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To Act or Not to Act: Supply Chain Vulnerabilities and Government Intervention

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ABSTRACT: We study when and how governments should intervene to mitigate supply chain vulnerabilities. We develop a model in which firms optimally source inputs but do not internalize that aggregate import dependence increases both the probability and severity of supply disruptions, leading to excessive reliance on external suppliers. Policy can reduce this vulnerability, but at a cost, creating a trade-off between resilience and efficiency. Our framework implies that optimal intervention is hump-shaped in baseline dependence. We illustrate the quantitative relevance using rare earths, natural gas, and semiconductors in Europe, showing that even small trade exposures can generate sizable macroeconomic effects through production network amplification. Our results suggest that intervention is most valuable when inputs are central, hard to substitute, and shocks are large, while policies that reduce underlying distortions can enhance both efficiency and resilience. By linking endogenous disruption risk, production networks, and policy design, the paper provides a unified framework to assess supply chain resilience as a macroeconomic policy trade-of.

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WORKING PAPERS

To Act or Not to Act: Supply Chain Vulnerabilities and Government Intervention

Prepared by Allan Gloe Dizioli and Richard Varghese [1]

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1 Introduction

Global supply chains are being reshaped by rising geopolitical fragmentation, altering the organization of production and exposing new sources of macroeconomic risk. For open economies such as the European Union, the increasing concentration of critical imports, combined with heightened geopolitical tensions, has renewed concerns about supply disruptions and their potential to generate large and persistent output losses. Recent discussions in Europe on "economic security" or "strategic autonomy" reflect these concerns, emphasizing the need for policies to reduce exposure to external dependencies while preserving the efficiency gains from international integration (Macron, 2017; Draghi, 2024; von der Leyen, 2026).

In this paper, we define policies aimed at enhancing economic security—often framed as "strategic autonomy"—as those designed to reduce the risk of abrupt declines in economic activity stemming from disruptions to externally sourced inputs.[1] These risks can be mitigated through measures that expand domestic production capacity in targeted sectors, as well as through diversification across foreign suppliers.[2] We develop a framework to evaluate the associated cost–benefit trade-offs and to assess the potential unintended consequences of these interventions.

A central challenge in this debate is that policies aimed at strengthening resilience may come at the cost of efficiency. Firms optimally source inputs from the lowest-cost suppliers, often located abroad, leading to globally efficient production structures. However, when many firms make similar sourcing decisions, the resulting equilibrium can feature highly concentrated supply chains that are vulnerable to common disruptions. This reflects a coordination failure: individual firms do not internalize the aggregate consequences of their sourcing choices—particularly when disruption risks depend on economy-wide import dependence—so the decentralized equilibrium may exhibit excessive exposure to external shocks. This creates a potential role for policy to enhance economic security, but one that requires carefully weighing the insurance benefits of greater resilience against the fiscal and allocative costs of intervention.

These concerns are quantitatively material in the EU. Extra-EU imports of rare earth elements come almost entirely from three suppliers while roughly 60 percent of euro area automotive value added is linked to products containing rare earths. The EU consumes around 20 percent but produces only 10 percent of global semiconductors, with five partners accounting for more than three-quarters of imports of electronic integrated circuits. Natural gas imports, despite the diversification undertaken after 2022, remain concentrated, with the United States now supplying close to 60 percent of LNG. Recent firm-level evidence indicates that a halving of foreign critical inputs could reduce EU manufacturing value added by an average of 2.7 percent, with losses concentrated in a small number of firms, sectors, and regions (Panon and others, 2026). Against this backdrop, the question of whether—and how—governments should intervene in private sourcing decisions has become a first-order concern for macroeconomic policy.

Enhancing economic security often entails efficiency losses, creating a fundamental trade-off between

[1] We acknowledge that avoiding GDP losses is not the only possible objective of such policies. Alternatives include preventing a sharp deterioration in public health (which may, for example, motivate the stockpiling of critical medical supplies) and protecting against outages in essential national security services (e.g., through investment in satellite communication infrastructure).

[2] In the EU, examples of the former include the Industrial Accelerator Act (IAA), the Security Action for Europe (SAFE) defense financing instrument, the Grids Action Plan, and the digital euro project. On the external front, trade agreements with partners such as Mercosur, India, and Australia illustrate diversification efforts.

cost minimization and resilience (Bruegel, 2023). While firms' sourcing decisions generate an efficient allocation in normal times, policies aimed at reducing vulnerability require shifting resources toward higher-cost or less specialized suppliers in order to insure against disruption risk. This gives rise to an insurance problem at the aggregate level: improving resilience involves incurring upfront costs to reduce the expected losses from adverse events. Whether through expanding domestic capacity or diversifying external sourcing, the optimal degree of intervention depends on a comparison between these insurance costs and the expected economic losses associated with supply chain disruptions.[3]

In this context, this paper develops a framework to assess these trade-offs. It provides a framework to assess when—and how—policy intervention is warranted to mitigate supply chain vulnerabilities. Specifically, we introduce a stylized model in which firms choose between domestic and foreign inputs under uncertainty about supply disruptions. The key feature of the model is a coordination externality: while firms take disruption risk as given, the likelihood and severity of disruptions increase with the aggregate reliance on foreign suppliers. In this setting, equilibrium import dependence is socially excessive, and policy interventions that tilt sourcing toward domestic or diversified suppliers can improve welfare. At the same time, such interventions generate fiscal costs and efficiency losses due to resource misallocation and capacity constraints in domestic production. The model delivers tractable conditions under which corrective intervention is warranted and characterizes how the optimal policy depends on structural parameters such as substitutability, production network centrality, and disruption risk.

Building on this framework, we develop an approach to quantify these trade-offs in output terms, comparing the expected GDP losses from supply disruptions with the costs of insurance. The magnitude of disruption costs depends on sectoral centrality in production networks, the degree of external dependence, and the availability of substitutes. In turn, the cost of insurance reflects the fiscal resources required to expand alternative sources of supply, as well as the associated efficiency losses from resource reallocation.

We complement the theoretical framework with quantitative illustrations of supply disruptions in three sectors of particular relevance for the European economy—rare earth elements, natural gas, and semiconductors. These sectors combine highly concentrated supply structures, critical downstream uses, and limited short-run substitutability, making them natural candidates for policy attention. Using a range of modeling approaches, we show that disruptions to such inputs can generate macroeconomic effects that are disproportionately large relative to their direct trade shares, reflecting amplification through production networks and input–output linkages.

Specifically, a disruption to rare earth elements—quantified using an input–output framework (Bems, Johnson, and Yi, 2011)—can generate sizable output losses despite their negligible share in aggregate imports, with GDP declines reaching several percentage points in highly exposed countries and close to 1 percent on average across the EU, owing to strong sectoral interdependencies. Similarly, a shock to natural gas supply, modeled in a multi-country macroeconomic framework(Andrle and others, 2015), can reduce euro area output by around 0.8 percent in the first year, with persistent effects and significant inflationary pressures. In the case of legacy low-tech semiconductors, simulations based on a DSGE framework (Anderson and others, 2013) show that temporary disruptions to critical inputs

[3]Historically, such disruptions have tended to be low-probability, high-impact events—rare realizations that can generate outsized economic losses (e.g. the COVID-19 pandemic and associated cross-border supply chain disruptions). However, the likelihood of a severe disruption is a function of the prevailing geoeconomic environment, and often subjective.

can lead to output losses of around 0.4 percent, reflecting tight linkages across manufacturing value chains and limited short-run substitution possibilities. Taken together, these findings highlight that the macroeconomic impact of supply disruptions is driven less by the direct size of trade exposure than by the structure of production networks, with important implications for policy design.

Our paper contributes to several strands of the literature. First, it relates to the growing body of work on geoeconomic fragmentation and its macroeconomic consequences, by focusing on the vulnerability of economies that are exposed to concentrated supply dependencies. Second, it complements recent theoretical models of strategic interdependence by formalizing the externality arising from decentralized sourcing decisions and deriving policy prescriptions in a tractable setting. Third, it connects to empirical work on supply chain propagation by highlighting the importance of network structure in amplifying shocks and shaping policy trade-offs.

The analysis yields three main insights. First, the case for intervention depends critically on the interaction between disruption risk and production structure: policies are most valuable when inputs are central, substitution is limited, and shocks are both likely and severe. Second, the effectiveness of intervention is non-linear, with diminishing returns when import dependence is either very low or very high. Third, policies that reduce pre-existing distortions—such as deeper market integration—can simultaneously enhance resilience and efficiency, in contrast to distortionary interventions such as subsidies or local content requirements.

