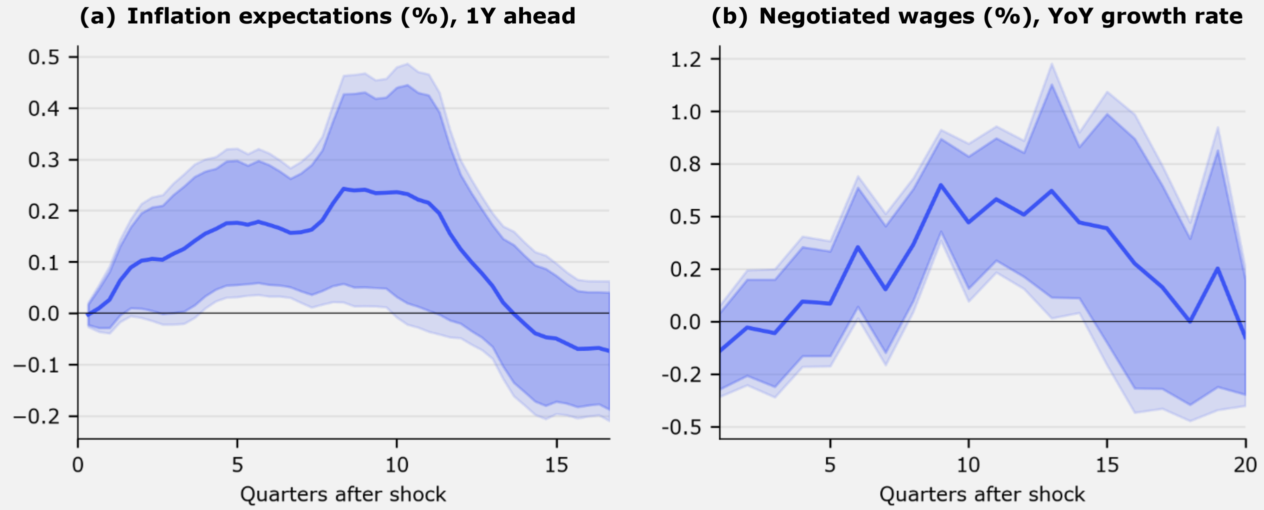
Prices of manufacturing goods that are more upstream in the supply chain respond more strongly to global supply chain pressure shocks. We can zoom further into different product categories by focusing on the dynamic responses of prices set by firms across the manufacturing sector in the euro area. This sector is of particular interest for our analysis, since it produces goods that are generally highly tradable and therefore likely more sensitive to external shocks, such as global supply chain disruptions (see also Friesenbichler et al., 2026). Within the manufacturing sector, some goods are more 'upstream' while others more 'downstream'. We define upstream goods as those goods that are predominantly used as an intermediate input to produce another good, whereas downstream goods are mostly used for final consumption. Figure 2.4 shows that, on average, the prices of upstream goods are more responsive to global supply chain pressure shocks than those of downstream goods.

2.3 Transmission channels

Global supply chain pressures are followed by an increase in inflation expectations. We examine the transmission channels of global supply chain shocks using the same approach as before, i.e. using the shocks as identified by the Bayesian VAR model in a series of local projection models for various variables of interest. Just like actual inflation, the response of short-term (1-year ahead) inflation expectations to a global supply chain pressure shock is hump-shaped: the initial response is weak yet builds up over time before it converges back to zero (Figure 2.5, panel a). This result reflects the fact that inflation expectations are not particularly sensitive to supply chain disruptions but are instead strongly driven by realized inflation. Therefore, even though global supply chain disruptions are pronounced and visible and grab everyone's attention, they only translate into higher inflation expectations once they result in inflation realisations actually picking up. In terms of magnitude, the response of inflation expectations to the global supply chain shock is about as strong as the response of inflation, as shown earlier in Figure 2.3 panel a. Higher realized inflation, in turn, drives up wages, which reflects workers' efforts to secure their *real* income and, thereby, their purchasing power (see Figure 2.5, panel b). Note that wages take longer to respond to the global supply chain pressure shock than inflation (expectations): the response doesn't become significant until almost two years after the shock.

Figure 2.5 Both inflation expectations and wages rise following global supply chain disruptions

Responses of inflation expectations and wages to a global supply chain shock

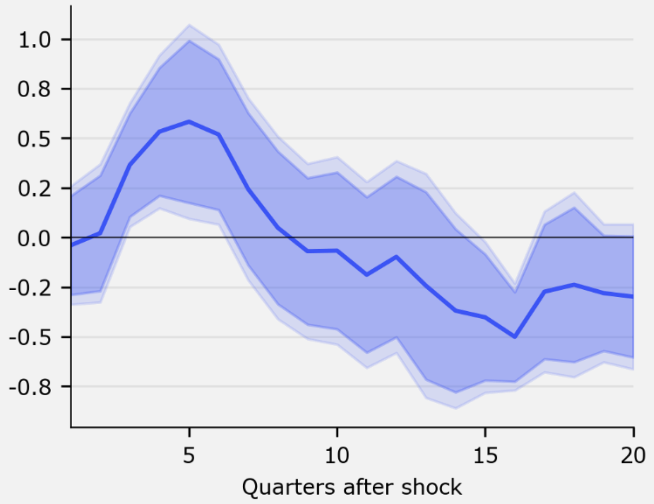


Note: 1-year ahead inflation expectations are constructed as the weighted average of current and next year expectations of the year-on-year growth rate of consumer prices, taken from Consensus Economics. Light and dark blue shaded areas represent the 90% and 95% confidence level.

Source: Consensus Economics, ECB and own calculations

Figure 2.6 Global supply chain shocks temporarily raise profits

Response of the profit share (%) to a global supply chain shock with confidence bands



Note: The profit share is defined as the ratio between profits and value added. Light and dark blue shaded areas represent the 90% and 95% confidence level.

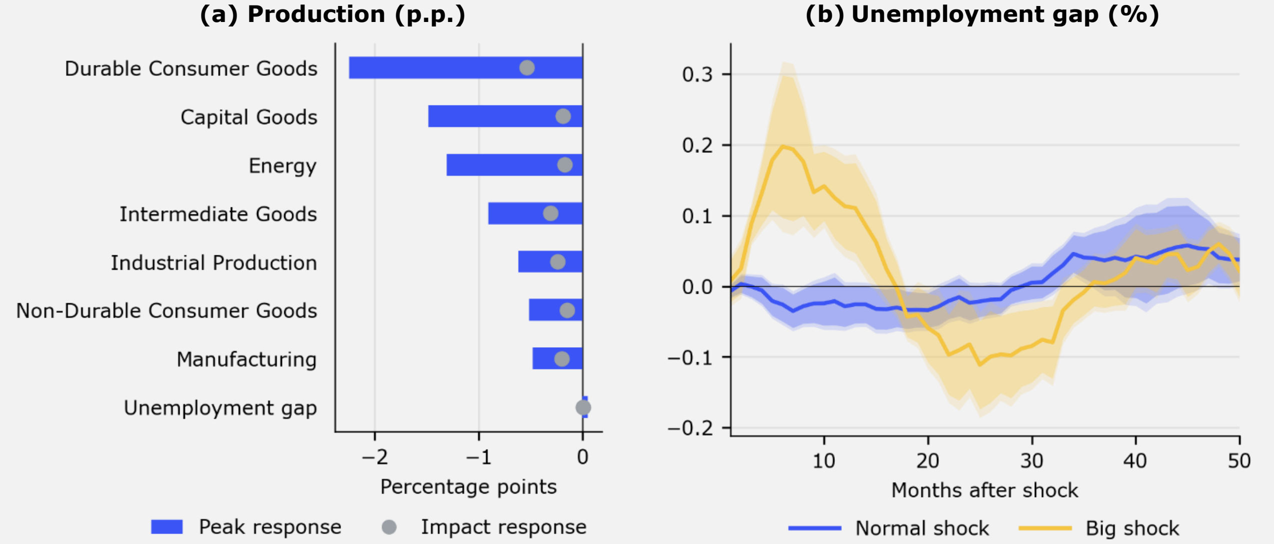
Source: Eurostat and own calculations

Global supply chain pressures result in a small and short-lived increase in firm profits (Figure 2.6). When disruptions to global supply chains create a scarcity of necessary inputs – that cannot easily be replaced by alternative suppliers in the short run – firms dependent on these inputs face greater input costs. If such firms maintain a fixed markup over marginal costs, and prices adjust one-for-one with marginal costs, then the profit share would remain constant as long as all factor payments adjust proportionally. However, if prices increase while nominal wages adjust slowly, real wages fall. This reduces the labour share of value added and leads to a (temporary) increase in the profit share, even in the absence of higher markups. The strength of this effect increases with higher pass-through of input costs to producer prices, more flexible producer prices, more rigid nominal wages, and a smaller role of labour costs in value added. Moreover, low short-run demand elasticity can strengthen this mechanism by limiting the negative impact of higher producer prices on sales volumes and profits.

Production declines following a global supply chain disruption, while labour market conditions do not change much, unless the disruption is historically severe. Figure 2.7 panel a, shows that – alongside a rise in prices, especially in tradable and upstream sectors – global supply chain shocks have an adverse effect on firm production. These effects appear to be most pronounced in sectors that are relatively more capital intensive – such as durable consumer goods, capital goods and energy – which rely heavily on large production facilities, machinery and automation. The response of the unemployment gap to a global supply chain pressure shock is positive yet relatively muted. However, when we isolate the responses to only very big shocks, which we define as shocks greater than twice the standard deviation of the shock series, then we find a much more substantial and persistent impact on the unemployment gap (Figure 2.7, panel b). At around 2 years, the impact of the latter on labour market conditions dies out and equilibrium is restored. This result points to an important non-linearity in the transmission of global supply chain disruptions: larger disruptions have a disproportionate impact on the macroeconomy more broadly as they hamper production, not only in sectors most directly exposed to global supply chains, but also in more domestic-oriented sectors. Moreover, larger disruptions will likely take more time to unwind and thereby induce greater pressure on demand and employment to restore the balance between supply and demand. In contrast, the impact of 'normal' shocks (that are smaller than twice the standard deviation) on the unemployment gap is much more muted and even negative in the months that follow immediately after the shock. This negative response could reflect a brief rise in the production of domestically produced goods that arises as domestic firms face less competition from abroad and there is a need to substitute away from imported goods.

Figure 2.7 Production declines following global supply chain disruptions, while the labour market response depends on the severity of the disruption

Responses of production activity and the unemployment gap to a global supply chain shock



Note: Production is measured as the year-on-year growth rate of production volume. The unemployment gap is measured as the difference between the unemployment rate and its HP-filtered trend. In panel b, the response labeled 'big shock' ('normal shock') is conditional on the global supply chain pressure shock being larger (smaller) than 3 times its own standard deviation. Shaded areas represent the 90% and 95% confidence level

Source: Eurostat and own calculations

2.4 Monetary policy responses to supply-driven inflation

This section discusses the implications of global supply chain disruptions, and supply-driven inflation more generally, for the conduct of monetary policy. We focus on optimal monetary policy as prescribed by economic theory and the lessons we can draw from the actual conduct of monetary policy in the euro area.

2.4.1 Optimal monetary policy response in theory

A large literature studies how monetary policy should respond to supply shocks in New Keynesian models with nominal rigidities. An important starting point in this literature is that such shocks cannot be undone by monetary policy. When production costs rise, this reflects a deterioration in the real economy that monetary policy cannot reverse. Instead, higher costs lead to both higher inflation and lower output, confronting policymakers with a trade-off. Tightening monetary policy can help contain inflation, but at the cost of further weakening economic output, while supporting output would risk adding to inflationary pressures (Clarida, Galí and Gertler, 1999; Woodford, 2005).

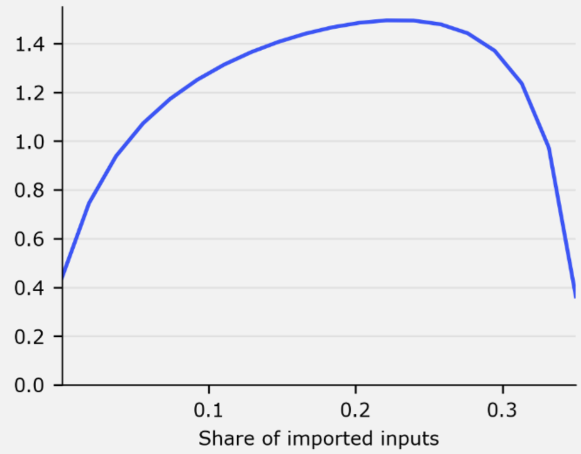
In this context, the textbook prescription is often to 'look through' such shocks, particularly when they are expected to be temporary, and to avoid reacting to short-lived increases in inflation. However, this approach has limits. When supply shocks are large, persistent or broad-based, they are more likely to feed into wages, expectations and pricing behavior, making inflation more persistent and increasing the risk of second-round effects, as also emphasized in the ECB's monetary policy strategy review (ECB, 2025a). As a result, monetary policy needs to strike a balance between accommodating the initial impact of the shock and preventing inflation from becoming entrenched. This implies that optimal monetary policy does not fully offset the increase in inflation, but instead allows for a more gradual adjustment of inflation to its target.

To illustrate this trade-off, we analyze the optimal monetary policy response to global supply chain disruptions using a stylized framework that features international trade linkages. Our analysis is based on an open economy New Keynesian model with trade in intermediate goods between two countries, Home and Foreign, following Ascari, Bonam and Smadu (2024). Global supply chain disruptions are modelled as adverse foreign supply shocks that reduce the availability of foreign inputs that are used in the production of domestic final goods. Countries' reliance on global supply chains is governed by the share of foreign intermediate inputs in domestic production. We evaluate monetary policy in Home under Ramsey optimal policy, which maximises welfare of households that live in Home (see Ascari et al., 2024, for more technical details).

Figure 2.8 The model-implied optimal response depends on import dependence

Optimal monetary policy response

Model-based cumulative response of policy interest rate to global supply chain shock under optimal policy



Note: The simulations are based on an open economy New Keynesian model with trade in intermediate goods between two countries, Home and Foreign. The global supply chain shock is proxied by an adverse productivity shock in Foreign that reduces the supply of Foreign intermediate goods that are used in the production of goods in Home. The figure shows the cumulative response (over 5 years) to this shock of the interest rate set by the central bank in Home that maximises the welfare of Home households. See Ascari et al. (2024) for more details. Units are expressed as annualised percentage points.

Source: own calculations

In the model, global supply chain disruptions generate inflationary pressures while simultaneously weighing on economic output. When supply conditions abroad deteriorate, imported inputs become scarce and more expensive. Firms that depend on these inputs face higher costs and reduced production capacity, pushing up prices while constraining output. These mechanisms capture, in a simplified way, the inflation-output trade-offs faced by monetary policymakers: bringing down inflation through higher interest rates risks worsening the contraction in output, while stimulating output by lowering interest rates could add to inflationary pressures.

The strength of these effects depends critically on the degree of import dependence. When reliance on imported inputs is limited, higher foreign prices shift demand towards domestically produced goods and support domestic output, which raises domestic inflation. In contrast, when economies are more open and internationally integrated, supply disruptions feed directly into domestic production costs, which reduces domestic output and simultaneously amplifies the impact on inflation.

In the model, the prescribed monetary policy reaction varies non-linearly with a country's import dependence. This relationship is illustrated in Figure 2.8, which plots the cumulative policy interest rate response under optimal policy as a function of the share of imported inputs used in domestic production. Although the central bank faces a trade-off between stabilising inflation and output, the welfare-optimal response to global supply chain disruptions involves a tightening of monetary policy which is needed to limit the distortionary effects of inflation. When import dependence is low, tightening can be relatively moderate, as it will mainly offset demand-driven inflationary pressures. As the economy relies more strongly on global supply chains, stricter tightening is warranted as supply chain disruptions have stronger inflationary effects. However, once import dependence is very high, monetary policy tightening should be less aggressive. In this case, supply chain disruptions are not only inflationary, but also lead to sizeable contractions in output and employment as firms cannot easily substitute away from foreign inputs. Figure 2.8 shows that, under greater degrees of import dependence, the optimal policy response becomes more cautious to avoid amplifying the economic downturn. These results highlight that monetary policy faces limits when responding to supply-driven shocks and that the optimal response depends on the economy’s exposure to global supply chains.