The remainder of the paper is organized as follows. Section 2 reviews the related literature. Section 3 presents the theoretical framework and characterizes the equilibrium and optimal policy. Section 4 provides quantitative illustrations of sectoral disruptions and their macroeconomic impact. Section 5 concludes.

2 Literature review

Our paper integrates four strands of research. The first documents the realignment of global economic relationships along geopolitical lines and its macroeconomic consequences. The IMF Staff Discussion Note on geoeconomic fragmentation (International Monetary Fund, 2023) provides a systematic account of the channels—trade, capital flows, technology diffusion, migration, and the provision of global public goods—through which policy-driven fragmentation imposes costs on the global economy, with severe-scenario output losses ranging from 0.2 to 7 percent of GDP and up to 8–12 percent once technological decoupling is layered on. Gopinath and others (2024) offer granular empirical evidence, documenting declines of roughly 12 percent in trade and 20 percent in FDI between geopolitically distant blocs since Russia's invasion of Ukraine, while identifying the emergence of nonaligned 'connector" countries that sustain aggregate flows without necessarily reducing underlying strategic dependencies. Our paper takes the existence of fragmentation as given and focuses on its consequences for economies that have concentrated supply dependencies.

A second strand provides the theoretical foundation for treating supply-chain vulnerabilities as a macroeconomic, rather than purely sectoral, problem. Production-network models (Acemoglu and others, 2012; Carvalho and Tahbaz-Salehi, 2019) establish that asymmetric input–output structures can translate idiosyncratic shocks into sizable aggregate fluctuations through hub sectors and second-order interconnections. Firm-level sourcing models (Antràs, Fort, and Tintelnot, 2017) endogenize the formation of these dependencies, showing that interdependent fixed costs of sourcing generate concentrated import patterns that rationally cluster around low-cost suppliers. Clayton, Maggiori, and Schreger (2026) develop a general-equilibrium framework in which a hegemonic country exploits its position in global input–output networks to coordinate joint threats across disparate economic relationships, demonstrating that the mere prospect of coercion distorts equilibrium sourcing decisions. A key insight is that input–output amplification implies that the strategic value of a sector can be substantially larger than its direct trade share. We build on these contributions by modeling the externality that arises when firms fail to internalize the aggregate vulnerability their individual import decisions create, and by characterizing the optimal corrective intervention.

Relatedly, a complimentary line of policy research provides the institutional context for our analysis. President Macron's 2017 Sorbonne speech framed the EU's external dependencies as a strategic vulnerability requiring a coordinated European response (Macron, 2017). The European Economic Security Strategy adopted by the Council in 2023 formalized this agenda (European Union, 2023). The Draghi Report (Draghi, 2024) argued that fragmented internal markets and excessive reliance on external suppliers undermine the EU's long-run growth potential, and von der Leyen (2026) emphasized the urgency of building resilient supply chains. A recurring theme in this debate is the tension between economic efficiency and geopolitical resilience: as Bruegel (2023) observes, strategic autonomy requires a difficult balancing act in which policies that enhance security typically entail efficiency losses. Our framework formalizes this trade-off, derives conditions under which corrective intervention improves welfare, and makes explicit the fiscal and distortionary costs that such intervention entails.

A third strand of empirical literature maps supply-chain vulnerabilities and traces their propagation through production networks. The German Council on Foreign Relations (2023) catalogues critical infrastructure sectors across 193 UN member states, documenting wide cross-country variation in what governments designate as critical. Thurner and Klimek (2025) argue that the EU should develop a firm-level "Digital Twin" of its economy capable of stress-testing supply disruptions in real time, emphasizing that the macroeconomic impact of a disruption depends on the structure of production linkages rather than on the direct trade share of the affected input. Aguilar and others (2026) study export controls on rare earth elements using a combination of partial equilibrium, closed-economy DSGE, and multi-country multi-sector models, showing that even partial restrictions can generate meaningful output losses and inflationary pressures, particularly in automotive, electronics, aerospace, and defence sectors. Bonadio and others (2021) and Panon and others (2026) provide complementary firm- and country-level evidence on the propagation of supply shocks through global value chains, with the latter documenting EU manufacturing value-added losses of 2.7 percent on average under a 50 percent reduction in foreign critical inputs.

Finally, our analysis connects to the literature on the efficacy of government intervention in the presence of strategic dependencies. Brandão-Marques and Toprak (2024) provide causal evidence on state aid to listed nonfinancial firms in six European countries between 2016 and 2023, using a high-frequency identification strategy. They find that recipient firms increase employment and revenue but not investment or labor productivity, and that adverse spillover effects on competitors substantially offset—and after two years more than offset—the direct benefits. Their results underscore a point central to our framework: even where a market failure justifies intervention, the design of the instrument matters.

Our paper contributes along three dimensions. First, we formalize the coordination externality that lies implicit in the strategic autonomy debate but has not been characterized in the existing theoretical literature. Production-network models take the structure of dependencies as given; firm-level sourcing models endogenize sourcing patterns but treat disruption risk as exogenous; and geoeconomic frameworks characterize the hegemon's exercise of pressure but not the targeted country's welfare-maximizing response. Our model closes this loop by making the probability of a disruption a function of aggregate import dependence and showing that the decentralized equilibrium is generically inefficient. Second, we derive sharp comparative statics that map structural parameters into the optimal intensity of intervention. The case for intervention strengthens with the probability and severity of disruption, the centrality of the input, and the substitutability between foreign and domestic sources, but weakens as domestic production rigidities raise fiscal and distortionary costs. The optimal intervention is hump-shaped in baseline import dependence, reflecting the diminishing effectiveness of policy at the extremes—a result that disciplines contemporary debates which often presume more protection is unambiguously safer. Third, we quantify the trade-off across three sectors of central policy interest—rare earth elements, natural gas, and low-tech semiconductors—using a deliberately heterogeneous set of modeling tools. The common thread is that aggregate GDP losses are an order of magnitude larger than the direct trade share of the disrupted input, reinforcing the case for treating supply-chain vulnerabilities as a first-order macroeconomic concern and providing analytical foundation for an emphasis on the complementarity rather than the trade-off between European integration and economic security.

3 A model of supply chain vulnerability

This section introduces a stylized theoretical framework designed to formalize the key trade-offs underlying policies aimed at improving economic security and resilience to supply chain disruptions. The model highlights a coordination externality arising from firms' sourcing decisions: when firms independently choose the cheapest available suppliers, production tends to become concentrated in a small set of low-cost, possibly foreign, suppliers. While individually optimal, these private decisions can collectively increase the economy's vulnerability to common supply disruptions. The framework is therefore useful for understanding why market outcomes may lead to socially excessive concentration in supply chains and underinvestment in resilience. Critically, the model also provides guidance on the factors that determine the desirability of policy intervention, including the likelihood and severity of disruptions, the substitutability across suppliers, and the costs associated with diversification or domestic production. In this framework, policy can be interpreted as trading off the insurance benefits of greater resilience against the fiscal costs and efficiency losses that may arise from interventions aimed at reshaping sourcing patterns or production structures.

3.1 Final goods production production technology

In this model, the final goods production is characterized by a representative firm that uses capital K, labor L, and a goods (intermediate input) composite M according to a Cobb–Douglas production function:

$$Y = A\, M^{\gamma} K^{\beta} L^{1-\gamma-\beta}, \tag{1}$$

where $A > 0$ denotes total factor productivity and $\gamma, \beta \in (0, 1)$.

Let's assume that the intermediate input used in the procution, M, is a constant elasticity of substitution (CES) aggregate of imported intermediate M_F and domestically produced intermediate

M_D, that is:

$$M = \left[\alpha^{\frac{1}{\sigma}} M_F^{\frac{\sigma-1}{\sigma}} + (1-\alpha)^{\frac{1}{\sigma}} M_D^{\frac{\sigma-1}{\sigma}}\right]^{\frac{\sigma}{\sigma-1}}, \qquad \sigma > 1, \tag{2}$$

where $\alpha \in (0,1)$ captures baseline import dependence and σ is the elasticity of substitution between foreign and domestic intermediate.

3.2 Domestic supply rigidity

Domestic intermediate production exhibits increasing marginal costs:

$$c_D(M_D) = \frac{\kappa}{1+\eta} M_D^{\eta}, \qquad \kappa > 0,\ \eta > 0, \tag{3}$$

where η captures the difficulty of ramping up domestic production capacity. A higher η implies stronger capacity constraints and steeper marginal costs.