The results in this subsection should be interpreted as a theoretical benchmark that assumes full information and well-identified shocks. The Ramsey optimal policy describes how monetary policy would ideally respond if policymakers could clearly identify the origin, size and persistence of a global supply chain shock and fully internalize its transmission through prices, output and welfare. In practice, such shocks are not directly observable, may coincide with other disturbances affecting demand and pricing behavior, and often exhibit strong state dependence and non-linearities (as shown in Figure 2.8). The implications of these real-world complications for monetary policy are discussed in the following subsection.

2.4.2 How did the ECB respond to supply-side shocks in the past?

Historically, monetary policy has tightened in response to a global supply chain pressure shock. We capture the monetary policy stance by the euro area shadow rate (as estimated by Krippner, 2013), rather than the policy rate, as the latter does not capture the accommodative instruments used by the European Central Bank (ECB) once the policy rate became constrained by its effective lower bound. These instruments include large-scale asset purchases, forward guidance and targeted long-term financing operations. Figure 2.9 shows that, in our sample, a global supply chain pressure shock of one-standard-deviation is associated, on average, with an increase in the shadow rate of around 0.25 percentage points at its peak. This response builds up gradually and indicates a tightening of monetary policy. This pattern is consistent with the inflationary pressures following such shocks and the ECB’s price stability mandate. Figure A1.5 in Appendix A1 shows that greater shocks (i.e. those that are larger than twice the standard deviation of the shock series) elicit a more gradual yet ultimately more persistent and stronger monetary tightening than smaller shocks. This more gradual approach could reflect a less favourable trade-off between addressing, on the one hand, the inflationary consequences of global supply chain disruptions and, on the other hand, the economic fallout from these disruptions. At the same time, historical monetary policy responses differ across episodes, reflecting judgement about inflation persistence, risks of second round effects and the state of economic output.

Uncertainty about the size, persistence and transmission of supply shocks complicates monetary policy in practice. Unlike the benchmark setting discussed above, such shocks are not directly observable in real time, and their effects on inflation and output depend on firms’ pricing behavior and production structures, including input-output linkages. Transmission is often state dependent: smaller shocks may be absorbed through profit margins, while larger or more persistent shocks are passed through along value chains, generating broader price pressures (ECB, 2025a).

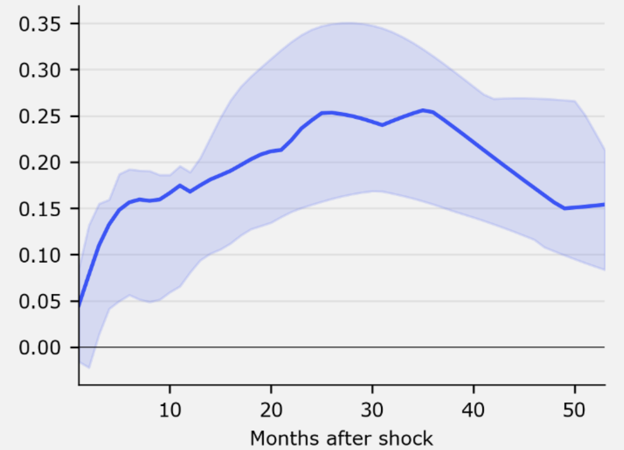
Consistent with recent policy discussions (Lagarde, 2026), the monetary policy response ranges from looking through temporary shocks to stronger tightening as shocks become larger or more persistent. In this context, and consistent with our findings on non-linear and persistent inflation effects, the scope for 'looking through' supply-driven inflation becomes more limited when shocks are large or broad-based, as these are more likely to generate persistent price pressures and second-round effects. This is also in line with recent evidence on state dependence and non-linear price and wage dynamics (ECB, 2021a; Ascari et al., 2025).

In hindsight, the ECB's rate hikes in 2008 and 2011 illustrate the difficulty of assessing supply-driven inflation pressures in real time. Following the financial market turmoil of 2007, headline inflation peaked in mid-2008 amid rising energy and commodity prices. At the time, Eurosystem staff forecasts pointed to inflation remaining above 3% until 2009 and above 2% until late 2010. Against this backdrop, concerns about credibility and second-round effects prompted an interest rate hike in July (Rostagno et al., 2019). In retrospect, this decision appears excessive given the build-up of financial imbalances and the subsequent crisis. A similar pattern emerged in 2011: although energy-driven inflation rose sharply and created sizeable upstream inflationary pressures, projections showed inflation would soon peak while underlying inflation remained subdued (Rostagno et al., 2019). The subsequent policy tightening amplified financial and sovereign stress at a time when aggregate demand was still depressed.

Figure 2.9 The ECB has tightened in response to past global supply chain shocks

Monetary policy stance in euro area

Response of the shadow rate (%) to a global supply chain shock



Note: The shaded area represents the 68% posterior credibility sets. Note that these are different from the confidence intervals around the impulse responses from the local projection models, which are frequentist sampling-uncertainty bands. The sample period is the same as in the figures based on the BVAR (2001 to 2025).

Source: Krippner (2013) and own calculations.

The 2022 episode shows that sufficiently large and persistent shocks can trigger a rapid adjustment in policy. Following an initially gradual response, the ECB increased the policy stance by approximately 450 basis points cumulatively between July 2022 and September 2023. The inflation surge again reflected the difficulty of assessing interacting supply-driven pressures in real time. The combination of rising energy prices, global supply disruptions and the war in Ukraine generated broad-based inflation, while strong demand during the post-pandemic recovery added to upward pressure, with supply factors particularly important in the initial phase (ECB, 2025a; DNB, 2024). As these disruptions proved more persistent than initially expected, inflation gradually spread across sectors and became more entrenched, reflecting second-round effects through wages, expectations and firms' price-setting behaviour. Against this background, the ECB gradually normalised and tightened its monetary policy stance from mid-2022 onwards. In hindsight, policy initially lagged the inflation surge but caught up through a rapid and forceful tightening cycle, bringing policy broadly in line with economic conditions. While earlier action would likely have reduced the inflation peak, it would also have come at the cost of weaker economic output.

Looking ahead, central banks face a more uncertain, fragmented and structurally complex global environment. Global shocks now account for a larger share of domestic business-cycle fluctuations and tend to be more persistent and supply-driven (Forbes et al., 2026). Our results suggest that this shift is particularly relevant when disruptions affect upstream or widely used inputs, or when shocks are large, as such disruptions can generate more persistent and broad-based inflationary pressures than suggested by average historical estimates. Structural transformations driven by geopolitics, trade reconfiguration, technological change, population ageing and climate risks are reshaping the global economy and increasing uncertainty. These ongoing structural changes complicate the separation of cyclical and structural forces shaping inflation (Kozicki, 2026), while increased supply chain complexity and geopolitical tensions are likely to amplify future shocks. In such an environment, understanding the economy’s exposure to global supply chains and critical inputs becomes increasingly important for assessing the inflation–output trade-off faced by monetary policy.

3 Identifying supply chain vulnerabilities at the product level

3.1 Identifying supply chain vulnerabilities

Countries weaponise positions in supply chains to achieve geopolitical aims, leading to new risks of supply chain disturbances. Recent examples include conflicts over semiconductor lithography, advanced chip manufacturing, rare earth minerals and fossil fuel energy supplies. These examples all involve products that occupy a central position in global production networks, meaning that they are necessary for the production of a wide variety of downstream products. As discussed in section 2.2, the more central the affected production, the stronger the effects of a supply chain disruption. Moreover, each of these examples showcases significant production concentration, which means that one or a small group of countries control production, allowing for effective exertion of geopolitical pressure. While these forms of intentionally induced supply chain disruptions are not new, with the 1973 oil crisis being perhaps the most infamous example in living memory, the opportunities for weaponisation of supply chains have increased with the high level of vertical supply chain integration over the past half a century (see chapter 1).

This chapter focuses on identifying these critical supply chain vulnerabilities for Europe at the product level. To this end, we use an (unpublished) FIGARO-HS dataset which contains granular trade data for over 5,000 products,[6] which we connect in supply chains to EU critical goods and technologies using an AI-generated production network. We analyse both the sectoral[7] and geographical distribution of products that are vulnerable to supply chain disruptions (hereafter: vulnerabilities), as well as their persistence over time and their position within the supply chain. In addition, we assess the potential for product substitution within the EU by examining how closely current vulnerabilities align with existing European production structures. Finally, we draw some conclusions and policy recommendations aimed at mitigating critical supply chain dependencies.

3.1.1 Earlier work to map Europe's supply chain risks

A growing body of studies has sought to map Europe's supply chain risks to strengthen economic resilience and strategic autonomy. One of the first comprehensive exercises to identify EU external dependencies was carried out by the European Commission (EC, 2021) in the context of the update of the EU industrial strategy. That study introduced a two-step methodology based on granular product-level data. In the first step three core dependency indicators (CDIs) were used to identify products with 1) low level of import diversification, 2) for which foreign sources were particularly relevant for the EU, 3) and where the substitutability potential with EU supply was limited. In the second step the dependent products were manually matched to a set of pre-defined strategic and sensitive ecosystems.[8]

Later studies have proposed several data and methodological improvements to the EC study. The 2023 update of the EC corrects for re-export bias (mostly for EU countries) using FIGARO data, adds an additional 'rank' approach to the CDIs in addition to the threshold approach, and uses a longer time window to account for time-variance of trade dependencies. Bruegel (Mejean & Rousseaux, 2024) add two extra indicators that narrow the set of flagged goods to a much smaller subset of genuinely hard-to-replace dependencies. The

[6] The FIGARO-HS database is jointly compiled by Eurostat in collaboration with the European Commission's Joint Research Centre. In this paper, we used the underlying (unpublished) version of the trade data as described in Remond-Tiedrez and Rueda-Cantuche (2019, chapter 6).

[7] More precisely, we aggregate our analysis at the HS-1 product category level. We acknowledge that product categories do not map one-to-one to industries or sectors: a given product category may be produced by multiple industries, while a single industry may produce products spanning several HS categories (e.g. Dietzenbacher & Romero, 2007). For expositional simplicity, however, we use the terms *product category* and *sector* interchangeably in the remainder of the paper.

[8] 1) security and safety, 2) health, 3) the green and digital transformations.

first is a more stringent indicator for intra-EU substitution based on actual production data (Prodcom). The second is a "relationship stickiness" measure to proxy how hard supplier substitution would be after a shock. Moreover, they introduce an 'upstreamness' metric calculated as the average number of stages between the production of a good and its absorption by final consumers, labelling a product more 'upstream' if it enters value chains earlier in the production process. The idea is that dependencies in these upstream goods are more problematic because shocks to intermediate inputs can cause a ripple effect throughout the production chain. In a similar vein, the European Commission (EC, 2023) introduced a methodology to identify so-called single points of failure (SPOFs), focusing on exporters that are highly central in the global trade network while also accounting for a large share of world exports. The underlying assumption is that disruptions affecting such central nodes could have far-reaching consequences for global trade, particularly when these exporters cannot be easily substituted. The ECB (2025c) applied this SPOF approach for selected cases and links the resulting dependencies to model-based estimates of potentially disproportionate output/inflation costs from supply disruptions. Table 3.1 summarizes the methodological choices of the three studies described above, including those of the current study.

Table 3.1: similarities and differences with earlier studies mapping EU supply chain vulnerabilities

Study	Concentration	Critical good	Centrality	Application
EC, 2021/ 2023	• Import HHI>0.4 • EU not top exporter • Intra-EU trade <50% global trade	• Strategic ecosystems*	First-step centrality**	List of critical dependencies for policy purposes
Mejean & Rousseaux (2024)	• As EC • Prodcom data for EU production	• Strategic ecosystems • Stickiness	• Upstreamness • Production stage	Improving identification methodology, thereby policy
ECB, 2025c	• As EC • Global export concentration (for cases)	• Strategic ecosystems	First-step centrality	Comparison China, US, EU; development dependencies over time
DNB, 2026	• As EC, but looks at global export instead of import HHI>0.4 • Prodcom data for EU production	• Strategic ecosystems	Links to end products based on value chain data	Identification of goods with risk of supply chain disturbance

Note: * All studies listed in this table identify critical goods based on predefined strategic and sensitive ecosystems, such as products essential for the green transition; **First-step centrality is a measure of the number of countries to which a product is traded, which is directly observable from the FIGARO-HS dataset.

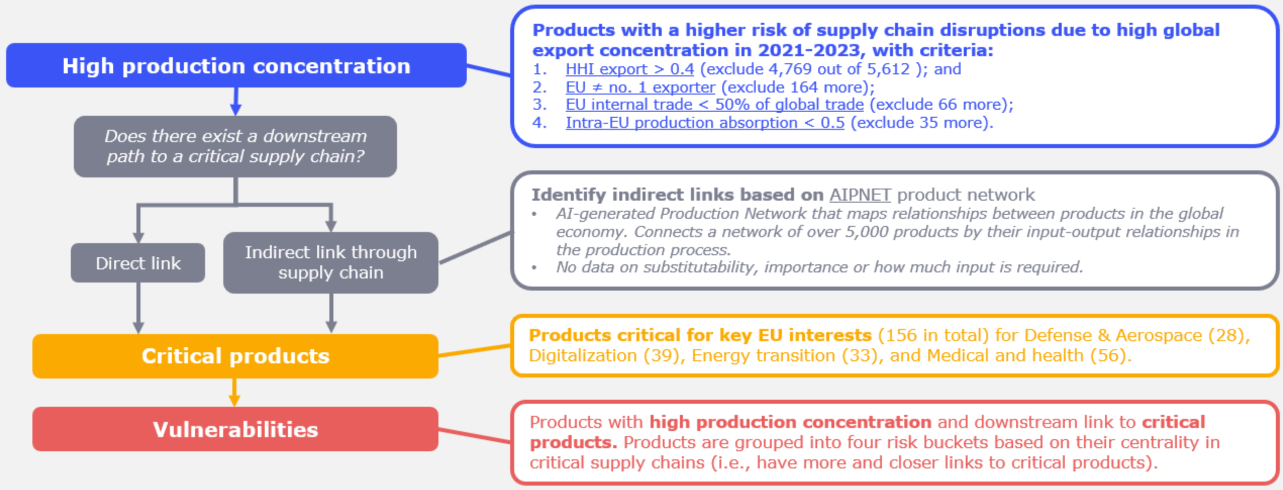
3.1.2 Methodology of this analysis

While earlier studies primarily mapped geopolitical dependencies, our analysis focuses on identifying vulnerabilities arising from supply chain disruptions. This broader lens captures risks along global value chains, including disruptions that are not directly targeted at the EU but may nonetheless affect its economy by propagating downstream. This analysis proceeds in three steps: 1) it identifies products with high production concentration outside the EU using the FIGARO-HS database, 2) it compiles a list of critical goods and technologies based on the literature and links these to specific products, and 3) it assesses whether the goods identified as highly concentrated outside the EU can be linked to these critical goods and technologies using

AIPNET[9] - an AI-generated production network that captures input–output relationships between products. The first two steps are standard in the literature, where we focus – in line with the EC (2023) and ECB (2025c) studies - on production rather than import concentration since we are also interested in broader global supply chain disruptions. As table 3.1 shows, the main contribution of this analysis is the third step. Where earlier analyses looked only at first step centrality, the use of AIPNET enables us to look at vulnerabilities higher up in the supply chain. Another point where this analysis adds to the existing literature is that it introduces a method to identify which countries are best positioned to reduce EU-wide dependencies based on a proximity indicator (section 3.4). The three-step approach of this analysis is visualized in figure 3.1 and will be explained in more detail below. A complete description of methods and data used can be found in Appendix A.2.

Figure 3.1 Methodological steps from all HS6-products to vulnerable products

Steps from all HS6-products to vulnerable products



Source: DNB (2026)

Step 1: Production concentration is measured as the extent to which the global production of a good is dominated by a limited number of countries. A very high concentration signals a greater risk of supply disruptions: a single producer (or small set of producers) can restrict output or weaponise supply, and other suppliers may not be able to rapidly scale up or enter the market, reflecting a low supply elasticity. To gauge this, in our study a product is flagged as "highly concentrated" if it meets the following four criteria. First, the Herfindahl–Hirschman index (HHI) of export shares exceeds 0.4. Second, the EU must not be the world's leading producer. In other words, such a good's supply is largely in the hands of one or a few foreign countries. Third, intra-EU trade must not represent more than 50% of the value of global trade. And fourth, EU production data do not show production of more than 50% of global trade. The third and fourth criteria capture an inability to use domestic stocks or production for compensation of reduced imports. In line with EC (2023) we use FIGARO-HS trade data (HS 6-digit) that corrects for re-export bias (mostly for EU countries). Since trade vulnerabilities can

[9] See for a full description of the model Fetzer et al. (2024).

vary greatly from one year to the next (Vicard and Wibaux, 2023) we are pooling trade data over three consecutive years, from 2021 to 2023, thus focusing on persistent trade vulnerabilities.[10]

Step 2: Critical goods and technologies are derived from policy and literature sources and linked to product codes. Not all concentrated products are equally likely to be used geopolitically to cause a supply chain disruption. What makes a supply concentration vulnerable is if the product in question is necessary for goods with critical applications, such as products that are essential for healthcare, defence, energy or digital infrastructure. A disruption in such an input could be strategically exploited to inflict economic harm. In our analysis, we operationalise this concept as follows. First, drawing on policy and literature sources (detailed in Appendix A2), we assemble a list of 155 critical goods and technologies grouped into the themes defence & aerospace, energy transition, digital technology, and health/biopharma. Second, we link these goods and technologies to specific product codes. For example, solar panels are identified as critical good based on the Net-Zero Industry Act and were subsequently linked to five HS-codes covering (assembled) PV cells (HS 854143, 854142) and PV generators (850171 – 850173). This step is similar to the critical industries approach taken by the EC (2021; 2023), Mejean & Rousseaux (2024) and the ECB (2025c).

Step 3: Tracing each product with high production concentration (identified in step 1) to see if it is used as an input in the production of any of the critical goods (identified in step 2) using an AI-based production network. Earlier studies that looked further in the supply chain typically focused on specific critical goods such as batteries (e.g. TNO, 2023) or raw materials (EC, 2023), relying on extensive desk research and expert judgement. Given the broader scope of this analysis - which aims to identify vulnerabilities across the economy as a whole - such an approach is not feasible here. Instead, we employ the AIPNET AI-based production network, which maps input–output relationships among approximately 5,000 products, to identify direct and indirect linkages between concentrated products and critical goods and technologies which we manually checked. Other studies, notably Berthou et al. (2024) and Lemmers et al. (2023), have used alternative methods for mapping supply chains, which allow for quantification of shocks but are less suitable for identifying geopolitical vulnerabilities. We then establish a four-bracket indicator of centrality, which is based on the number of times a product is part of supply chains of critical goods, and how many supply chain steps there are between the good and the critical application. The more often a product is used, and the fewer the supply chain steps to the critical good, the more central we consider it to critical supply chains. This yields a higher risk of producers exerting geopolitical pressure by withholding exports. All methodological details – including the definition and sources of critical goods, the mapping of products to that list, and supply chain mapping – are provided in the Appendix A2.

3.2 Mapping EU supply chain vulnerabilities

3.2.1 Concentration and vulnerabilities

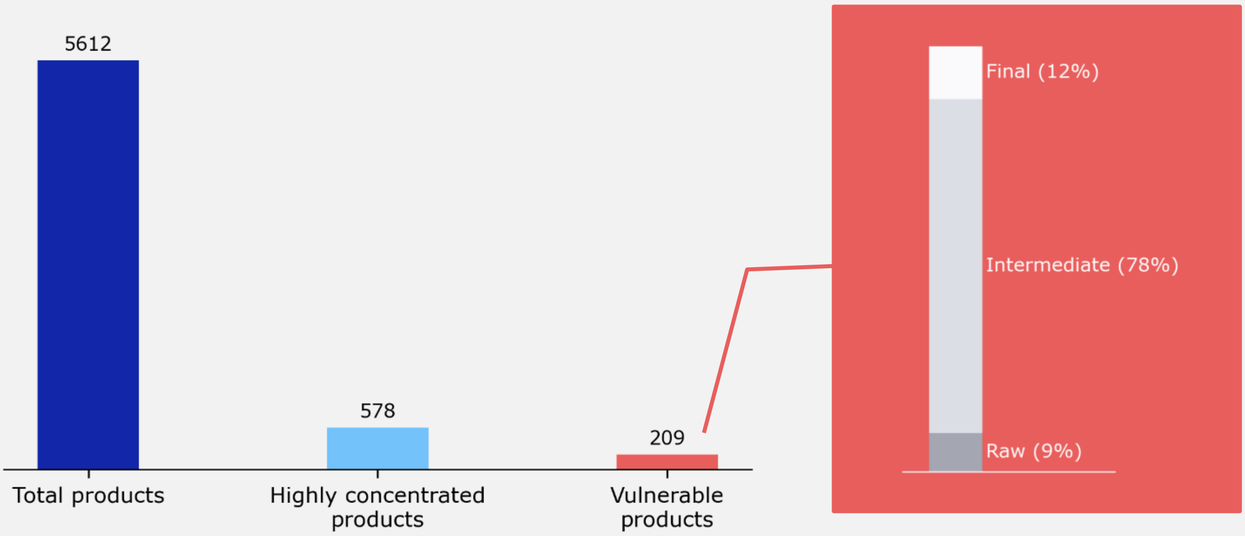
According to our criteria, 209 products are vulnerable to supply chain disruptions. We start with the full dataset of 5,612 goods. These are all goods that are present in at least one year of the HS6-trade-dataset between 2021 and 2023. Production of 10% of goods is globally concentrated outside of Europe, leaving us with a set of 578 goods with high production concentration (see figure 3.2). As defined in section 3.1, these are

[10] The exact concentration metrics, thresholds and data sources are described in more detail in Appendix A2.

goods which are produced by so few countries that exports can effectively be withheld, and in the production of which Europe does not control a significant stake. For other goods, greater import diversification reduces the likelihood that a few countries can exert geopolitical leverage through export restrictions. About one in three of the concentrated products can be linked to a critical application. In this step, for example, many food items are excluded. These two steps yield a total of 209 vulnerable products, representing 4% of all goods in our data. Out of these 209 vulnerabilities, only 11 appear directly on the lists of critical goods, with the remaining 198 being part of the supply chains of critical goods.[11] Examples of products with direct links to critical goods are PV panels (850172) and medicaments containing insulin (300331). Examples of one-step and multi-step links are cobalt ores (260500) that link to permanent magnets and Chromium ores (261000) that link to armored vehicles via stainless steel (721891/9). The large share of intermediate goods (78%) and raw materials (9%) among vulnerable products underscores the importance of identifying vulnerabilities further upstream in the supply chain.

Figure 3.2 Only a small fraction of all products (4%) is classified as vulnerable

Steps from all HS6-products to vulnerable products, 2021-2023



Note: persistent vulnerabilities over the years 2021-2023 where the production stage (right) is based on the UN BEC classification.

Source: Own calculations based on FIGARO-HS, Prodcom database and AIPNET

3.2.2 Vulnerabilities by sector

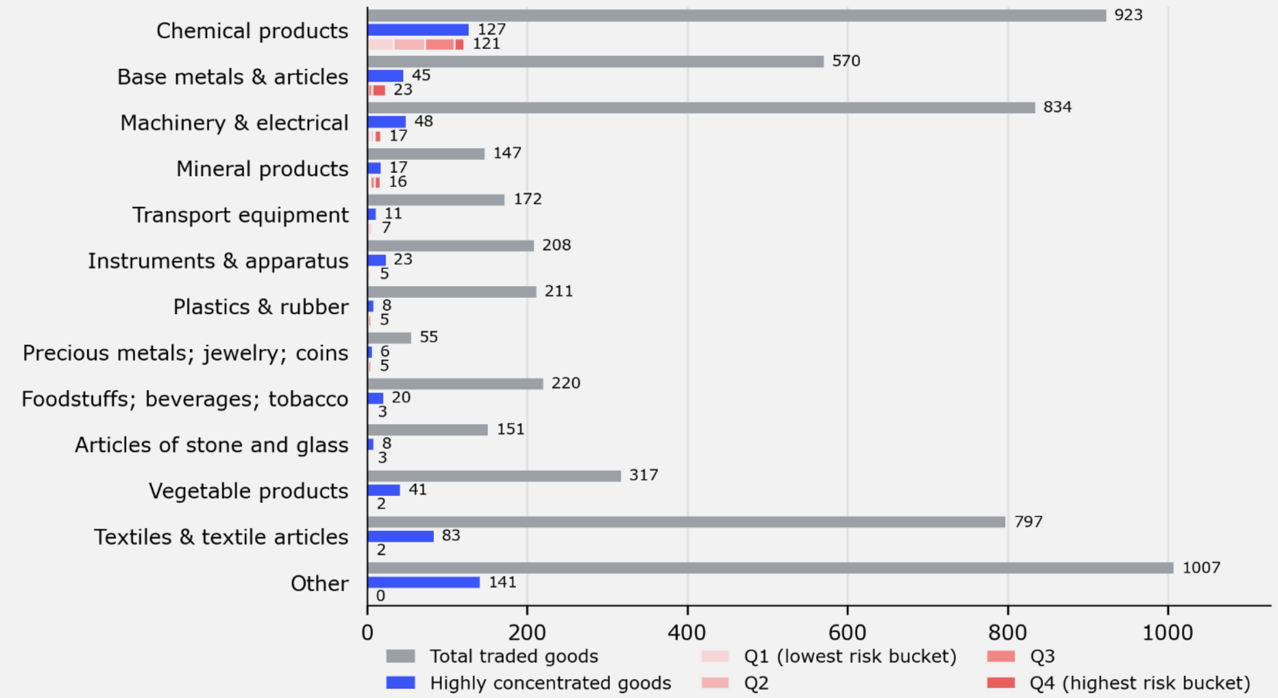
Even in the sectors with the highest share of vulnerabilities, only a small percentage of all products is vulnerable. Figure 3.3 shows that in the chemical products sector, the share of vulnerabilities among all goods is the highest at 13% (121 out of 923), followed by mineral products at 11% (16 out of 147). All other sectors have a percentage of less than 4%. Figure A2.2 in the appendix shows that, measured as a share of total export value, vulnerable products account for an even smaller fraction, with the share in chemical products falling to 4%. Conversely, as a share of all vulnerabilities, the chemical products sector represents a significant

[11] Applying AIPNET yielded links between 390 of the 578 concentrated products and critical goods. Following manual corrections, 209 products were retained for the analysis. The excluded products were mainly animal and vegetable products.

share of 58% (121 out of 209) of total products. Again, looking at the share of chemical products in the total export value of all vulnerabilities, this is significantly lower at 16%. A caveat to these findings regarding vulnerabilities among chemical products is that the necessity and substitutability of chemical products in practice is hard to assess without detailed technical knowledge of the application of chemical products in specific end products. It is hence possible that the data mostly reflects high production concentration (=blue bars in graphs 2.2 and 2.3), but not actual vulnerabilities in chemical production. The remaining vulnerabilities are spread over a wide variety of product categories, including, machinery, mineral products and transport equipment. This distribution is in line with earlier studies (e.g. EC 2021/23, Mejean & Rousseaux, 2024). In summary, while recognizing a potential cluster of vulnerabilities in the chemical products sector, for policy purposes vulnerabilities can best be identified at the product level (Mehlbaum and Heerma van Voss, 2025). For all sectors, a sectoral policy aimed at overcoming vulnerabilities is largely untargeted, affecting mostly goods that are not vulnerable.

Figure 3.3 Even in the sectors with the highest share of vulnerabilities, only a small percentage of all products is vulnerable

Number of total, concentrated, and vulnerable products per sector (2021-2023)



Note: Product categories are based on HS sections; Other aggregates all sections without vulnerable products. Concentrated products are ranked by the number of critical products they are connected to in the production network, with closer connections receiving slightly higher weight (links weighted inversely by distance). Products are then grouped into quartiles based on this combined connectivity measure.

Source: Own calculations based on FIGARO-HS, Prodcom database and AIPNET

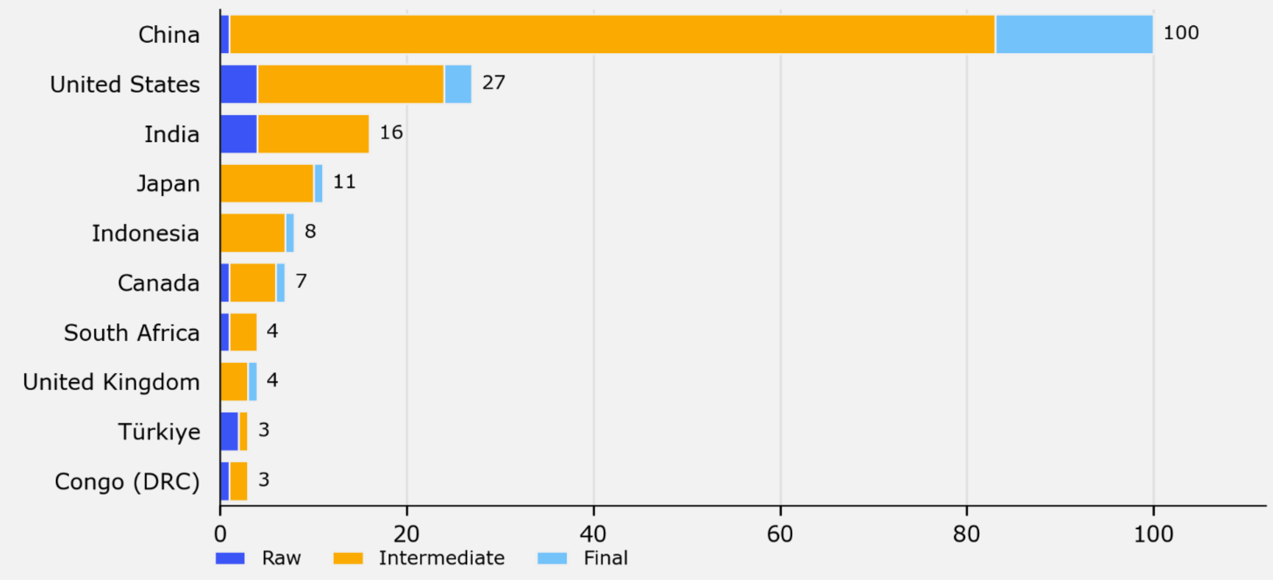
3.2.3 Vulnerabilities by country

Most vulnerabilities are associated with goods produced in China. This reflects both the importance of China as a manufacturing hub and an effort to occupy strategic supply chain positions. Flagship initiatives such as Made in China 2025 explicitly aimed to gain control over chokepoints in materials and components. They did so most prominently in rare earth processing and advanced materials, by tolerating low margins, consolidating capacity, and later backing this effort with regulatory and export controls (Fang et al., 2025; Atlantic Council, 2025). Earlier studies (Vicard & Wibaux, 2023; Lefebvre & Wibaux, 2024), show that geographic vulnerabilities have become increasingly dependent on China over time. More recently, however, this pattern appears to be shifting: Arjona et al. (2024) show that since 2021 EU imports have been moving away from countries without EU trade agreements and reorienting towards intra-EU suppliers and regional partners engaged in active trade initiatives, in line with evidence from Baltenau et al. (2024) that EU firms are increasingly EU-shoring suppliers to enhance supply-chain resilience.