3.3 Foreign dependency and its relation with the elasticity of substitution

Let p_F denote the price of imported intermediate and p_D the price of domestic intermediate. Cost minimization implies that the unit price of the intermediate composite is given by the CES price index:

$$p_M = \left[\alpha p_F^{1-\sigma} + (1-\alpha) p_D^{1-\sigma}\right]^{\frac{1}{1-\sigma}}. \tag{4}$$

The optimal sourcing condition implies:

$$\frac{M_F}{M_D} = \frac{\alpha}{1-\alpha} \left(\frac{p_F}{p_D}\right)^{-\sigma}. \tag{5}$$

Hence, lower foreign prices increase the equilibrium reliance on imported intermediate. The elasticity of substitution parameter σ is key to determine the dependency on foreign intermediates. With a high enough elasticity of substitution, even small price differences can lead to substantial more foreign dependency.

From the equation 4, we can calculate the import share, which is define as θ, as:

$$\theta = \frac{\alpha (p_F)^{1-\sigma}}{\alpha (p_F)^{1-\sigma} + (1-\alpha)(p_D)^{1-\sigma}} \tag{6}$$

3.4 Probability of supply disruptions

Suppose that the probability of supply disruptions is given by Π. This probability could depend on exogenous factors such as the weather, an exogenous shock like COVID, or can be endogenous, for example, the probability that the shock materializes is higher if the input supply is provided by just one country[4] To capture this idea, suppose that the probability that of supply disruptions is a function of import share of intermediates dependence θ, and satisfies the following conditions:

$$\Pi'(\theta) > 0 \text{ , and } \Pi''(\theta) \geq 0 \tag{7}$$

which means that higher import dependence increases the probability of supply disruptions.

In case the supply disruption materialize, we could map the lower supply as a shock to the price of the intermediate good in the following form:

[4] A shock can hit this one country with more probability, or if the dependency is high, a foreign government could use its supply chain dominance in negotiations.

$$p_F \to p_F(1+\tau), \qquad \tau > 0. \tag{8}$$

Thus, under supply disruptions, the intermediate price index becomes:

$$p_M(\tau) = \left[\alpha(p_F(1+\tau))^{1-\sigma} + (1-\alpha)p_D^{1-\sigma}\right]^{\frac{1}{1-\sigma}}, \tag{9}$$

which raises unit costs and reduces output.

If the supply disruption materializes, the economy must substitute away from foreign intermediates at higher cost. The output loss depends on the initial import dependence θ and the elasticity of substitution σ.

3.5 Private sector solution

From cost minimization we know that output Y is a function of input prices

$$Y = A\left(\frac{\gamma}{pm}\right)^{\gamma}\left(\frac{\beta}{r}\right)^{\beta}\left(\frac{1-\gamma-\beta}{w}\right)^{1-\gamma-\beta} \tag{10}$$

therefore, the supply disruption affects output through its effect on the input price pm.

if we divide equation 9 by equation 4 and use the definition in 6, we can rewrite the input price as a function of the import dependence:

$$p_M(\tau) = p_m\left[\theta(1+\tau)^{1-\sigma} + 1 - \theta\right]^{\frac{1}{1-\sigma}}. \tag{11}$$

Using the closed form solution for Y in equation 10 and what we derived in equation 11, we can write the output loss because of the supply disruption as:

$$\Delta Y(\theta,\tau) = Y - Y(\tau) = Y(1 - \left[\theta(1+\tau)^{1-\sigma} + 1 - \theta\right]^{\frac{\gamma}{1-\sigma}}), \tag{12}$$

Note that $\frac{\partial \Delta Y}{\partial \theta} > 0$, which means that countries with higher import dependence suffer larger output losses from the same supply disruption shock.

Let's then define the expected output loss from a supply disruption as:

$$\mathbb{E}\mathcal{L}(s) = \pi(\theta(s))\Delta Y(\theta(s),\tau). \tag{13}$$

3.6 The Government problem

Given the probability of disruption described earlier, a government tries to minimize the cost of disruption weighted against the cost of intervention. Note that there are other ways that governments can reduce the risks of supply disruption and not impose neither fiscal nor distortionary effects. For example, the government can achieve trade deals with other countries, that lowers the cost of individual companies from buying from different suppliers. Even withing a trade block, there could be domestic structural reforms that could lower the cost of production and lower domestic costs without adding any distortion. In fact, those policies enhance supply security by removing resources allocation distortion.

In case of distortionary interventions, the government can choose to support the industry/good supply at the rate $s \in [0,1)$ to minimize the sum of of the Expected output loss from supply disruptions: $\pi(\theta(s))\Delta Y(\theta(s))$ and the total cost of the intervention, which includes the fiscal cost, and the deadweight loss from distortions. The support could be through subsidies, directing companies to buy inputs with a certain local content.

Direct fiscal cost: The government pays intervention s per unit of domestic intermediate:

$$\text{Fiscal cost(s)} = s \cdot p_D \cdot M_D(s), \tag{14}$$

Under a intervention s, domestic intermediate demand implied by the CES aggregator scales as

$$M_D(s) \propto (1-s)^{-\sigma}. \tag{15}$$

where $M_D(s) = (1-\alpha)\left(\frac{(1-s)p_D}{p_M(s)}\right)^{-\sigma} M(s)$.

Government expenditure associated with the intervention is therefore

$$\mathcal{C}(s) = s\frac{\kappa}{1+\eta}(1-s)^{-\sigma(1+\eta)}. \tag{16}$$

Deadweight loss: The intervention distorts production decisions, creating efficiency losses. The appendix shows a formal derivation of the deadweight loss:

$$\mathcal{DWL}(s) = \frac{1}{2}\kappa\eta\sigma^2 \cdot s^2 \cdot p_D \cdot M_D(s), \tag{17}$$

where $\kappa\eta\sigma^2 > 0$ captures the distortionary cost per unit of intervention. Higher $\kappa\eta\sigma^2$ reflects greater misallocation from directing resources to less efficient domestic production.

Total cost: The government's total cost of the intervention is:

$$\mathcal{C}(s) = \text{Fiscal cost(s)} + \mathcal{DWL}(s) = s \cdot p_D \cdot M_D(s)\left(1 + \frac{\kappa\eta\sigma^2 s}{2}\right). \tag{18}$$

Using $M_D(s) \propto (1-s)^{-\sigma}$ and $p_D = c_D(M_D) = \frac{\kappa}{1+\eta}M_D^{\eta}$, we can write:

$$\mathcal{C}(s) = \underbrace{s\frac{\kappa}{1+\eta}(1-s)^{-\sigma(1+\eta)}}_{\text{fiscal cost}} + \underbrace{\frac{\kappa^2\eta\sigma^2 s^2}{2(1+\eta)}(1-s)^{-\sigma(1+\eta)}}_{\text{deadweight loss}}. \tag{19}$$

The government problem is then given by the following optimization problem

$$\min_{s\in[0,1)} \ \pi(\theta(s))\Delta Y(\theta(s)) + s \cdot p_D \cdot M_D(s)\left(1 + \frac{\kappa\eta\sigma^2 s}{2}\right). \tag{20}$$

The first-order condition becomes:

$$\underbrace{\left[\pi'(\theta)\Delta Y(\theta) + \pi(\theta)\Delta Y'(\theta)\right]\frac{d\theta}{ds}}_{\text{marginal benefit: reduced vulnerability}} = \underbrace{\frac{\partial \mathcal{C}}{\partial s}}_{\text{marginal cost: fiscal + DWL}}. \tag{21}$$

This explicitly shows the trade-off: the intervention s reduce both the probability of disruption ($\pi'(\theta) < 0$) and the severity of losses when they occur ($\Delta Y'(\theta) > 0$), but at increasing fiscal and efficiency costs. Note that if the marginal benefit is larger than the marginal cost when $s = 0$, then we have an interior solution and the private sector solution is not socially optimal, that is, the import dependence, $\theta_{private}$ is higher than socially optimal θ_s. The reduction in expected loss is the marginal benefit of the policy.

The private firm cares only about its own production cost. It treats a supply disruption as an ex post risk that it cannot influence; therefore it does not internalize the term $\pi(\theta(s))\Delta Y(\theta(s))$

3.7 How does this intervention depend on model parameters?

Appendix B fully derives the optimal solution of the government's problem (equation 21). In this section, we just briefly describe how that solution depends on parameters:

Initial dependence, is ambiguous. For low to initial moderate dependence, higher θ_0 increases vulnerability and raises the optimal intervention. However, for very high dependence, the sensitivity of import dependence to subsidies collapses, making policy ineffective.

Elasticity of substitution between different input supply sources, higher substitutability increases the effectiveness of subsidies;

Potential size of disruption, The disruption can usually be mapped into a "tariff" equivalent (the τ). Larger shocks justify larger interventions.

Cost of increasing domestic production, greater domestic supply rigidity raises fiscal costs.