All other economic blocs produce substantially fewer vulnerable goods. The next largest concentration of vulnerabilities is in the US, the world's largest economy, that nevertheless produces less than a quarter of the total vulnerable goods that China produces. Other countries where vulnerabilities are concentrated include large industrial producers such as India, Canada and Japan, as well as producers of primary commodities, such as Indonesia, South Africa, and DR Congo. Because low-volume products can still trigger sharp price increases and cascading supply-chain effects, Figure 3.4 focuses on the number of vulnerabilities rather than their total export value. Nonetheless, Figure A2.2 in the appendix shows that when vulnerabilities are measured by export value for products where a country is the largest exporter, China remains strongly overrepresented.

Figure 3.4 Most vulnerabilities are associated with goods produced in China and to a lesser extent the US

Number of vulnerable products for which a country is the largest exporter (2021-2023)



Note: Vulnerable goods are assigned to the country that is their largest exporter. The figure shows the top 10 exporting countries. Products for which the EU is the top exporter are excluded by construction, in line with the methodology, and therefore the EU does not appear in the chart.

Source: Own calculations based on FIGARO-HS, Prodcom database and AIPNET

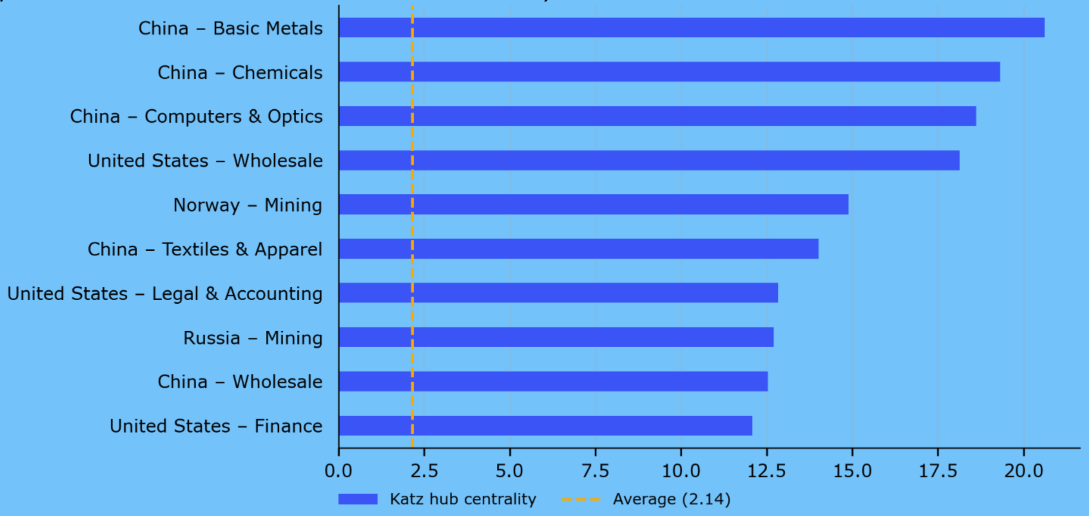
Interdependencies with other trading blocs give the EU substantial leverage if supply chains are weaponised. As figure A2.3 in appendix A2 shows, the EU itself is top exporter of 84 vulnerable goods, which, compared to other economic blocs, are relatively often final goods. Both in terms of number of vulnerable goods and export value of these goods it ranks second after China, suggesting that the EU could hold substantial leverage in a scenario where supply chains are weaponised. This aligns with Lefebvre & Wibaux (2024), who show that while the EU imports many dependency-intensive vulnerable products from China, accounting for mutual interdependencies substantially reduces its exposure to bilateral trade conflicts, with the dependency balance for the United States even turning positive.

Box 2 – Contrasting vulnerabilities with centrality in the world production network

This box complements the product-level analysis in this chapter by contrasting it with centrality at a more aggregated level in the world production network. Detailed product-level data is needed to identify vulnerabilities in global supply chains, but the data used in this chapter does not contain information on the economic value of trade flows and on how strongly products are embedded in global production networks. This limits the use cases: quantifying the propagation of supply chain disruptions and other price shocks through a production network requires capturing the value inputs and outputs. Moreover, services are excluded. To address these shortcomings, this box uses more aggregated data that captures these broader linkages. The aggregated product-data captures the value of goods and services traded between products and countries in the global production network. The box identifies country–product group hubs that are central in global supply chains. Products with high centrality are those whose disruption is most likely to propagate widely through global production chains.

Figure B.2 China ranks high in central product hubs

Top-10 Product-country pairs outside the EU and rest-of-world group with highest hub centrality in global production network based on Katz hub centrality measure



Note: Centrality is measured using the Katz hub-centrality measure (Katz, 1953), which identifies upstream production hubs in the global economy. Nodes are products which rank highly if it supplies many other products, if these links are economically large, and if it supplies other highly central nodes. The dashed line indicates the average Katz hub centrality across all product–country pairs in the dataset. The measure is calculated using the 2023 product by product FIGARO multiregional input output (MRIO) tables. The dataset covers 64 products and 50 regions, one of which is a rest-of-world group. Further methodological details on data, centrality and import shares are provided in [DNB 2026b, Chapter 4.3].

Source: Eurostat and own calculations

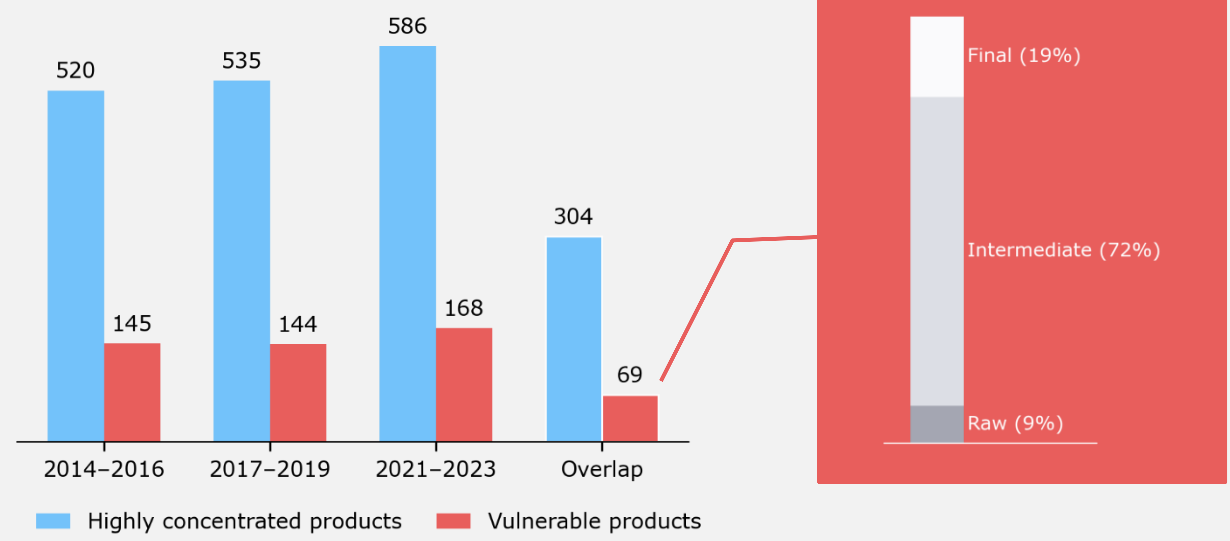
The results show that China ranks high in central product hubs, which is consistent with the vulnerabilities identified in the detailed product-level analysis. In particular, the three most central Chinese hubs are basic metals, chemicals, and computers and optical products. This largely aligns with the detailed product-level findings, where chemical products, metals and machinery were identified as especially vulnerable. Other country–product group pairs with a high centrality score are three services in the United States (wholesale; legal and accounting; finance), mining in Norway and Russia, and textile and apparel in China. Taken together, these top10 central hubs account for around 4% of total EU household consumption. The exposure is highest for EU household consumption of textiles and apparel (21%), computers and optical products (19%) and electrical equipment (12%).

3.3 How quickly do vulnerabilities change?

The data reflect both a high flux in vulnerabilities, as well as significant continuities. Around a third of all vulnerable products in the most recent data show consistent production concentration in the preceding decade. Out of 209 vulnerable products identified in the 2021-2023 data, 168 were present as traded goods in all years between 2014 and 2023 except 2020. We exclude 2020, as the COVID-19 pandemic caused substantial distortions in trade statistics. The 41 remaining products are relatively new in trade data, and contain recent innovations or products in which trade has expanded enough to be included, such as drones. Out of the 168 vulnerable products, production of 69 was also concentrated in the data of 2014-2016 and in 2017-2019. Around three-fifths of vulnerable products are either new in trade data or did not show consistent concentration before, while the total number of vulnerabilities is roughly constant. The data do however also show significant continuity, with 69 products being vulnerable for each period. Almost half (49%) of those products consist of chemical products, followed by machinery (12%) and base metals (10%). There is a slight overrepresentation of final goods in the durable vulnerabilities. The durability of a vulnerability can serve as a criterion for policy: historically durable vulnerabilities are perhaps also more likely to remain in the future, increasing the premium on policy correction.

Figure 3.5 Vulnerabilities show substantial variation over time

Durability of concentration and vulnerabilities, 2014-2023 (excl 2020)



Note: The graph includes only HS products that existed continuously over 2014–2023, with 5,296 products in total; 2020 is excluded due to COVID-19. The product network mapping is based on AIPNETHS2017. The total number of concentrated products is likely overstated, as the fourth vulnerability criterion—requiring EU production to cover more than 50% of global trade cannot be applied consistently over the full period due to data availability constraints. As a result, the ability to compensate reduced imports through domestic production or stocks is not fully captured.

Source: Own calculations based on FIGARO-HS, Prodcom database and AIPNET

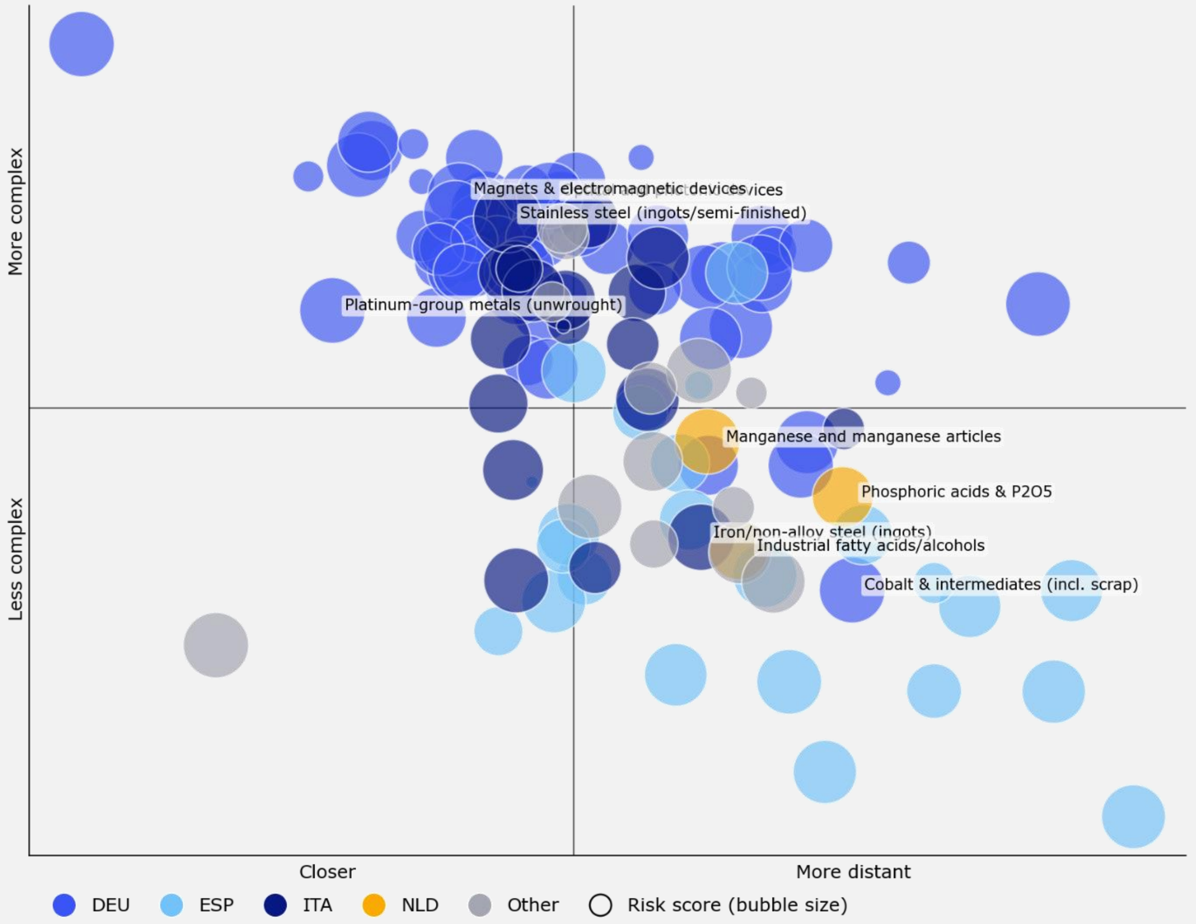
3.4 Supply chain vulnerabilities and their fit with current European production

For manufactured products, measures of the complexity and distance to the European production structures provide insight into the scope for substituting foreign supply with domestic production. Scaling up European production of manufactured products is likely to be harder if the product is more complex and fits less well with current production structures. Ceteris paribus, complex products require higher investment in technological know-how to start production off. Higher complexity scores typically signal greater barriers to entry, higher value added, and stronger links to long-run economic growth (e.g., Hidalgo & Hausmann, 2009; Balland et al., 2022). For example, producing complex semiconductor machinery requires more technological know-how than producing a relatively simple piece of garment. In addition, production of goods that have fewer production synergies with existing production factors requires more upfront investment. For example, costs for producing specific chemical products are likely to be lower if there is already a chemical production cluster present. Both complexity and distance to current European production structures can be matched to the current European vulnerabilities, providing insight into the scope for production substitution. The Harvard Complexity Atlas contains an indicator of product complexity at the HS4 level. This is calculated based on how many other countries can export the product and the economic complexity of those countries. In addition, it contains for each HS4 product and country pair an indicator of the distance of the product to the country's production structure. The measures of distance are based on correlations between product-level exports for 128 countries' export data over 50 years. See appendix A2 for a more detailed description.

There are clear differences across European countries in the extent to which starting or scaling up production of current vulnerabilities fits with existing production structures. Figure 3.6 below maps for all vulnerabilities on a 4-digit level (121 in total, excluding primary commodities, for which distance to current production structures is a less relevant variable) the complexity on the y-axis and the distance to the production structure of the best positioned EU country (least distance) to produce the good on the x-axis. Overall, figure 3.6 shows a negative correlation between complexity and distance. This reflects the relatively high complexity of the production by European industrial producers that are best positioned to overcome these vulnerabilities. Germany is best positioned to produce more than half (51%) of all European vulnerabilities that we are able to map. Spain and Italy follow with 19% and 17%, respectively. This reflects the status of these countries as the largest industrial producers of Europe, with a particular focus on the production of chemical products. As is visible from figure 3.3, vulnerabilities are relatively concentrated in that sector. The rest of all EU member states are collectively best positioned to overcome only 13% of all vulnerabilities.

Figure 3.6 A small subset of EU member states are best positioned to overcome EU vulnerabilities by starting new production

Complexity and distance to European economies of vulnerabilities



Note: The size of the bubbles represent the aggregated risk score. Concentrated products are ranked by the number of critical products they are connected to in the production network, with closer connections receiving slightly higher weight (links weighted inversely by distance). Raw commodities are excluded. Distant scores are reported for EU countries with the lowest distance score for that product (i.e. which production structure is best positioned to produce that product). When multiple 6-digit vulnerable products map to the same 4-digit category, a risk-score-weighted average is used. More complex indicates above-average production complexity (complexity score > 0), while less complex indicates below-average complexity. More distant refers to products in the top half of the distance distribution (above the median), whereas closer refers to products in the lower half.

Source: Own calculations based on FIGARO-HS, Prodcom database, AIPNET and Harvard Complexity Atlas

3.5 European product-level vulnerabilities and consequences for policy

Markets are unlikely to resolve all vulnerabilities to the point of the societal optimum. Private parties do have an incentive to overcome vulnerabilities and make their own supply chains more robust. They can do so, for example, by reshoring production capacity or finding alternative suppliers abroad. These measures act as an insurance against future disruptions. However, it is regularly the case that more than one party benefits from reducing vulnerabilities and such gains are hard to capture privately. Building out chips manufacturing, for example, benefits all downstream companies and consumers that see their geopolitical risk reduced. As it is hard for all beneficiaries to coordinate, the social returns of such measures are higher than the private returns (Acemoglu & Tahbaz-Salehi, 2025). In other words, reducing supply chain vulnerabilities carries positive externalities, that can justify governmental intervention in the form of industrial and trade policies. Of course, such interventions carry costs that should be balanced carefully against the benefits of reducing vulnerabilities. Moreover, some vulnerabilities are a direct consequence of political choices, and cannot be addressed by markets under current policies. For example, primary commodities make up 9% of the current vulnerabilities in European supply chains. These include mined goods. If goods are present in European earth layers but currently not mined, as is the case for several rare earth minerals (Ahonen et al., 2015), new mining activities can be developed. Usually, however, there are public welfare reasons for a lack of mining activity, such as environmental consequences. Balancing such environmental concerns against the vulnerabilities that have arisen due to our dependency on suppliers of rare earth minerals, implies a political choice. The same is true for other policies aimed at overcoming such primary commodity dependencies, such as active diversification of suppliers through new trade deals, stockpiling, and balancing dependencies on other countries (so-called chokepoints; Pisa et al., 2024) with European supply chain strengths (so-called control points; ibid).

A product-level analysis can inform industrial and trade policy with the aim of reducing future vulnerabilities. The results of sections 3.2-4 contain policy lessons that can be helpful in addressing the market failures described in the paragraph above. The low shares of vulnerabilities in total production within each sector, discussed in section 3.2, demonstrate the limitations of a sectoral approach. Instead, vulnerabilities can be best targeted at the product level. Including supply chain data expands the identification significantly: 95% of the vulnerabilities we identified are linked to critical applications indirectly through supply chains. The concentration of global vulnerabilities in China suggests that there are benefits to a policy of active global diversification of suppliers. A concentration of vulnerabilities in one country increases the likelihood that they can be exploited effectively for geopolitical purposes, as a balanced retaliation by other countries appears less likely. Of course, building out new production and diversifying suppliers imply costs, and these should be balanced against the risks that vulnerabilities pose. A view on the duration of vulnerabilities in section 3.3 shows, on the one hand, a core group of vulnerabilities that are constant over time. A targeted industrial policy can first aim these vulnerabilities. However, it also shows significant flux. Limited durability of vulnerabilities implies limitations of a targeted approach overcoming vulnerabilities identified on the basis of historical data. This highlights the necessity of an industrial policy aimed at maintaining a competitive and innovative economy. For Europe, this includes progress towards a Savings and Investment Union, as well as taking away remaining barriers to the internal market (Draghi 2024; Letta 2024; IMF 2024; IMF 2026). Finally, a small subset of European countries, mostly large industrial producers, is best positioned to overcome manufacturing vulnerabilities. This shows the necessity of European coordination of policies aimed at reducing vulnerabilities, to achieve policy aims with most efficiency.

There are data limitations to a product-level analysis of vulnerabilities. Firstly, the available data contains only limited information on the expected duration and severity of economic effects caused by withholding exports of an individual good. Theoretically, such outcomes could be predicted if we would know both the functions of supply and demand elasticities of individual products. As a measurement of the supply elasticities, we include production concentration as proxied by share in global exports. While goods for which production is more concentrated can indeed be assumed to have a lower supply elasticity, with fewer alternative producers to raise production in case of price increases, this is obviously an imperfect measure. In addition, we do not know demand elasticities, reflecting our limited knowledge of the costs of substituting or foregoing imports of a good. While linking products to critical applications in Europe gives us some information on the likelihood that demand will respond slowly to increases in price following export stops, our data on this point are lacking. Second, while AIPNET offers a novel and systematic way to map production networks, the quality of these individual linkages cannot be guaranteed. The model does not capture substitutability between inputs, their economic importance, or the quantities required. Other limitations include the inherent subjectivity of the selection of critical products, the exclusion of services, and the fact that even HS6-level products are not sufficiently granular to capture all vulnerabilities (e.g. individual weapon systems can pose vulnerabilities but fall under more general product categories). See appendix A2 for a more complete discussion of data limitations. Together, these data limitations mean that, while targeting vulnerabilities with the aim of preventing future supply chain disruptions can be informed by product-level data analysis, a role for expert judgment remains for the foreseeable future.

4 Conclusions and policy

4.1 Global supply chain disruptions: an old policy challenge and a new one

Global supply chain disruptions have become a more structural and macroeconomically relevant risk of disturbance to the European economy. While supply interruptions have historically accompanied trade, the structure of modern supply chains has changed how such shocks propagate and how costly they are to absorb. Production is increasingly organised in specialised, internationally dispersed networks, in which narrowly defined inputs play a central role across many downstream activities. In this setting, disruptions propagate through production networks rather than operating through isolated relative price changes, generating persistent inflationary pressures and adverse effects on economic output. Disruptions affecting upstream inputs with limited short-run substitutability can therefore have disproportionately large and persistent effects. Empirical evidence for the euro area shows that global supply chain pressure shocks raise inflation in a hump-shaped and persistent manner, with stronger effects for goods than for services, and particularly pronounced responses in sectors with high import content and upstream characteristics.

Supply chain disruptions expose the limits of relying on ex-post macroeconomic stabilisation alone. Monetary policy can respond once inflationary pressures materialise, but when inflation reflects real supply constraints such responses come at the cost of weaker output, as supply-driven shocks typically move inflation and output in opposite directions. These trade-offs become particularly acute when disruptions are persistent, propagate widely through production networks, or interact with inflation expectations and wages. Markets will not reduce vulnerabilities to the point of the societal optimum. This in some cases warrants government policies aimed at reducing exposure to future disruptions. Such policies operate on longer horizons than monetary policies and involve explicit efficiency–resilience trade-offs. These trade-offs are rarely analysed within a single framework, yet their interaction is increasingly central to macroeconomic outcomes, calling for closer consideration of how stabilisation and resilience policies interact.

4.2 Considerations for monetary policy

4.2.1 The impact of supply chain disruptions exhibits non-linearities

The macroeconomic impact of supply-chain disruptions depends critically on the size of the shock and exhibits important non-linearities. Smaller disruptions are often absorbed through margins, inventories or delayed adjustment, with limited labour-market effects and inflation easing as supply conditions normalise. By contrast, large and severe disruptions generate disproportionately stronger and more persistent effects, including sustained inflationary pressures and, in some episodes, more visible declines in production and employment. Evidence from recent episodes shows that once inflationary pressures cross certain thresholds, state-dependent pricing behaviour and wage dynamics can amplify persistence, making stabilisation more challenging.

4.2.2 Centrality within production networks shapes inflation risks and policy trade-offs

Beyond shock size, the network position of the disrupted input is central to its macroeconomic impact. Disruptions affecting upstream or widely used inputs propagate more broadly through production networks and are more likely to give rise to persistent inflationary pressures. Centrality within production networks sharpens monetary policy trade-offs by increasing the risk that initially local shocks spread economy-wide through expectations, wage setting and pricing behaviour. As a result, assessing supply-driven inflation requires not only monitoring headline outcomes, but also understanding where disruptions occur within supply chains.

4.2.3 Import dependence matters non-linearly for optimal monetary policy

Import dependence shapes the inflation–output trade-off faced by monetary policy in a non-linear manner. At moderate levels of import dependence, stronger cost-push pressures following a supply disruption can justify a more forceful policy response to stabilise inflation. At very low import dependence, inflationary effects are weaker and aggressive tightening is less warranted. At very high levels of dependence, supply disruptions increasingly operate through sharp contractions in output, limiting the scope for aggressive monetary tightening despite elevated inflation. Both relatively low and relatively high import dependence therefore generally prescribe a less aggressive policy stance than intermediate levels.

These mechanisms are particularly challenging in a monetary union. Member states differ markedly in import dependence, sectoral specialisation and substitution possibilities. As a result, common global supply chain disruptions can translate into heterogeneous national inflation–output dynamics, complicating the calibration of a single monetary policy stance and increasing the relevance of country-specific fiscal policies in absorbing asymmetric effects.

4.2.4 Monetary policy dilemma under supply shocks and the case for prevention

Monetary policy cannot prevent supply chain disruptions and has limited ability to offset their real economic costs. Even under optimal policy, stabilising inflation in response to supply-driven shocks often entails output losses, as monetary tightening restrains aggregate demand without alleviating the underlying supply constraint. Trade and industrial policies aimed at diversification, stockpiling, infrastructure investment or reconfiguration of production address the underlying sources of vulnerability directly, albeit over longer horizons.

As supply-driven disturbances are likely to become more frequent or persistent, this highlights the complementary role of such ex-ante measures alongside monetary stabilisation. Rather than reflecting a simple efficiency–resilience trade-off, policies that reduce supply-chain risk can be viewed as a form of insurance against repeated episodes of inflation volatility and output losses. Such policies can address market failures that lead to underinvestment in resilient supply chains. In an environment characterised by elevated climate- and geopolitically driven risks, investing in resilience may therefore be economically efficient by reducing the likelihood and macroeconomic costs of future stabilisation challenges.

4.3 Industrial policy and reducing supply chain risk

4.3.1 Policy targeted at products, technologies and clusters

Product-level analysis provides a useful lens for identifying where supply-chain vulnerabilities are most likely to arise, but it does not by itself deliver policy prescriptions. Reducing vulnerabilities carries positive externalities, for example by reducing exposure to geopolitical pressure and by limiting risk of broad societal inflation. This legitimizes government intervention where the benefits exceed the costs. The mapping exercise in this study shows that Europe's vulnerabilities are concentrated in a relatively small set of products, often embedded within otherwise diversified sectors. This limits the effectiveness of broad sector-level approaches and points towards more targeted interventions focused on specific products, technologies or production stages. The appropriate policy response depends on the nature of the vulnerable product and its position in the supply chain. For primary commodities and geographically constrained goods, options are often limited to diversification, stockpiling or managing dependencies through international partnerships. For manufactured goods, vulnerabilities may be reduced through investment in production capacity, technological capabilities or clustering, although such measures typically involve long implementation lags and substantial costs. These policies generally imply a loss in economic efficiency, that should be balanced against the risks posed by vulnerabilities.

4.3.2 European cooperation on reducing dependencies

European cooperation is essential for a policy that reduces vulnerabilities efficiently. Coordination at the European level can help exploit complementarities, avoid duplication of effort and preserve the dynamism and competition necessary for innovation. A small subset of countries appears best positioned to overcome the majority of manufacturing vulnerabilities. At the same time, the evidence shows that vulnerabilities evolve rapidly over time, highlighting the need for an adaptive economy alongside more targeted interventions. The constraints to European productivity and technological development are by now well-described and understood (Letta, 2024; Draghi, 2024). Priority should be given to reducing barriers to the internal market (IMF, 2024) and advancing the savings and investment union. Targeted interventions informed by product-level data explorations, while necessary, are no replacement for operating at the technological frontier when it comes to reducing supply chain vulnerabilities.

4.4 Going forward: improving our understanding of product-level demand elasticities and trade-offs between monetary and industrial policy

A key remaining uncertainty concerns demand elasticity and substitutability. Product-level concentration and data on supply chain links expose vulnerabilities but give little information on their relative economic importance or the speed of adjustment when supply is disrupted. While analysis on the recent increases in US import tariffs can help us understand the overall impact on inflation (see, e.g. DNB, 2026), limited reliable data on how product-level demand and supply changes with the duration of the disruption is needed to advance our understanding at the product-level. Improving data availability and integrating quantitative analysis with sector-specific expertise are therefore essential for moving from vulnerability mapping to more robust assessments of inflation risks and coercion potential.

As global production becomes more dispersed and geopolitically contested, both monetary stabilisation and supply-side resilience are important to limit economic upheaval. Monetary policy will remain central in responding to inflationary consequences of supply disruptions, but its effectiveness depends critically on production structures and exposure. Better identification of supply-chain vulnerabilities can discipline policy debates and clarify how monetary, fiscal, trade and industrial policies interact, while respecting differences in mandates and time horizons.

Going forward, policy faces two interrelated challenges: strengthening resilience to critical supply disruptions, and reducing one-sided dependencies by building leverage in key segments of global value chains. Both objectives can be pursued through a mix of deeper European integration—building on the single market and capital markets union—and more active engagement with external partners. While further analysis is needed to refine priorities, measures to strengthen resilience need not wait until all uncertainties have been resolved, particularly where vulnerabilities have clear macroeconomic relevance.

References

Acemoglu, D., & Tahbaz-Salehi, A. (2025). The macroeconomics of supply chain disruptions. *Review of Economic Studies*, 92(2), 656–695.

Ahonen, S., Arvanitidis, N., Auer, A., Baillet, E., Bellato, N., Binnemans, K., Blengini, G. A., Bonato, D., Brouwer, E., Brower, S., et al. (2015). Strengthening the European rare earths supply chain: Challenges and policy options. European Commission.

Andriantomanga, Z., Bolhuis, M.A., Hakobyan, S., 2022. Global supply chain disruptions: Challenges for inflation and monetary policy in Sub-Saharan Africa. Technical report, International Monetary Fund, Working Paper WP/23/39.

Antràs, P. (2015). *Global production: Firms, contracts, and trade structure*. Princeton University Press.

Arjona, R, W Connell and C Herghelegiu (2024). Supply Chain Tectonics: Empirics on how the EU is plotting its path through global trade fragmentation, Single Market Economy Papers WP2024/28, Publications Office of the European Union.

Ascari, G., Bonam, D., & Smadu, A. (2024). Global supply chain pressures, inflation, and implications for monetary policy. *Journal of International Money and Finance*, 142, Article 103029.

Ascari, G., Carrier, A., Gasteiger, E., Grimaud, A., & Vermandel, G. (2025). Monetary policy in the euro area: When Phillips curves … are curves. *De Nederlandsche Bank Working Paper*, forthcoming.

Balland, P. A., et al. (2022). Reprint of the new paradigm of economic complexity. *Research Policy*, 51(8).

Balteanu, I, M Bottone, A Fernández-Cerezo, D Ioannou, A Kutten, M Mancini and R Morris (2024). European firms facing geopolitical risk: Evidence from recent Eurosystem surveys", VoxEU.org, 18 May.

Berthou, A., Haramboure, A., & Samek, L. (2024). Mapping and testing product-level vulnerabilities in granular production networks. *OECD Science, Technology and Industry Working Papers*, 2024/02. OECD Publishing.

Bonam, D., Galati, G., Hindrayanto, I., Hoeberichts, M., Samarina, A., & Stanga, I. (2019). Inflation in the euro area since the global financial crisis. *DNB Occasional Studies*, 17-3. De Nederlandsche Bank.

Bruegel. (2024). How to de-risk: European economic security in a world of interdependence. *Bruegel Policy Brief*.

Cai, M., & Rueda-Cantuche, J. M. (2019). Bridging macroeconomic data between statistical classifications: The count-seed RAS approach. *Economic Systems Research*, 31(3), 382–403.

Carvalho, V. M. (2014). From micro to macro via production networks. *Journal of Economic Perspectives*, 28(4), 23–48.

Carvalho, V. M., & Tahbaz-Salehi, A. (2019). Production networks: A primer. *Annual Review of Economics*, 11, 635–663.

Cavallo, A., & Kryvtsov, O. (2023). What can stockouts tell us about inflation? Evidence from online micro data. *Journal of International Economics*, 146, Article 103769.

Clarida, R., Galí, J., & Gertler, M. (1999). The science of monetary policy: A New Keynesian perspective. *Journal of Economic Literature*, 37(4), 1661–1707.

Celasun, O., Hansen, M. N. J. H., Mineshima, M. A., Spector, M., & Zhou, J. (2022). Supply bottlenecks: Where, why, how much, and what next?. International Monetary Fund.