Convexity in the domestic production costs, Convex vulnerability (higher ν) increases the marginal value of the intervention.

Probability of supply disruption, the higher the probability of disruption, the more valuable the intervention is.

Importance of input for production, how much value the input brings to production and how easy it is to substitute across different production factors (for example, can we substitute the inputs with more capital and labor, or with a different input material?).

3.8 Numerical example

A numerical example can better illustrate the mechanics of the model. In Table 1 we provide some illustrative values. In particular, we set the production size to be large, a relatively high bias toward foreign production that implies a high dependence regardless of price difference, we set a high elasticity of substitution and a high importance for the intermediate sector, the cost of the disruption is high and set at an equivalent tariff of 50 percentage points, the probability of disruption is set at 30 percentage points, we set mild production cost parameters and set domestic price 20 percentage points above the international price.

With these parameters, the marginal benefit of no intervention, $s = 0$, is $MB = 0.61$, while the marginal cost is $MC = 0.29$. This implies that some positive intervention will reduce society losses. With this calibration, the intervention that would minimize society losses is $s = 0.18$. This intervention would reduce external dependence from 72 percent to 58 percent.

Now, let's suppose that the triple the probability of intervention, the λ, from 15 percent to 45 percent. In this case, the optimal intervention is much higher at $s = 0.75$ and the external dependence is decisively reduced to just above 4 percent. This illustrative example just shows that the intervention that would minimize society losses could be much larger if the probability of disruption is higher. In other words, a larger probability of disruption makes an intervention much more valuable.

Parameter	Value	Description
Y	50	Size of the economy
α	0.6	Bias towards foreign product
σ	4	Elasticity of Substitution
γ	0.5	Importance of intermediate
τ	0.5	Cost of Disruption mapped into tariff value
λ	0.15	Probability of disruption
κ	0.4	Cost to Scale up production
η	0.4	Non linearity in Cost to Scale up production
p_f	1	International price without taxes
p_d	1.2	Domestic price without Intervention

Table 1: Model parameter values

3.9 Private equilibrium and inefficiency

The expected loss that the whole economy incurs because of the combined firms' decision of where to import their inputs from, which causes the whole economy import dependence to be θ, is given by:

$$\pi(\theta(s))\Delta Y(\theta(s)). \tag{22}$$

Note that this expected loss term to the whole economy does not enter in the firm's objective functions, so each atomistic firm does not internalize that. Even if each individual firm could calculate their individual output loss in case of a supply disruption, and adjust their inputs to account for that, the market failure would still arise if the probability of disruption, $\pi(\theta)$, depends on the economy-wide import dependence, which each individual firm would not internalize. Consequently, the decentralized equilibrium features excessive reliance on imported intermediate.

4 Illustrative quantification of sectoral disruptions

The theoretical framework described in section 3 laid out the externality problem that might arise in the private sector equilibrium and also provided some important elements that make the state intervention more beneficial. In this section, we go one step further and use different calibrated macroeconomic models to simulate stylized extreme illustrative scenarios of supply chain disruptions.

The intention is not to be exhaustive in our product choice and not to give any sense of prioritization. The only goal is to illustrate how to approach the quantification of disruption costs in sectors that contain some of the main elements described in section 3. We look for intermediate products with high sectoral-interlinkages, highly concentrated global supply structures, and limited short--run substitutability, which all create structural vulnerabilities to external shocks. Specifically, we evaluate three product markets: rare earth elements (REEs), natural gas, low-tech microchips and memory products. These sectors are of critical importance for the EU economy—REEs as indispensable inputs for automotive, defense, and green-transition manufacturing; natural gas as a key source of energy for industry and households; and low-tech microchips and memory products as essential and pervasive components in vehicles, industrial machinery, and consumer electronics industrial control systems, telecommunications equipment, and consumer devices.

These illustrative examples of supply chain disruptions highlight distinct channels through which concentrated strategic dependencies can transmit to aggregate activity, with the potential to generate disproportionate near-term output effects relative to the size of the initial disruption. Although the examples are comparable in their focus on critical inputs, high supply concentration, and limited short-run substitutability, their economic transmission mechanisms differ markedly. These differences shape the speed, magnitude, and sectoral incidence of the macroeconomic adjustment, as well as the associated policy trade-offs. This heterogeneity underscores that a uniform analytical treatment to measure the costs of supply-chain disruptions might not be either feasible or desirable, and that effective risk assessment might require different analytical tools.

4.1 Case 1: Rare Earth Elements Markets

This section quantifies the potential short-run impact of a disruption in rare earth elements (REE) markets. It describes the main elements of the market and the simulation assumptions and methodology. Overall, the impact is heterogeneous, with the largest impacts in Germany, Romania, Czech Republic, and Hungary.

4.1.1 Market Structure and Strategic Importance

Although the EU's total imports of rare earth elements (REEs) are quantitatively small—amounting to less than 0.1 percent of GDP in 2024 (12,900 tonnes, with an import value of €101 million)[5]—their macroeconomic relevance is amplified by pronounced supply- and demand-side concentration and limited short-run substitutability.

On the supply side, the EU's exposure is highly skewed, with China (46.3 percent), Russia (28.4 percent), and Malaysia (19.9 percent) jointly accounting for approximately 95 percent of total REE imports. This degree of concentration implies a high susceptibility to idiosyncratic geopolitical, logistical, or policy shocks originating from a narrow set of suppliers. On the demand side, REEs are embedded disproportionately in a small number of strategic downstream sectors, notably automotive, energy, and defense, where input substitution possibilities are limited in the near term. In the euro area automotive sector alone—which represents close to 2 percent of GDP and around 4 percent of extra-euro area exports—between 60 and 65 percent of gross value added is associated with products containing some REEs.[6] The combination of upstream concentration and downstream criticality implies that even modest disruptions to REE supply can propagate rapidly along value chains, leading to production bottlenecks and non-linear output losses.

As a result, the economic impact of REE supply disruptions is likely to be disproportionate to their direct trade or value-added footprint. Rather than operating through aggregate trade volumes, shocks transmit through production networks, generating outsized near-term output effects relative to the small import share of REEs in GDP. This feature makes REEs a salient example of how strategic dependencies on narrowly sourced inputs can pose material macroeconomic risks despite limited exposure in trade statistics.

[5] Eurostat (2025), "Imports of rare earth elements saw 30% drop in 2024".
[6] IW Consult (2024), Kritisch für die Wertschöpfung – Rohstoffabhängigkeit der deutschen Wirtschaft.

4.1.2 Methodology

We begin by estimating sectoral dependencies on rare earth elements (REEs). While comprehensive and granular measures of sector-level REE use are not directly observable, existing evidence allows for a structured approximation of relative exposure across sectors. Specifically, we classify industries into high, medium, and low REE dependency categories based on available quantitative estimates and complementary qualitative information from industry and policy sources. For example, industry studies indicate that the share of gross value added attributable to products containing some REEs is particularly high in the German automotive sector, at around 65 percent. Based on discussions with industry associations and sector experts, which emphasize the presence of acute bottlenecks and the risk of complete production shutdowns following REE supply disruptions, we conservatively treat the effective dependency of this sector as approaching 100 percent for the purposes of the stress-scenario calibration. Thus, we use such benchmark estimates to inform the classification of other sectors, combining partial quantitative evidence with sectoral characteristics and input-output linkages to construct a consistent mapping of REE exposure across the economy. The resulting classification of sectoral REE dependencies and the associated quantitative assumptions are summarized in Table 2.

Table 2: Assumptions on Sectoral REE Dependency

Sector	Dependency	Estimates (percent of GVA from products containing some REEs)
Motor Vehicles	High	∼ 100% for automobiles; ∼ 80% for trucks and other vehicles
Renewables	High	∼ 60%; cited as high, especially for wind and to a lesser extent for solar
Defense & Aerospace	Medium	∼ 40%; high for advanced systems, with limited evidence for less advanced systems
Electronics & ICT	Medium	∼ 40%; essential particularly for displays and related components
Other	Low	∼ 20%; not used in the simulations

Next, we assume that in the near term there are virtually no possibilities for substituting REEs with alternative materials or suppliers in the production process. While inventories or precautionary stockpiling may in practice provide some limited short-run cushioning, for our purposes we abstract from storage and assume that no REE inventories are available at the time of the shock. This assumption is consistent with modeling frameworks that focus on short-horizon disruptions in which firms are unable to adjust their input mix.