Dietzenbacher, E., & Romero, I. (2007). Production chains in an interregional framework: Identification by means of average propagation lengths. *International Regional Science Review*, 30(4), 362–383.

De Nederlandsche Bank. (2024). The monetary policy response to high inflation. *DNB Analysis*. De Nederlandsche Bank.

De Nederlandsche Bank. (2026a). How should monetary policy respond to tariffs? *DNB Analysis*. De Nederlandsche Bank.

De Nederlandsche Bank. (2026b). The economic consequences of defence spending? *DNB Analysis*. De Nederlandsche Bank.

De Santis, R.A., 2024. Supply chain disruption and energy supply shocks: impact on euro-area output and prices. *International Journal of Central Banking*, Volume 20, Issue 2, 193—235.

Draghi, M. (2024). *The Draghi report on EU competitiveness*.

European Commission. (2021). Strategic dependencies and capacities. *Commission Staff Working Document*.

European Commission. (2022). A chips act for Europe. *Commission Staff Working Document*.

European Commission. (2023a). Study on the critical raw materials for the EU 2023 – Final report. Publications Office of the European Union. https://data.europa.eu/doi/10.2873/725585

European Commission. (2023b). An enhanced methodology to monitor the EU's strategic dependencies and vulnerabilities. *Single Market Economics Papers*, 14.

European Commission. (2024). The Net-Zero Industry Act (NZIA) Annex: List of final products and specific components considered to be primarily used for the production of net-zero technologies.

European Central Bank. (2021a). The ECB's price stability framework: Past experience, and current and future challenges. *ECB Occasional Paper Series*, 269.

European Central Bank. (2021b). Understanding low inflation in the euro area from 2013 to 2019: Cyclical and structural drivers. *ECB Occasional Paper Series*, 280.

European Central Bank. (2021c). The implications of globalisation for the ECB monetary policy strategy. *ECB Occasional Paper Series*, 263.

European Central Bank. (2025a). A strategic view on the economic and inflation environment in the euro area. *ECB Occasional Paper Series*, 371.

European Central Bank. (2025b). Report on monetary policy tools, strategy and communication. *ECB Occasional Paper Series*, 372.

European Central Bank. (2025c). Unveiling the hidden costs of critical dependencies. *ECB Economic Bulletin*, 5/2025.

European Medicines Agency. (2026). Union list of critical medicines.

Finck, D., Tillmann, P., 2022. The macroeconomic effects of global supply chain disruptions. Technical report, BOFIT Discussion Paper No. 14/2022

Forbes, K., Ha, J., & Kose, M. A. (2026). Heaven or Earth? The evolving role of global shocks for domestic monetary policy. *NBER Working Paper*, 34806. National Bureau of Economic Research.

Federal Reserve Bank of New York. (2022). Global Supply Chain Pressure Index. https://www.newyorkfed.org/research/policy/gscpi

Fetzer, T., et al. (2024). AI-generated production networks: Measurement and applications to global trade. *CESifo Working Paper Series*, 11497.

Friesenbichler, K. S., Glocker, C., Hölzl, W., & Piribauer, P. (2026). Sectoral and aggregate effects of supply chain disruptions in a small open economy. *Empirical Economics*, 70, Article 69.

Gawande, K., Hoekman, B., & Cui, Y. (2015). Global supply chains and trade policy responses to the 2008 crisis. *World Bank Economic Review*, 29(1), 102–128.

Hale, G., Hobijn, B., Nechio, F., & Wilson, D. (2019). How much do we spend on imports? *FRBSF Economic Letter*, 2019-01. Federal Reserve Bank of San Francisco.

Hidalgo, C. A., & Hausmann, R. (2009). The building blocks of economic complexity. *Proceedings of the National Academy of Sciences*, 106(26), 10570–10575.

Igan, D., Rungcharoenkitkul, P., & Takahashi, K. (2022). Global supply chain disruptions: Evolution, impact, outlook. *BIS Quarterly Review*, 61. Bank for International Settlements.

International Monetary Fund. (2023). Fragmentation and commodity markets: Vulnerabilities and risks. In *World Economic Outlook: Navigating global divergences* (Chapter 3). International Monetary Fund.

International Monetary Fund. (2024). A recovery short of Europe's full potential. *Regional Economic Outlook: Europe*. International Monetary Fund.

International Monetary Fund (2026). Kingdom of the Netherlands: Staff Concluding Statement for the 2026 Article IV Consultation Mission. May 13, 2026.

Katz, L. (1953). A new status index derived from sociometric analysis. *Psychometrika*, 18(1), 39–43.

Kozicki, S. (2026). Canada's monetary policy framework in a world of supply-driven trade-offs. Remarks at the Norges Bank Monetary Policy Mandate Conference, Oslo, March 2, 2026.

Krippner, L. (2013). Measuring the stance of monetary policy in zero lower bound environments. *Economics Letters*, 118(1), 135–138.

Lagarde, C. (2026, March 25). Navigating energy shocks: Risks and policy responses. Speech at *The ECB and Its Watchers* Conference. European Central Bank.

Lefebvre, M., & Wibaux, G. (2024). Import dependencies: Where does the EU stand? *CEPII Policy Brief*, 47.

Lemmers, O., Notten, T., Wong, K. F., Dahlmans, D., & Prenen, L. (2023). *De toeleveringsketens van vijf bedrijfstakken: Welke landen van zeggenschap, welke producten*. Statistics Netherlands (CBS).

Letta, E. (2024). *Much more than a market*.

Mehlbaum, C., & Heerma van Voss, B. S. (2025). Kijk voor strategische afhankelijkheden naar goederen, niet sectoren. *ESB*.

Mejean, I., & Rousseaux, P. (2024). Identifying European trade dependencies. In J. Pisani-Ferry, B. Weder Di Mauro, & J. Zettelmeyer (Eds.), *Paris Report 2: Europe's economic security*. CEPR Press.

OECD. (2022). An industrial policy framework for OECD countries: Old debates, new perspectives. *OECD Science, Technology and Industry Policy Papers*, 127.

Remond-Tiedrez, I., & Rueda-Cantuche, J. M. (2019). EU inter-country supply, use and input-output tables (FIGARO). *Eurostat Statistical Working Papers*.

Rodrik, D. (2011). *The globalization paradox: Democracy and the future of the world economy*. W. W. Norton & Company.

Rostagno, M., Altavilla, C., Carboni, G., Lemke, W., Motto, R., Saint Guilhem, A., & Yiangou, J. (2019). A tale of two decades: The ECB's monetary policy at 20. *ECB Working Paper Series*, 2346.

Pisa, D., Vierhout, J., Geurts, A., & Van Bree, T. (2024). Getting a grip on control points: An exploration of literature. TNO Report 2026-R10598. TNO.

TNO. (2023). *Zicht op strategische ketenafhankelijkheden voor de Nederlandse economie: Ontwikkeling van een methode*. TNO.

U.S. Census Bureau. (2026). Advanced technology code descriptions. https://www.census.gov/foreign-trade/reference/codes/atp/index.html

Vicard, V., & Wibaux, G. (2023). EU strategic dependencies: A long view. *CEP Policy Brief*.

Woodford, M., & Walsh, C. E. (2005). Interest and prices: Foundations of a theory of monetary policy. *Macroeconomic Dynamics*, 9(3), 462–468.

World Inequality Lab. (2024). World Inequality Database (WID). Retrieved April 20, 2026, from https://wid.world/

Appendix: methodology and additional results

A.1 Methodology and additional results to chapter 2

Bayesian VAR model and local projections

The global supply chain shocks (shown in Figure 2.1) are estimated based on the methodology outlined in Ascari, Bonam and Smadu (2024), who use a Bayesian VAR model for the euro area and a combination of sign and narrative restrictions. Please see the paper for more details on the model and these restrictions. For the purpose of this analysis, the model has been re-estimated with data over the period 2001m1 to 2025m12. The impulse responses that are shown in Chapter 2 (with the exception of the responses shown in Figure 2.8) are estimated using a local projection model that regresses a generic variable of interest, x_{t+h}, at different horizons $h = 1,2,\ldots$, on the estimated global supply chain shocks from the Bayesian VAR model, s_t, and a set of controls, X_t. The baseline local projection model has the following specification:

$$x_{t+h} = c_h + \beta_h s_t + \sum_{j=1}^{J} \rho_{hj} X_{t-j}$$

where X_t is a vector that contains 12 lags of x_t and s_t. The impulse responses are then captured by the coefficients β_h. These local projection models are also estimated over the period 2001m1 to 2025m12.

Data sources used

The table below shows, for each variable used in the figures of Chapter 2, the corresponding sources.

Variable	Source	Figure
GSCPI	Federal Reserve Bank of New York	2.1
HICP, excluding energy and food	Eurostat	2.3
HICP subcomponents	Eurostat	2.3
Manufacturing goods producer prices	Eurostat	2.4
Inflation expectations, 1-year ahead	European Commission Business & Consumer Survey	2.5
Negotiated wages	ECB Data Portal (EA), Statistics Netherlands (NL)	2.5
Profit share	Eurostat	2.6
Production	Eurostat	2.7
Unemployment rate	Eurostat	
Unemployment gap	Unemployment rate minus its HP-filtered trend	2.7

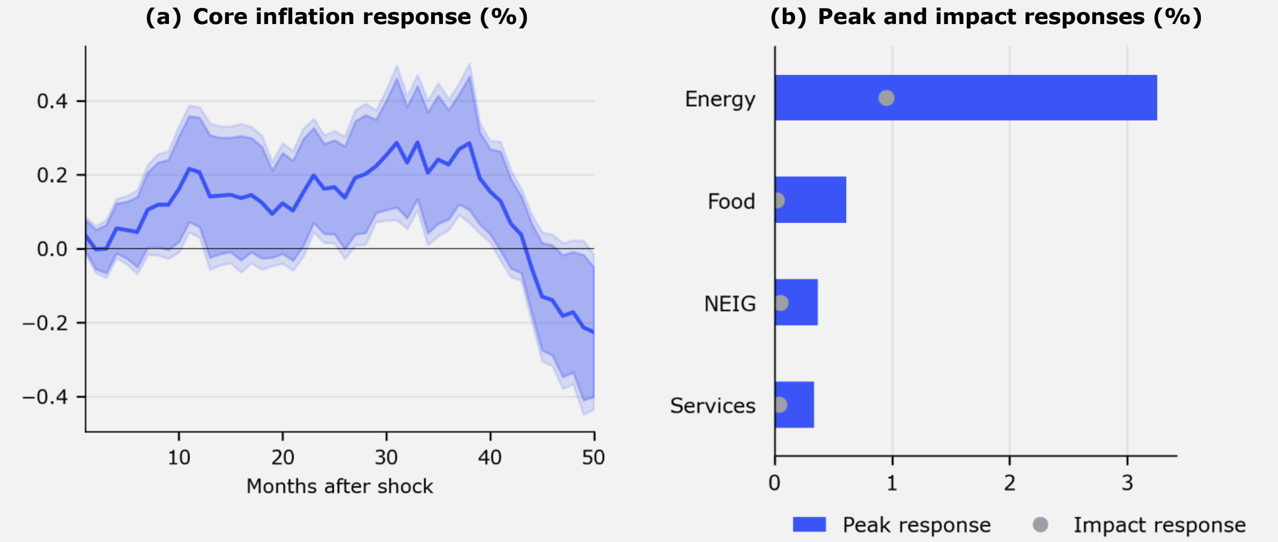
Notes: All variables are expressed in annual growth rates, except for the GSCPI (standard deviations from the mean), profit share (percentage of value added) and the unemployment gap (level).

Estimation results for the Netherlands

In the main text, we present the estimation results for the euro area aggregate. Below, we show the corresponding results for the Netherlands for Figures 2.3, 2.5, 2.6 and 2.7. The results are largely similar to those for the euro area. The pattern of the dynamic responses to global supply chain shocks of most Dutch variables closely mirrors those euro area variables, although magnitudes differ for some. The main differences are found in the somewhat larger responses of the HICP components—particularly energy inflation—and the slightly stronger impact response of the profit share for the Netherlands than for the euro area aggregate. The response of inflation expectations is broadly in line with what we find for the euro area, while the wage response is more muted in the Netherlands than in the euro area. Finally, the effects of global supply chain shocks on Dutch production and labour market slack are very similar to those found for the euro area.

Figure A.1.1 Supply chain shocks result in a larger peak response of energy inflation in the Netherlands compared to the euro area aggregate

Responses of Dutch inflation to a global supply chain shock

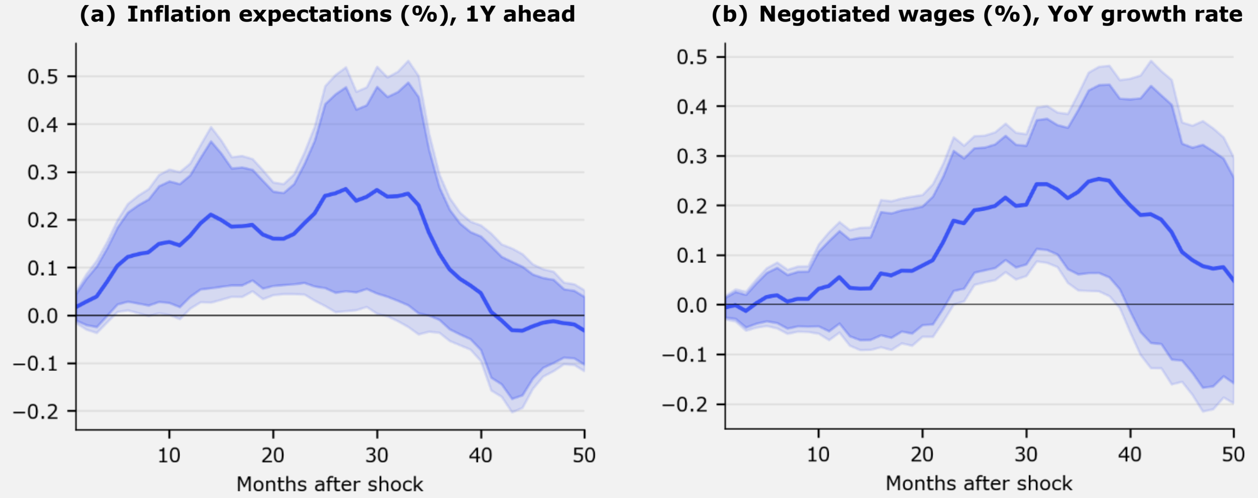


Note: Core inflation is measured as the year-on-year growth rate of HICP excluding energy and food. The size of the shock is one standard deviation. Light and dark blue shaded areas represent the 90% and 95% confidence level. The impact and peak responses are the year-on-year growth rate of different HICP sub-categories to a one-standard deviation global supply chain pressure shock. The impact response is the response occurring in the same month in which the shock occurs. The peak response is the greatest (positive) response over a horizon of 4 years.

Source: Eurostat and own calculations.

Figure A.1.2 Response of inflation expectations in line with that for the euro area, while the wage response is more limited in the Netherlands

Responses of Dutch inflation expectations and wages to a global supply chain shock

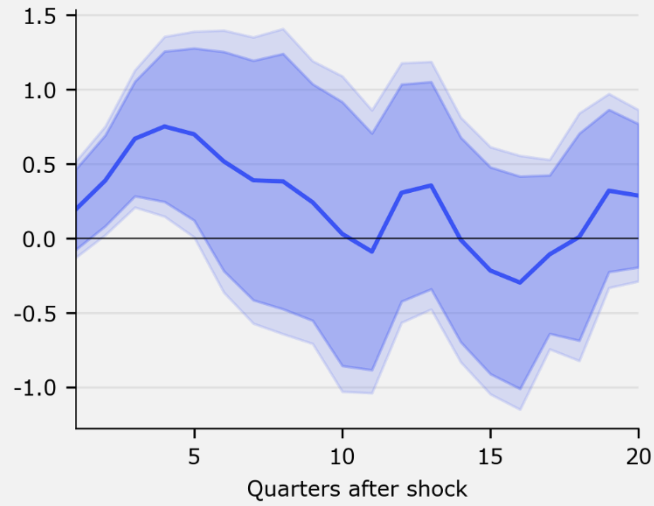


Note: 1-year ahead inflation expectations are constructed as the weighted average of current and next year expectations of the year-on-year growth rate of consumer prices, taken from Consensus Economics. Light and dark blue shaded areas represent the 90% and 95% confidence level.