In particular, Bems, Johnson, and Yi (2011) provide a tractable framework to quantify such near-term supply disruptions by assuming Leontief production technologies and using input–output methods to trace the propagation of sectoral shocks across the production network when input substitutability is absent. In this setting, disruptions can be amplified through vertical production linkages: reduced output in downstream sectors lowers demand for upstream inputs, generating second-round effects. Additional amplification may arise through international trade linkages, as supply-chain disruptions in one country depress demand for intermediate inputs produced abroad. At the same time, partial dampening effects may occur when multiple sectors are simultaneously constrained, as lower production in one sector mechanically reduces intermediate input requirements in others. [- ALLAN READ AND FIX PLEASE - The net effect reflects the balance between these amplification and offsetting mechanisms along domestic and cross-border value chains. [Finally there could be some dampening effect if two sectors are shocked at the same time because if production is lower be].

To operationalize the framework proposed by Bems, Johnson, and Yi (2011), we first map the sectors discussed in the previous section to the corresponding sectors in an input–output classification. We rely on the World Input–Output Database (WIOD), which provides harmonized input–output tables covering 56 sectors across 44 countries, including all EU-27 member states. This mapping allows us to translate sector-specific REE dependencies into shocks at the level of the input–output structure used in the quantitative analysis.

We map the sectors most exposed to rare earth element (REE) imports to the corresponding aggregate industries in the World Input–Output Database (WIOD). Specifically, the automotive sector is mapped to *Manufacture of motor vehicles, trailers and semi-trailers*, which accounts for around 2 percent of EU GDP. The renewable energy sector is treated as a subset of *Electricity, gas, steam and air conditioning supply*, with its weight computed as the share of renewable energy production in total energy output; this sector is estimated to represent approximately 0.75 percent of EU GDP. The defense and aerospace sector is mapped as a subset of *Manufacture of fabricated metal products, except machinery and equipment*. For simulation purposes, we compute its weight using data on defense and aerospace manufacturing output relative to total output in the fabricated metal products sector; this activity accounts for roughly 0.1 percent of EU GDP. Finally, the electronics and ICT sector is mapped to *Manufacture of computer, electronic and optical products* as well as *Manufacture of electrical equipment*, jointly representing close to 1 percent of EU GDP.

4.1.3 Scenario Design

We consider a stylized extreme stress scenario in which a major disruption in global rare earth element (REE) markets leads to an abrupt 50 percent reduction in EU REE imports (approximately €50 million). Given the highly concentrated supply structure and the lack of short-run substitutability, we assume that this import shock results in a proportional shutdown of 50 percent of REE-dependent production activities across affected sectors.

Applying the sectoral dependency assumptions summarized in Table 2, this translates into sizable sector-specific production losses. In the motor vehicles sector, where REE content is estimated to be close to 100 percent for automobiles and around 80 percent for trucks and other vehicles, the implied production impact ranges between 40 and 50 percent. In the renewables sector, where REE dependency is estimated at around 60 percent—particularly high for wind energy—the shock implies a production decline of roughly 30 percent. For defense and aerospace as well as electronics and ICT, each characterized by medium REE dependency of about 40 percent, the corresponding production impact is around 20 percent. Sectors with low estimated REE dependency (around 20 percent) are not explicitly modeled in the simulations. Consistent with the near-term focus of the analysis, we further assume that no REE inventories are available to buffer production in the year of the shock.

4.1.4 Results

The results indicate that a major disruption in global rare earth element (REE) markets could have sizable macroeconomic effects across EU member states. The estimated GDP impact in 2026 reaches

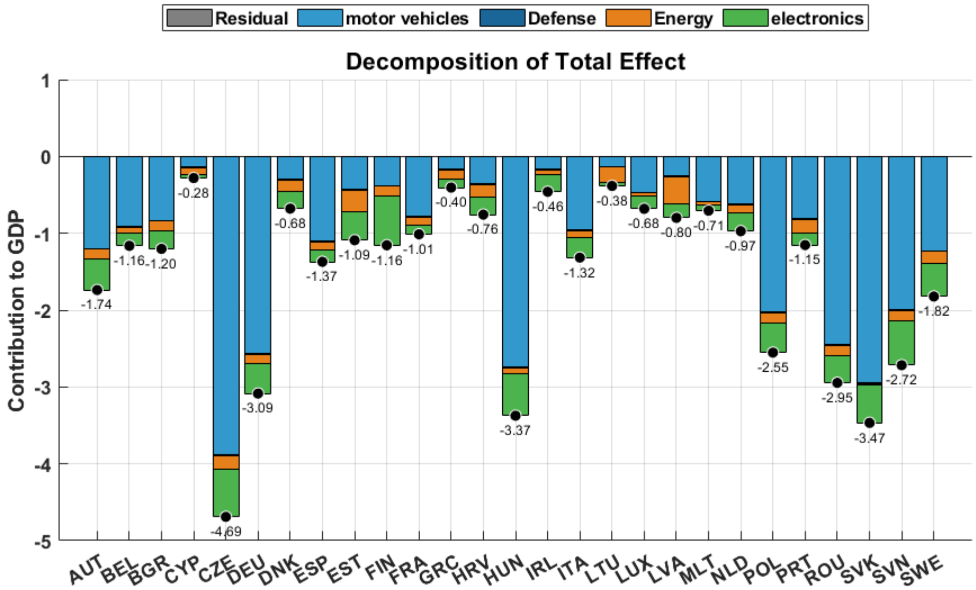

Figure 1: GDP impact of REE import disruption.

Note: The figure decomposes the total GDP impact of a rare earth elements (REE) import disruption across sectors. Bars report country-level GDP contributions (percent), with colors indicating sectoral channels (motor vehicles, defense, energy, and electronics). The residual captures spillovers through input–output linkages and other indirect effects. Negative values indicate output losses; labels denote the total effect by country.

up to 4.5 percent in the Czech Republic, while for most other countries losses fall in the range of 0.3 to 3.5 percent. On average, the GDP effect across the EU is estimated at around −0.9 percent. Figure 1 sectoral contributions to output losses across countries EU member states.

Notably, the implied decline in GDP is smaller than the initial country-level production shock computed for REE-dependent sectors. This wedge reflects several accounting and propagation mechanisms. First, lower domestic production mechanically reduces imports, which partially offsets the GDP impact in expenditure terms. Second, reduced output in downstream sectors lowers demand for intermediates produced by upstream sectors—for example, a contraction in automotive production reduces demand for electronics. To avoid double counting, such indirect demand effects are excluded from the aggregate GDP impact. As a result, the overall GDP loss is smaller than the simple sum of initial sectoral production declines.

4.2 Case 2: Natural Gas

The second stylized scenario examines the short-run macroeconomic impact of an exogenous disruption to EU natural gas imports.

4.2.1 Market Structure and Strategic Importance

The EU's natural gas imports remain sizable, with average monthly inflows in 2025 amounting to 17.3 million tonnes and a total value of €10 billion (about 0.7 percent of 2024 GDP). These imports comprise 8.4 million tonnes of LNG, valued at €4.7 billion, and 8.9 million tonnes of pipeline gas in gaseous form, valued at €5.3 billion (Eurostat, 2025). While supply is relatively concentrated—both in terms of the external producers on which the EU relies and the regasification terminals that facilitate LNG processing—demand is dispersed across buildings, power generation, and industrial uses. Near-term substitution options remain limited, particularly for winter heating and power plants operating between baseload and peak load, where natural gas provides essential system flexibility. Substitution is somewhat more feasible in parts of industry through fuel-switching and efficiency gains. This asymmetry between concentrated supply and diffuse, partly inelastic demand underscores the EU energy system's vulnerability to LNG supply disruptions and the potentially uneven propagation of such shocks across sectors.

On the supply side, the EU's natural gas imports remain highly concentrated among a small number of suppliers, following the substantial diversification undertaken after Russia's invasion of Ukraine. Norway, the United States, and Algeria now constitute the primary suppliers. Norway provides more than half of all pipeline deliveries, while the United States accounts for roughly 60 percent of LNG imports, underscoring the growing strategic importance of these partners. In the pipeline segment, Norway was the largest supplier in the third quarter of 2025 with a 51.8 percent share of imports, followed by Algeria (14.6 percent) and the United Kingdom (13.4 percent). LNG imports were even more concentrated, with the United States supplying 59.9 percent of arrivals in the same quarter, followed by Russia (12.7 percent) and Algeria (7.7 percent). This evolving supplier configuration reflects both the EU's accelerated shift away from Russian gas and the increased centrality of Norway and the United States in Europe's energy security architecture.