Source: Consensus Economics, ECB and own calculations

Figure A.1.3 Profit response in line with response found for euro area

Response of the Dutch profit share (%) to a global supply chain shock with confidence bands

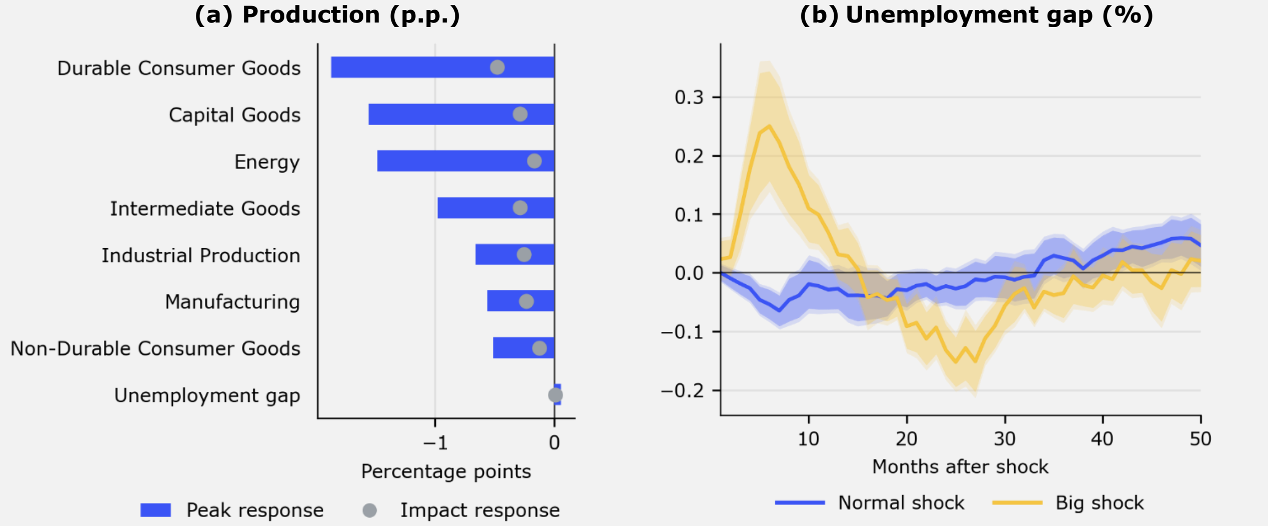


Note: The profit share is defined as the ratio between profits and value added. Light and dark blue shaded areas represent the 90% and 95% confidence level.

Source: Eurostat and own calculations

Figure A.1.4 Production and employment respond similarly to global supply chain shocks in the Netherlands and the euro area aggregate

Responses of Dutch production and the unemployment gap to a global supply chain shock



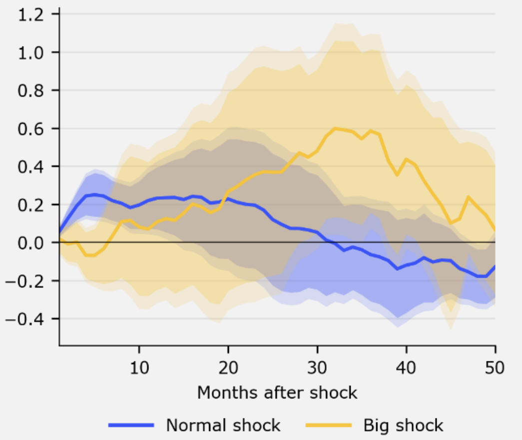
Note: Production is measured as the year-on-year growth rate of production volume. The unemployment gap is measured as the difference between the unemployment rate and its HP-filtered trend. In panel b, the response labeled 'big shock' ('normal shock') is conditional on the global supply chain pressure shock being larger (smaller) than 3 times its own standard deviation.

Source: Eurostat and own calculations

Figure A.1.5 Monetary policy responses to large and small supply shock

Monetary policy stance in euro area

Response of the shadow rate (%) to a global supply chain shock



Note: The shaded area represents the 68% posterior credibility sets. Note that these are different from the confidence intervals around the impulse responses from the local projection models, which are frequentist sampling-uncertainty bands. 'Big shocks' refers to those that are larger than twice the standard deviation of the shock series.

Source: Krippner (2013 -right, shadow rate) and own calculations

Monetary policy responses to different shock sizes

Figure A1.5 shows monetary policy responses to supply shocks of different sizes. Large shocks (exceeding twice the standard deviation) are followed by a more gradual but more persistent tightening, while smaller shocks trigger a quicker and less sustained response.

A.2 Methodology and additional results to chapter 3

This analysis aims to identify vulnerabilities in EU supply chains using product-level data. For the purposes of this study, a vulnerability is defined as a good—final, intermediate, or commodity—whose production is highly concentrated outside the EU and that either has a critical application or is used in the production of other goods with a critical application.

To identify these vulnerabilities we use granular trade data for over 5000 products, which we connect to supply chains of EU critical goods and technologies using an AI-generated production network.

The analysis proceeds in three steps which are visualized in figure 3.1 in the main body of the study and will be discussed in more detail below:

1. First, it identifies, from over 5000 products in the FIGARO database, those whose production is highly concentrated outside the EU.
2. Second, it compiles a list of critical goods and technologies derived from policy and literature sources and links these to specific HS product codes.
3. Third, it assesses whether the goods identified as highly concentrated outside the EU can be linked to these critical goods and technologies, using an AI-generated production network that captures input–output relationships between products.

1. Production concentration outside the EU

This analysis uses the FIGARO-HS Database which is jointly compiled by Eurostat in collaboration with the European Commission's Joint Research Centre. More specifically we used the underlying (unpublished) version as described in Remond-Tiedrez and Rueda-Cantuche (2019, chapter 6). This dataset includes harmonized input-output tables for trade in over 5000 products on the HS 6-digit level with adjustments for re-exports (mostly for EU countries).[12]

Production concentration is measured by the extent to which global production of a good is dominated by a limited number of countries, proxied by their shares in global exports. As trade vulnerabilities can vary greatly from year to year (Vicard and Wibaux, 2023) we pool trade data over three consecutive years (2021-2023). To focus on persistent vulnerabilities a product is classified as "highly concentrated" if it meets the following concentration criteria over the pooled data[13]:

1. The Herfindahl–Hirschman index (HHI) of export shares exceeds 0.4.
2. The EU must not be the world's leading producer.
3. Intra-EU trade must not represent more than 50% of the value of global trade.
4. EU production data do not show production of more than 50% of global trade.

These criteria and benchmarks are standard in the literature (e.g. EC 2021/23, Mejean & Rousseaux, 2024). One modification we make is to measure export concentration rather than import concentration for the first criterion. This reflects the broader scope of our analysis, which also considers disruptions that are not directly targeted at the EU but may nonetheless affect its economy through downstream propagation. The first two criteria therefore capture the extent to which the supply of a good is concentrated in one or a small number of non-EU countries. The third and fourth criteria reflect limited scope to compensate for reduced imports through domestic stockpiles

[12] The exact number depends on the HS revision and the years covered, as product categories may be added, removed or consolidated over time. In our main analysis, we use the most recent HS 2022 revision for the period 2021–2023, which yields 5,612 unique HS codes that appear in at least one of these years.

[13] For HS-codes which are only present in one or two years the conditions should hold for those years.

or production. Throughout this exercise, data are consolidated at the EU-27 level, with intra-EU trade flows excluded.

The fourth criterion follows Mejean and Rousseaux (2024), who classify a product as vulnerable if more than 50% of domestic absorption - defined as domestic output plus imports minus exports - originates from foreign sources. EU production is measured using Eurostat Prodcom data.[14] This information is linked to the FIGARO database using concordance tables, resulting in successful matches for 469 out of 5,612 products. To link product codes across classifications, we use CPA–HS correspondence tables. Only one-to-one and many-CPA-to-one-HS matches are retained. Correspondences involving many-HS-to-one-CPA or many-to-many relationships are excluded to avoid ambiguity in the mapping. In addition, observations with negative production values are excluded from the analysis.

We conduct several further sensitivity analyses to assess the robustness of the identification of vulnerable products. First, lowering the export-concentration threshold from HHI ≥ 0.4 to HHI ≥ 0.35 substantially expands the set of vulnerable products from 209 to 297, indicating that a sizeable mass of products lies just below the baseline cutoff. These additional products exhibit somewhat less extreme, but still high, export concentration. This is consistent with the distribution of export concentration, which is highly skewed: more than half of products have low concentration levels (HHI between 0.01 and 0.25) and the density of products increases substantially as the threshold is lowered within the upper tail. In particular, 313 products lie in the HHI range 0.35–0.40, compared with 464 products between 0.30–0.35 and 657 products between 0.25–0.30. Second, increasing the threshold used to identify EU internal-market products from 50% to 60% of global exports adds four additional vulnerable products. Similarly, tightening the criterion based on EU production—raising the cutoff from products accounting for more than 50% to more than 60% of global trade—adds only one additional product. These limited changes indicate that the treatment of EU internal market size and production capacity has a modest impact on the results relative to the choice of the export-concentration threshold. Importantly, while the size of the vulnerable product set increases, the main patterns in terms of exposure to critical goods and the distribution across exporting countries remain qualitatively similar.

2. Identifying critical goods and technologies

Based on insights from earlier studies (e.g. EC 2020/21/23) and EU policy priorities, we organise critical goods and technologies into four strategic ecosystems: defence and aerospace, energy transition, digital technology and health/biopharma. Within these ecosystems we identify 18 critical goods and technologies based on policy and literature sources, including the Union List of Critical Medicines for the health/biopharma ecosystem and the list of strategic net-zero technologies from the Net-Zero Industry Act for the energy transition ecosystem. Table A2.1 shows the exact list of critical goods and technologies used in this analysis with their relevant sources. To limit the length of the appendix, the full list is not included but can be provided upon request.

These critical goods and technologies are then linked to HS6-codes. Most critical goods could be directly linked to one or multiple HS6 product code(s). For example, there is only one HS6-code for Electrolysers (854330), while solar panels are covered by five HS-codes covering (assembled) PV cells (HS 854143, 854142) and PV generators (850171 – 850173). For some technologies classified as 'strategic' – e.g. photonics - the link to HS6-codes was complex. In those cases, to limit bias and both false positives and negatives, we used LLM models to

[14] Database - Prodcom - statistics by product - Eurostat

identify links, which were subsequently manually checked. In the case of photonics we linked to 17 HS-codes (e.g. 845611 'Laser systems integrated in machines'). Some strategic technologies, including AI, could not be reliably mapped to HS codes and were therefore excluded from the analysis. In total 18 critical goods and technologies were linked to 155 HS6-codes, with no overlap across goods.

Acknowledging that the selection of critical goods and technologies inevitably involves some subjective judgement, we ran the analysis for a more broad list of critical goods or parts thereof. For the energy transition ecosystem, this broader list includes, for example, carbon capture and storage (CCS) technologies and sustainable alternative fuels technologies. This only slightly increased the number of vulnerable products and did not materially change the results of our analysis.[15]

Table A2.1: Overview strategic ecosystems, critical goods and sources

Strategic ecosystems	Critical good or technology	HS codes	Source
Defence & Aerospace	Weapons	12	US Census Bureau (2026) ATP-list for Aerospace (08) and Weapons (09) + military ships, armoured vehicles (inc. tanks) and handguns.
	Military Vehicles & Marine	2	
	Aerospace	14	
Energy transition	Solar panels & modules	5	EC (2024) - The Net-Zero Industry Act (NZIA) product Annex; EC (2023a) – Critical Raw Material Lists
	Wind turbines	1	
	Batteries & energy storage	13	
	Electrolysers	1	
	Heat pumps and geothermal energy	3	
	Nuclear fission technologies	3	
	Hydropower	3	
	EV transport	4	
Digital technology	Chips & semiconductors	19	EC (2023a) – Critical Raw Material Lists; EC (2022) - Chips Act
	Photonics	17	
	Cloud computing	1	
	Robotics	1	
	3D printing	1	
Health/ biopharma	Medicine and biotech	24	EMA (2026) - Union List of Critical Medicines
	Medical devices	31	US Census Bureau (2026) ATP-list part of life science (2)
Total	**18**	**155**	

[15] In total we labeled 372 (53 defence & aerospace, 35 energy transition, 122 digital technology, 162 health/biopharma) extra HS codes as critical, which only increased the number of vulnerable products by 7.

3. Linking concentrated products to the value chain of critical goods and technologies

The third step assesses which of the concentrated products identified in step 1 are used as inputs in the production of critically defined goods and technologies identified in step 2. More specifically, we examine whether the HS codes of concentrated products can be linked downstream to the HS codes of critical goods.
As figure A2.1 illustrates, a concentrated product can be linked either directly or indirectly to a critical good. 11 cases resulted in a direct match. Examples of these direct links are wind turbines (HS 850231) or medicaments containing insulin (HS 300331). The main contribution of this step, however, lies in identifying indirect upstream linkages further along the value chain. We therefore also consider whether a concentrated commodity or intermediate component is used as an input in the production of a critical good or technology at a later stage of production.

Earlier studies on upstream linkages typically focused on the value chains of individual critical goods—such as batteries (e.g. TNO, 2023)—and relied heavily on detailed desk research and expert judgement. Given the broader scope of this analysis, which seeks to identify vulnerabilities across the economy as a whole, such an approach is not feasible. Instead, we use AIPNET, an AI-based production network that maps input–output relationships across approximately 5,000 products, to identify indirect linkages between concentrated products and critical goods and technologies. For the main analysis, we rely on AIPNET HS2017 and AIPNET HS2022 and limit the network depth to four tiers.[16] See for more details on AIPNET's methodology Fetzer et al. (2024).

AIPNET linked 390 of the 578 concentrated products to critical goods.[17] As AIPNET does not assess substitutability, the economic relevance of inputs, or required quantities, all identified linkages were subsequently reviewed manually. Examples of excluded 'false positives' are fireworks (360410), which was linked to weapons via safety fuses, and wristwatches (910111) which was linked to time measuring instruments for aerospace.[18] After our manual check we were left with 209 vulnerable products (see figure 3.2 in the main body).[19] These vulnerable products are then further split by their production stage based on the Classification by Broad Economic Categories (BEC) from the UN.[20] The relatively high percentage of raw materials (9%) and intermediate goods (78%) illustrates the added value of this approach.

A single concentrated product may be linked to multiple critical goods or via multiple linkages to one critical good. For example, chromium ores and concentrates (HS 261000) are linked to stainless steel (HS 721891/ 721899) production, which in turn is connected to multiple critical goods including armoured vehicles (HS 871000) and wind turbines (HS 850231). To capture a product's centrality to critical supply chains, we construct a four-bracket indicator based on a proximity-weighted network reach measure. For each product, we identify all critical products reachable within the capped production-network depth and weight each link by the inverse of its shortest-path distance ($w(d) = 1/(1 + d)$). This ensures that closer connections in the value chain contribute more to the score, while more distant links still receive positive but smaller weight. Products are then ranked based on this weighted reach measure and grouped into quartiles for ease of interpretation.

[16] As a sensitivity check, we assess the impact of increasing the maximum number of linkages considered. Expanding the cutoff from 4 to 10 to 15 linkages adds only 5 additional matches and does not affect the substantive results, indicating that the analysis is not sensitive to this threshold.
[17] Analysis of the concentrated products that could not be linked showed that these were mainly animal and vegetable products. Other examples are umbrella's (660191) and pajama's (610722).
[18] An analysis of the manual corrections showed that over 50% of these were HS categories textiles, animal, vegetable and wood products.
[19] To keep the appendix concise, the full list is not included but can be obtained from the authors upon request.
[20] Classification by Broad Economic Categories (BEC) - United Nations Statistics Division

Complexity and distance
Paragraph 3.4 introduces the concepts of product complexity and distance to a country's existing production structure as a measure for the ease with which the EU is likely to build out production of currently vulnerable products. These concepts originate from the Harvard Atlas of Economic Complexity and are outlined briefly below. For a formal derivation and detailed methodology, see Hidalgo & Hausmann (2009). Since these indicators are only available at the HS-4 level, the vulnerable products on the HS 6 level are aggregated to their corresponding HS-4 code. When multiple vulnerable HS-6 products map to the same HS-4 category, we compute a weighted average, using the proximity-weighted network reach measure as weights, so that HS-6 products with stronger and closer links to critical products contribute more to the aggregated HS-4 indicator.