While Russia was the EU's primary supplier of natural gas until the end of 2021, its role has been increasingly superseded by the United States in recent years. This shift reflects two key developments: the sharp decline in Russia's market share following its invasion of Ukraine and the growing dominance of LNG as a substitute for pipeline gas. Russia's share of the LNG market fell from 21 percent in early 2021 to 13 percent by the third quarter of 2025, while its share of pipeline imports declined even more markedly, from 57 percent to 10 percent over the same period. At the same time, the EU's total pipeline imports contracted substantially between the first quarter of 2021 and the third quarter of 2025, mirroring a structural pivot toward LNG and a surge in its import volumes. Together, these trends underscore the reconfiguration of the EU's gas supply landscape and the increasing centrality of LNG—and U.S. LNG in particular—in the region's energy security framework.

On the demand side, the EU's critical energy and industrial systems remain heavily dependent on natural gas imports. As part of the broader energy category, these imports accounted for 15.4 percent of total EU imports in 2024, underscoring the degree to which the functioning of buildings, power generation, and key industrial sectors relies on external energy supply chains. This high import share highlights both the limited scope for rapid substitution and the economy's sensitivity to supply transitions and price volatility. The sustained volume of natural gas inflows thus reflects not only structural reliance on external suppliers but also the exposure of the EU's demand base to shifts in global energy markets.

Given the highly concentrated supply of natural gas, disruptions to global supply chains can trigger pronounced macroeconomic effects in the EU through extreme price volatility and rapid shifts in market tightness. An LNG-focused disruption provides a particularly informative illustrative example, as LNG has become the marginal source of supply balancing the EU gas system; shocks to LNG availability therefore transmit quickly to prices, storage dynamics, and downstream sectors, magnifying their near-term economic impact.

4.2.2 Methodology

We quantify the macroeconomic effects of a disruption in natural gas markets using the IMF's semi-structural Flexible System of Global Models (FSGM). We employ the global module of FSGM, a multi-region, forward-looking general equilibrium framework designed for policy analysis across a large set of countries and regions (Andrle and others, 2015). The model combines micro-founded blocks for consumption and investment with reduced-form representations of prices, labor markets, and international trade, allowing for tractability while preserving economically meaningful transmission channels.

FSGM explicitly features the production, consumption, and international trade of commodities, including oil, food, and metals. Commodity prices are determined at the global level and affect economic activity through multiple channels: as intermediate inputs into firms' production decisions, through household consumption baskets, and via terms-of-trade effects. In particular, commodities enter firms' production technologies indirectly by influencing total factor productivity and input costs, while persistent movements in energy prices can generate second-round effects on core inflation. These structural features make FSGM well suited to capturing the real and nominal effects of energy price shocks.

Crucially for our exercise, the model captures cross-border spillovers through both trade and global price linkages, while ensuring global consistency conditions such as world trade balance. Its semi-structural design enables the analysis of large, globally synchronized shocks with rich international propagation—an advantage relative to fully structural multi-good DSGE models whose dimensionality limits country coverage. As such, FSGM provides a natural framework to quantify the macroeconomic impact of a major disruption to global natural gas supply chains and its transmission across the EU and the rest of the world.

4.2.3 Scenario Design

We model an exogenous disruption to global natural gas supply chains that triggers a sharp increase in energy prices. The shock is calibrated to be comparable in nature—but smaller in magnitude—to the energy price surge observed in the aftermath of Russia's invasion of Ukraine. In contrast to 2022, the pass-through of the shock is assumed to be partially dampened by structural improvements since then, most notably enhanced intra-EU natural gas infrastructure, lower overall energy consumption, a higher share of renewable energy, and significant infrastructure upgrades.Nonetheless, vulnerability to rising costs of imported fossil fuels remains.

Accordingly, we assume that a disruption occurring in 2026Q1 generates an increase in oil and natural gas prices equal to one-half of the surge recorded in early 2022, with prices subsequently reverting at the same pace as observed during that episode over the course of 2026.

4.2.4 Results

The shock is estimated to reduce euro area GDP by about 0.8 percent in the first year (2026), as shown in Figure 2. Against the April 2026 WEO projection of 1.1 percent growth for 2026, this implies a loss of more than half of projected economic growth. The output shortfall remains sizable in the second year, with GDP still around 0.7 percent below the WEO baseline in 2027, compared with projected growth of 1.2 percent. Inflationary effects are front-loaded: headline inflation rises sharply on impact, peaking at close to 3 percentage points above baseline in the first year, before easing and turning mildly negative in the second year as demand adjusts and prices normalize.

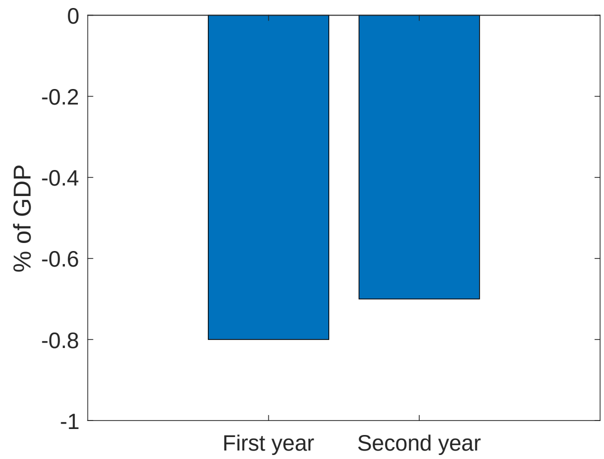

Figure 2: GDP impacts of LNG import disruption

Note: The figure reports the deviation of euro area GDP from the WEO baseline under a temporary LNG supply disruption. The shock generates a first-year (2026) output loss of about 0.8 percent, with persistent effects into the second year (2027).

Although the EU's total natural gas imports are quantitatively small—amounting to less than 0.1 percent of GDP in 2025—natural gas plays a critical role as an intermediate input across a wide range of production processes in the euro area. Its central position in input–output networks implies that supply disruptions propagate widely through production chains, generating disproportionate macroeconomic effects. As a result, the implied GDP loss exceeds the value of total EU natural gas imports by roughly a factor of eight, underscoring the importance of network effects in amplifying supply-side shocks.

4.3 Case 3: Semiconductors

The final stylized scenario examines the short-run macroeconomic impact of an exogenous disruption to EU semiconductor imports. Specifically, we examine disruptions in import of legacy foundation and low tech memory chips.

4.3.1 Market Structure and Strategic Importance

The EU remains structurally dependent on extra-EU semiconductor imports. In 2024, according to Eurostat Comext, total extra-EU imports of legacy foundation and low tech memory chips amounted to €116.3 billion—comprising €34.7 billion in semiconductor devices (HS 8541) and €81.7 billion in electronic integrated circuits (HS 8542)—equivalent to about 0.6 percent of EU GDP. Import values remained broadly stable in 2025 at €116.0 billion, around 0.6 percent of GDP, masking divergent developments across product categories. Imports of semiconductor devices declined sharply, while those of electronic integrated circuits increased, pointing to a shift in the composition of EU semiconductor sourcing toward more complex, high-value inputs.

Semiconductor devices account for a relatively small hare of EU extra-EU imports, falling from 1.41 percent in 2024 to 1.22 percent in 2025, alongside a reduction in their share of intermediate inputs. Supply in this segment is geographically concentrated, with imports sourced primarily from China, Malaysia, the United States, Japan, and Singapore; these five partners together accounted for more than three-quarters of imports in both years. Electronic integrated circuits represent a larger exposure. Their share of extra-EU imports increased modestly from 3.33 percent in 2024 to 3.40 percent in 2025, mirrored by a rise in their share of intermediate inputs, indicating reliance on imported ICs within EU production networks. Supply is more diversified than for semiconductor devices but remains concentrated among a limited number of partners. In 2024 and 2025, China, Malaysia, Taiwan, Israel, and Korea together accounted for over 60 percent of EU IC imports.

On the demand side, the European Union faces a structural mismatch between semiconductor consumption and production. The EU accounts for around 20 percent of global semiconductor demand, but produces only about 10 percent of global output, generating a persistent reliance on imports (European Court of Auditors, 2025). This imbalance translates into material supply-chain vulnerability in the event of disruptions. Industry evidence suggests that inventories of certain standardized chips used in sectors such as automotive and healthcare are limited, with existing stocks in some cases sufficient for only a few weeks of production (European Automobile Manufacturers' Association, 2025).

Risks are particularly acute in the automotive sector. In October 2025, the European Automobile Manufacturers' Association (ACEA) warned of potentially significant disruption to European vehicle manufacturing after a major supplier announced it could no longer guarantee deliveries of high-volume chips used in electronic control units of vehicle electrical systems (European Automobile Manufacturers' Association, 2025). Beyond near-term disruptions, official assessments point to continued structural dependence. The European Court of Auditors finds that, despite the EU Chips Act, the EU's share of the global semiconductor market is projected to increase only modestly—from 9.8 percent in 2022 to around 11.7 percent by 2030—well below stated policy objectives, leaving the EU reliant on external suppliers for the foreseeable future (European Court of Auditors, 2025).