<u>Product complexity</u>
Product complexity provides a measure of the diversity and sophistication of the productive know-how required to produce a product. Product Complexity Index (PCI) is calculated based on how many other countries can produce the product and the economic complexity of those countries.

<u>Distance</u>
A measure of a country's ability to enter a specific product. A product's distance (from 0 to 1) looks to capture the extent of a location's existing capabilities to make the product as measured by how closely related a product is to its current exports. An 'adjacent' product requires related capabilities to those that exist, which implies greater likelihood of success of expanding production to this product. Every two products have a globally defined proximity between them as measured by the probability of co-export, which measures the probability that if a country exports product A, it also exports product B. The product proximities are fixed globally and measured using 128 countries' export data over 50 years. The distance of a product is then the sum of the proximities connecting that product to all the products that the location is not currently exporting.

Limitations
A first set of limitations of our analysis relates to the measurement of supply and demand elasticities. To proxy supply elasticity, we use production concentration as measured by a product's share in global exports. While higher concentration plausibly implies lower supply elasticity—because fewer alternative producers can expand output following price increases—this remains an imperfect proxy. In addition, we do not observe demand elasticities and therefore lack direct information on the costs of substituting or foregoing imports. Linking products to critical applications in Europe provides some indication that demand may respond sluggishly to price increases following supply disruptions, but the underlying data remain limited. Other structural limitations include the inherent subjectivity involved in selecting critical products, the exclusion of services from the analysis, and the fact that even HS-6–level product categories may be too coarse to capture certain vulnerabilities, such as those related to specific weapon systems embedded in broader product classes.
A second set of limitations concerns data quality and the methods used to identify inter-product linkages. While AIPNET offers a novel and systematic way to map production networks, the quality of individual linkages cannot be guaranteed, as the model does not capture substitutability between inputs, their economic importance, or the quantities required. Moreover, the used Prodcom data on domestic production are affected by substantial missing values. The use of proximity and complexity indicators relies on export co-occurrence as a proxy and therefore provides only an imperfect measure of technological relatedness or strategic relevance; these indicators are also available only at the HS-4 level. Taken together, these limitations imply that identifying

supply-chain vulnerabilities cannot be a fully data-driven exercise, and that expert judgement remains essential when interpreting the results and drawing policy conclusions.

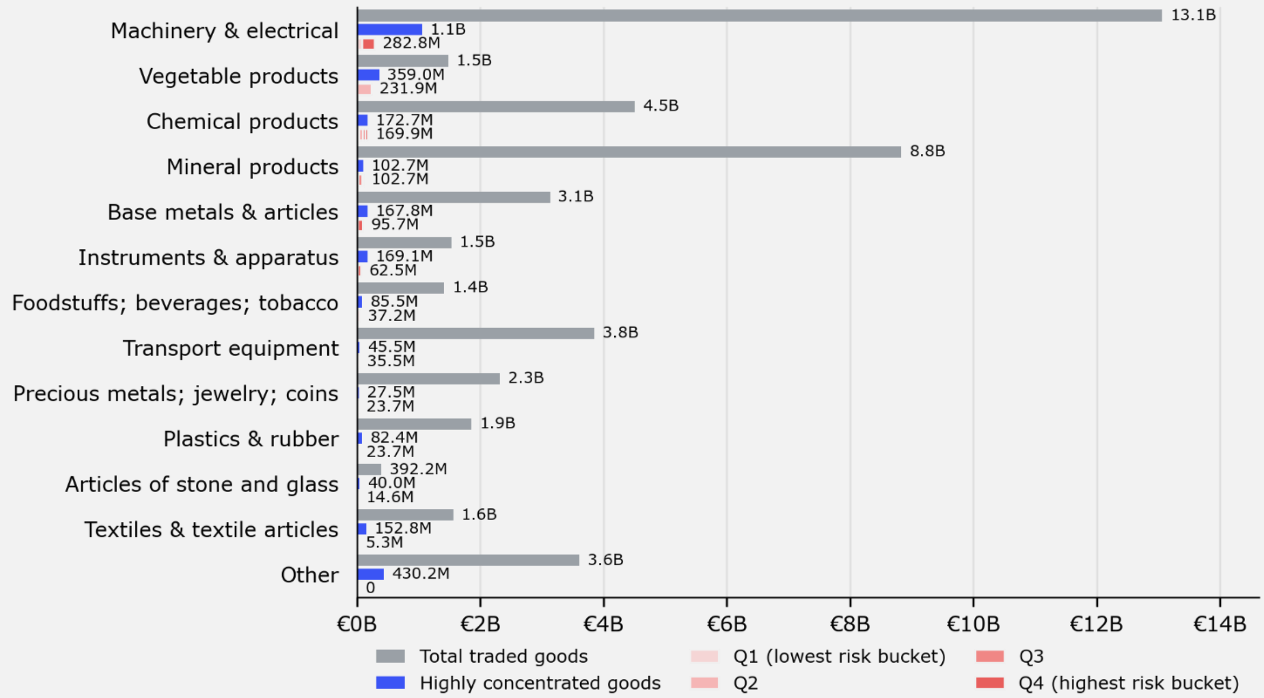
Additional results

Vulnerable goods by export value

In the main body of the text, we analyse the total number of vulnerable goods rather than their export value. We do so because current traded volume may give a false idea of total economic impact, as precisely for vulnerable goods the demand elasticities may be low and prices can sharply increase when supply is distorted. Nevertheless, as a robustness check, below we show the results of our analysis in section 3.2 when we use the export value of vulnerabilities rather than the number of vulnerabilities as the key indicator. The results reinforce the notions of concentrations at the product- rather than the sector-level (figure A2.2), and at the country-level within China (figure A2.3).

Figure A2.1 Vulnerable goods make up a small part of export value in each sector

Vulnerabilities per sector based on export value (2021-2023)

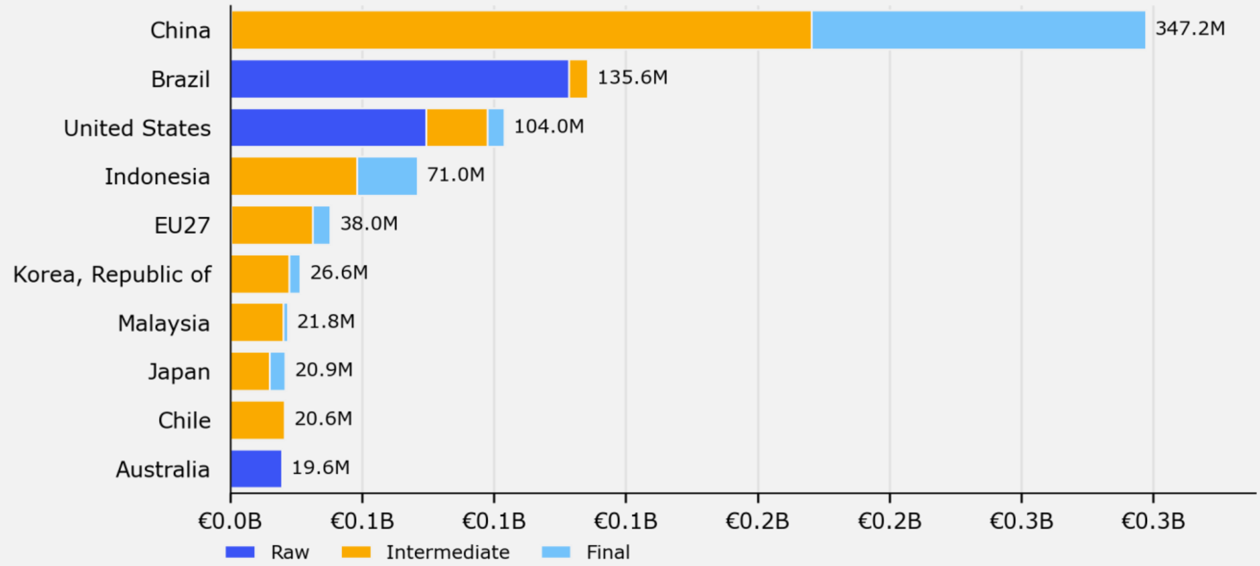


Note: Product categories, in title and main body called sectors, are based on HS sections; Other aggregates all sections without vulnerable products. Concentrated products are ranked by the number of critical products they are connected to in the production network, with closer connections receiving slightly higher weight (links weighted inversely by distance). Products are then grouped into quartiles based on this combined connectivity measure.

Source: Own calculations based on FIGARO-HS, Prodcom database and AIPNET

Figure A2.2 By export volume, vulnerabilities are still concentrated in China

Vulnerabilities per country based on export value (2021-2023)



Note: Vulnerable goods are assigned to a country if that country is among the top three largest exporters of the product. The figure shows the top 10 exporting countries based on export value. Products for which the EU is the largest exporter are excluded by construction, in line with the methodology. As a result, the EU can appear in this chart when it is the second or third largest exporter, but it does not appear in Figure 3.3, where only products with non-EU top exporters are shown.

Source: Own calculations based on FIGARO-HS, Prodcom database and AIPNET

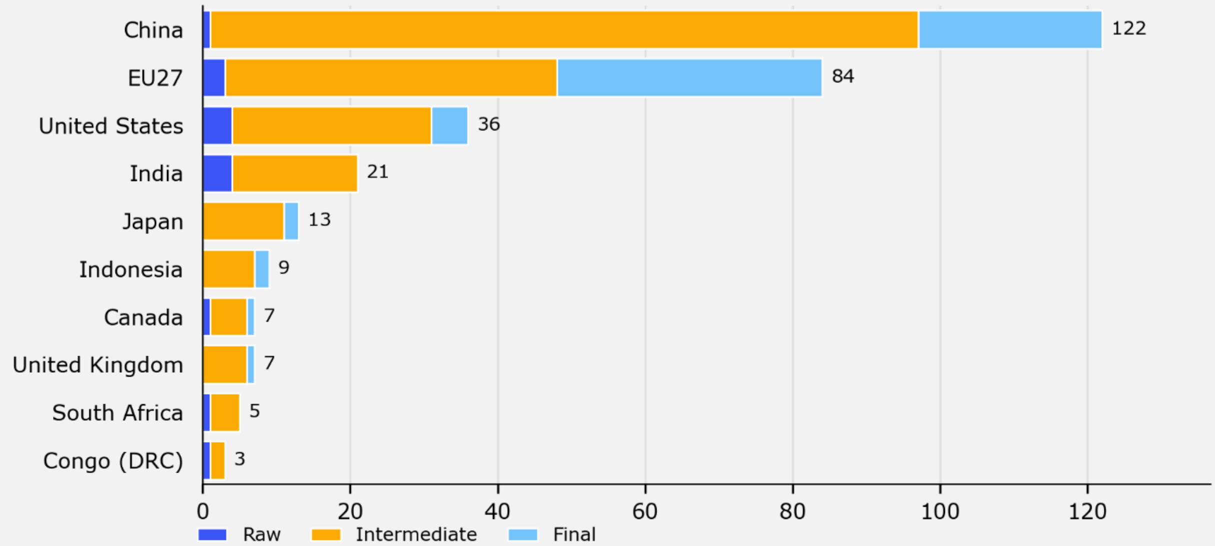
No filter for production, internal market or EU top exporter

The analysis in the main body contained three filters to exclude products for which the EU was likely to be able to have domestic alternatives. Firstly, it excluded products for which the EU was a top exporter. Secondly, it excluded goods for which intra-EU trade represents more than 50% of the value of global trade. And thirdly, it excluded goods for which EU production data show production of more than 50% of global trade. However, these filters mean that we cannot assess EU production of vulnerable goods vis-à-vis that of other economic blocs from the analysis in the main body. From a policy perspective, balancing production of vulnerabilities by other economic blocs (chokepoints) with EU production of vulnerabilities (control points) is nevertheless a viable option. Therefore, in figures A2.4 and A2.5 below, we show the results *without* those filters and *including* the EU.

From these figures, we can see that the EU cannot match the number or the export value of vulnerabilities produced by China. Nevertheless, as a bloc it ranks second before other economies such as the US, India or Indonesia. This means the EU is likely to hold significant leverage in a geopolitical conflict in which supply chains are weaponised.

Figure A2.3 The EU produces more vulnerable goods than the US, but fewer than China

Vulnerabilities per country based including EU (2021-2023)

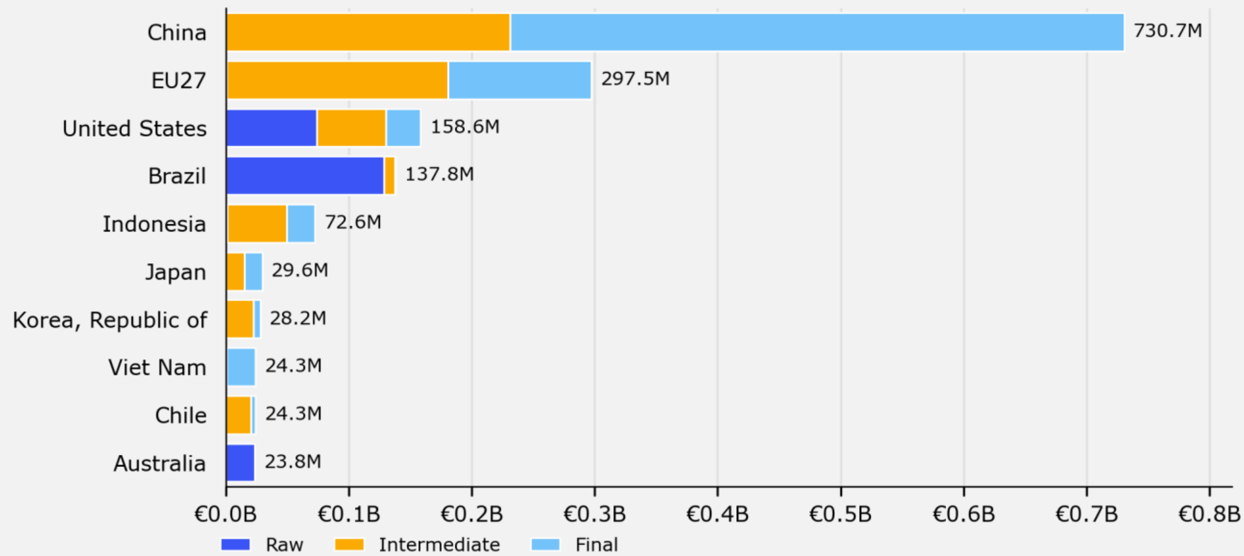


Note: The figure includes all products with high export concentration (HHI ≥ 0.4) that can be linked to critical goods through the production network. In contrast to the previous figures, products for which the EU is the main exporter, has a large internal market or substantial EU production are included in this sample. Vulnerable goods are assigned to the country that is their largest exporter. The figure shows the top 10 exporting countries.

Source: Own calculations based on FIGARO-HS and AIPNET

Figure A2.4 The EU ranks second by export value of vulnerable goods

Vulnerabilities per country based on export value including EU (2021-2023)



Note: The figure includes all products with high export concentration (HHI ≥ 0.4) that can be linked to critical goods through the production network. Vulnerable goods are assigned to a country if that country is among the top three largest exporters of the product. The figure shows the top 10 exporting countries based on export value. In contrast to earlier figures, products for which the EU is the main exporter, has a large internal market or substantial EU production are included in this sample. As a result, the EU can appear in this chart when it is either the largest, second, or third exporter.

Source: Own calculations based on FIGARO-HS and AIPNET