4.3.2 Methodology

The analysis in this section relies on the IMF's Global Integrated Monetary and Fiscal (GIMF) model, a fully structural, multi-country dynamic stochastic general equilibrium framework with explicit modeling of global value chains and bilateral trade flows. GIMF features rich sectoral input–output linkages, incomplete international asset markets, and nominal and real rigidities, allowing for a detailed tracing of cross-sectoral and cross-country spillovers following supply disruptions (Anderson and others, 2013). Production relies on tradable and non-tradable intermediate goods with limited short-run substitutability, making the model particularly well suited to studying semiconductor shocks that propagate through tightly interconnected value chains. The explicit representation of international trade and relative prices further enables the analysis of amplification effects arising from global sourcing patterns and external spillovers.

4.3.3 Scenario Design

The disruption in legacy foundation and low tech memory chips is modeled as a large, temporary price shock to these critical semiconductor inputs. Specifically, input prices are assumed to increase by 80 percent for one year—corresponding to a shock roughly four times the magnitude observed during the October 2025 Nexperia supply episode (Reuters, 2025). To capture limited short-run adjustment possibilities in tightly integrated value chains, the elasticity of substitution across intermediate inputs is assumed to be substantially lower than in the baseline calibration, set at one-fifteenth of its benchmark value in the near term. This assumption reflects technological and organizational rigidities that constrain firms' ability to substitute away from disrupted inputs over short horizons.

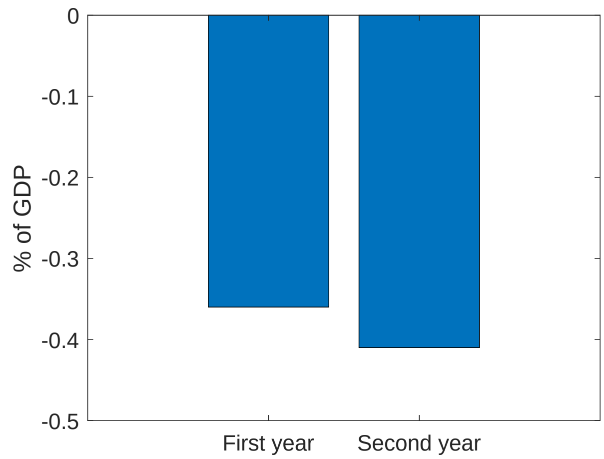

Figure 3: GDP impacts of semiconductor imports disruption

Note: The figure reports the deviation of euro area GDP from the WEO baseline under a temporary semiconductor market disruption. The shock generates a first-year (2026) output loss of about 0.4 percent, with persistent effects into the second year (2027).

4.3.4 Results

The disruption to semiconductor imports is estimated to reduce euro area GDP by around 0.4 percent in the first year (2026), as shown in Figure **??**. The output loss remains persistent, with GDP declining further to around 0.4 percent below baseline in the second year (2027), indicating continued drag from supply constraints and limited short-run adjustment margins. The persistence reflects the central role of semiconductors as essential intermediate inputs embedded across a wide range of production processes, particularly in manufacturing sectors with tightly integrated supply chains.

Despite the relatively modest direct import share of semiconductors in GDP, the aggregate impact is amplified through input–output linkages. Disruptions propagate along production networks, constraining downstream activity and generating sizable spillovers across sectors. Consistent with the model's limited substitutability assumption in the short run, firms are unable to easily replace critical inputs, resulting in prolonged output losses. These findings underscore the importance of network effects in magnifying supply-side shocks and highlight the macroeconomic relevance of dependencies in global value chains.

5 Conclusion

This paper examines the trade-offs that arise when policymakers seek to reduce supply chain vulnerabilities in an environment of rising geopolitical fragmentation. We show that decentralized sourcing decisions can lead to excessive reliance on external suppliers, reflecting a coordination failure in which firms do not internalize the aggregate vulnerability generated by their choices. As a result, the economy may be exposed to inefficiently high disruption risk, providing a rationale for policy intervention.

Our framework highlights that policies aimed at strengthening economic security operate as a form of insurance: they reduce the expected losses from adverse shocks at the cost of higher resource use or fiscal outlays in normal times. The desirability of such interventions depends on a set of key structural parameters, including the centrality of inputs in production networks, the degree of external dependence, the elasticity of substitution, and the likelihood and magnitude of disruptions. Quantitative illustrations for rare earth elements, natural gas, and semiconductors underscore the importance of these mechanisms, showing that even relatively small import exposures can generate sizable macroeconomic effects when shocks propagate through production networks.

The results point to three main findings. First, the case for intervention is strongest when disruptions are both likely and costly, and when inputs are central and difficult to substitute. Second, the effectiveness of policy is inherently non-linear: interventions are most impactful at intermediate levels of dependence, while becoming less effective when dependence is either very low or highly entrenched. Third, the design of policy is critical, as interventions that reallocate resources toward higher-cost production can entail significant fiscal and efficiency costs, potentially offsetting part of their insurance benefits.

Importantly, not all policies to enhance economic security involve a trade-off with efficiency. Some measures can strengthen resilience while simultaneously improving resource allocation. In the EU context, deeper single market integration can enhance risk sharing across member states and provide insurance against idiosyncratic shocks. For example, further progress toward a Savings and Investment Union could mitigate vulnerabilities to external funding disruptions. More broadly, lowering remaining barriers within the single market can generate efficiency gains through scale and specialization, expand the range of domestic production, and reduce reliance on external inputs. Such "win-win" policies, which remove pre-existing distortions, stand in contrast to more distortionary interventions and should form a central part of the policy toolkit.

These findings have clear implications for policy design. While targeted interventions may be warranted to address specific vulnerabilities, their use should be disciplined by a careful assessment of the underlying trade-offs and the potential for unintended consequences, including spillovers and inefficient self-insurance across countries. At the same time, priority should be given to structural reforms that both enhance resilience and improve efficiency.

Our analysis is subject to several limitations. The framework abstracts from strategic interactions across countries, which may amplify or attenuate the benefits of intervention in practice, and from dynamic adjustment margins such as innovation or long-run reallocation. Incorporating these dimensions, as well as richer firm-level heterogeneity and strategic behavior, represents a promising avenue for future research.

Taken together, the results suggest that strengthening economic security is not simply a matter of reducing external dependence, but of carefully balancing resilience and efficiency. A key challenge for policymakers is therefore to

A Derivation of deadweight loss using CES aggregator and cost functions

Setup: Without intervention, firms minimize cost:

$$\min_{M_F, M_D} \; p_F M_F + p_D M_D \quad \text{subject to} \quad M = \left[\alpha^{1/\sigma} M_F^{(\sigma-1)/\sigma} + (1-\alpha)^{1/\sigma} M_D^{(\sigma-1)/\sigma}\right]^{\sigma/(\sigma-1)}. \tag{23}$$

The first-order condition gives:

$$\frac{p_D}{p_F} = \frac{1-\alpha}{\alpha}\left(\frac{M_D}{M_F}\right)^{-1/\sigma}. \tag{24}$$

Efficient allocation (no intervention): Let M_D^* denote the efficient quantity. Total cost is:

$$TC^* = p_F M_F^* + p_D M_D^* + C_D(M_D^*), \tag{25}$$

where $C_D(M_D) = \int_0^{M_D} c_D(x)dx = \frac{\kappa}{1+\eta} M_D^{1+\eta}$ is the total resource cost of domestic production.

With intervention: The intervention s changes the private cost to $(1-s)p_D$, leading to a new allocation (M_F^s, M_D^s) where:

$$\frac{(1-s)p_D}{p_F} = \frac{1-\alpha}{\alpha}\left(\frac{M_D^s}{M_F^s}\right)^{-1/\sigma}. \tag{26}$$

The actual resource cost to society is still:

$$TC^s = p_F M_F^s + p_D M_D^s + C_D(M_D^s), \tag{27}$$

but firms behave as if domestic intermediate costs $(1-s)p_D$.

Deadweight loss calculation: The DWL is the excess resource cost due to inefficient allocation:

$$\mathcal{DWL}(s) = TC^s - TC^* = [p_F M_F^s + p_D M_D^s + C_D(M_D^s)] - [p_F M_F^* + p_D M_D^* + C_D(M_D^*)]. \tag{28}$$

Since total intermediate M is approximately constant (first-order), we have $M_F^s + M_D^s \approx M_F^* + M_D^*$, so:

$$\mathcal{DWL}(s) \approx (p_D - p_F)(M_D^s - M_D^*) + [C_D(M_D^s) - C_D(M_D^*)]. \tag{29}$$

Taylor expansion: For small subsidies, $M_D^s = M_D^* + \Delta M_D$ where $\Delta M_D \approx \sigma M_D^* \frac{s}{1-s}$.

Using Taylor expansion of C_D around M_D^*:

$$C_D(M_D^s) - C_D(M_D^*) \approx c_D(M_D^*)\Delta M_D + \frac{1}{2}c_D'(M_D^*)(\Delta M_D)^2. \tag{30}$$

At the efficient allocation, $c_D(M_D^*) = p_D$ (marginal cost equals price), so the first-order term cancels. The DWL is:

$$\mathcal{DWL}(s) \approx \frac{1}{2}c_D'(M_D^*)(\Delta M_D)^2. \tag{31}$$

With $c_D'(M_D) = \kappa M_D^\eta$ and $\Delta M_D \propto s$:

$$\mathcal{DWL}(s) \approx \frac{1}{2}\kappa (M_D^*)^\eta \cdot (\sigma M_D^*)^2 \cdot \left(\frac{s}{1-s}\right)^2. \tag{32}$$

For small s, this simplifies to:

$$\boxed{\mathcal{DWL}(s) \approx \frac{1}{2}\underbrace{\kappa\eta\sigma^2}_{\equiv \xi} \cdot s^2 \cdot M_D^* \cdot (M_D^*)^\eta = \frac{\xi}{2} s^2 p_D M_D.} \tag{33}$$

B Solving the Government's problem

The government solves

$$\min_{s\in[0,1)} \pi(\theta(s))\Delta Y(\theta(s),\tau) + \mathcal{C}(s), \tag{34}$$

where

$$\pi(\theta) = \lambda\theta, \tag{35}$$

$$\Delta Y(\theta,\tau) = Y\left(1 - \left[\theta(1+\tau)^{1-\sigma} + 1 - \theta\right]^{\frac{\gamma}{1-\sigma}}\right), \tag{36}$$

and

$$\mathcal{C}(s) = \frac{\kappa}{1+\eta}(1-s)^{-\sigma(1+\eta)}\left[s + \frac{\kappa\eta\sigma^2}{2}s^2\right]. \tag{37}$$

Define for convenience

$$\Psi(\theta) = \theta(1+\tau)^{1-\sigma} + 1 - \theta. \tag{38}$$

Then

$$\Delta Y(\theta,\tau) = Y\left(1 - \Psi(\theta)^{\frac{\gamma}{1-\sigma}}\right). \tag{39}$$

Taking the derivative with respect to θ:

$$\boxed{\Delta Y'(\theta) = -Y\frac{\gamma}{1-\sigma}\Psi(\theta)^{\frac{\gamma}{1-\sigma}-1}\left[(1+\tau)^{1-\sigma} - 1\right].} \tag{40}$$

Also note that the dependence also depends on the size of the intervention s:

$$\frac{d\theta}{ds} = -(\sigma-1)\theta(1-\theta)\frac{1}{1-s}. \tag{41}$$

On the cost side, we have:

$$\mathcal{C}(s) = \frac{\kappa}{1+\eta}(1-s)^{-a}\left[s + \frac{\kappa\eta\sigma^2}{2}s^2\right]. \tag{42}$$

where we defined $a \equiv \sigma(1+\eta)$

Taking the first derivative with respect to s, we have:

$$\frac{\partial\mathcal{C}}{\partial s} = \frac{\kappa}{1+\eta}\Bigg\{a(1-s)^{-a-1}\left[s + \frac{\kappa\eta\sigma^2}{2}s^2\right] \tag{43}$$

$$+ (1-s)^{-a}\left[1 + \kappa\eta\sigma^2 s\right]\Bigg\}. \tag{44}$$

The first-order condition of the government objective function is then:

$$\boxed{\left[\lambda\Delta Y(\theta) + \lambda\theta\Delta Y'(\theta)\right]\frac{d\theta}{ds} = \frac{\partial\mathcal{C}}{\partial s}.} \tag{45}$$

Substituting the expressions derived above yields the exact implicit condition:

$$\lambda\left[\Delta Y(\theta)+\theta\Delta Y'(\theta)\right]\left[-(\sigma-1)\theta(1-\theta)\frac{1}{1-s}\right] \tag{46}$$

$$=\frac{\kappa}{1+\eta}\left\{a(1-s)^{-a-1}\left[s+\frac{\kappa\eta\sigma^2}{2}s^2\right]+(1-s)^{-a}\left[1+\kappa\eta\sigma^2 s\right]\right\}. \tag{47}$$

$$\lambda(\sigma-1)\theta(1-\theta)\frac{1}{1-s}\left[\Delta Y(\theta)+\theta\Delta Y'(\theta)\right] \tag{48}$$

$$=\frac{\kappa}{1+\eta}\left\{a(1-s)^{-a-1}\left[s+\frac{\kappa\eta\sigma^2}{2}s^2\right]+(1-s)^{-a}\left[1+\kappa\eta\sigma^2 s\right]\right\}. \tag{49}$$

B.1 Derivation of comparative statics

Let the optimal intervention s^* be implicitly defined by

$$F(s;\lambda,\tau,Y,\gamma,\sigma,\kappa,\eta)=0, \tag{50}$$

where

$$F(s)\equiv\lambda(\sigma-1)\theta(1-\theta)\frac{1}{1-s}\left[\Delta Y(\theta)+\theta\Delta Y'(\theta)\right]-\frac{\partial\mathcal{C}}{\partial s}. \tag{51}$$

An interior optimum satisfies $F_s\equiv\frac{\partial F}{\partial s}<0$ (second-order condition: marginal benefit decreasing, marginal cost increasing).

For every parameter in the model, the comparative statics satisfies:

$$\frac{\partial s^*}{\partial x}=-\frac{F_x}{F_s}. \tag{52}$$

Since $F_s<0$, the sign of $\frac{\partial s^*}{\partial x}$ equals the sign of F_x.

We now determine the sign of F_x for each parameter.

1. Strategic aggressiveness (λ)

$$F_\lambda=(\sigma-1)\theta(1-\theta)\frac{1}{1-s}\left[\Delta Y+\theta\Delta Y'\right]>0. \tag{53}$$

Therefore,

$$\boxed{\frac{\partial s^*}{\partial\lambda}>0.} \tag{54}$$

2. Shock size (τ) Since $\Delta Y_\tau>0$ and $\Delta Y'_\tau>0$,

$$F_\tau>0. \tag{55}$$

Thus,

$$\boxed{\frac{\partial s^*}{\partial\tau}>0.} \tag{56}$$

3. Intermediate importance (γ) $\Delta Y_\gamma > 0$ and $\Delta Y'_\gamma > 0$ imply

$$F_\gamma > 0. \tag{57}$$

Therefore,

$$\boxed{\frac{\partial s^*}{\partial \gamma} > 0.} \tag{58}$$

4. Initial import dependence (θ)

First note that the cost term does not depend directly on θ.

The derivative of F_θ is given by:

$$\boxed{F_\theta = \lambda(\sigma - 1)\frac{1}{1-s}\left[(1-2\theta)\left(\Delta Y + \theta\Delta Y'\right) + \theta(1-\theta)\left(2\Delta Y' + \theta\Delta Y''\right)\right].} \tag{59}$$

We know:

$$\Delta Y(\theta) > 0, \tag{60}$$
$$\Delta Y'(\theta) > 0, \tag{61}$$
$$\Delta Y''(\theta) \geq 0, \tag{62}$$

because higher import dependence increases both the level and curvature of output losses.

So, the sign depends on the following term:

$$(1-2\theta)\left(\Delta Y + \theta\Delta Y'\right) + \theta(1-\theta)\left(2\Delta Y' + \theta\Delta Y''\right)$$

Note that

$$\theta(1-\theta) = 0 \quad \text{at} \quad \theta = 0, 1.$$

Hence:

- At $\theta = 0$,
$$F_\theta > 0.$$

- At $\theta = 1$,
$$F_\theta = -\lambda(\sigma - 1)\frac{1}{1-s}\left(\Delta Y(1) + \Delta Y'(1)\right) < 0.$$

Therefore, the derivative is **not globally positive** on $[0, 1]$.

More precisely:

- For $\theta < \frac{1}{2}$, both terms are positive $\Rightarrow H(\theta) > 0$.

- For θ sufficiently close to 1, the first term is negative and dominates because $\theta(1-\theta) \to 0$.

Hence:

$$\boxed{\exists\, \bar{\theta} \in (1/2, 1) \text{ such that } \frac{\partial s^*}{\partial \theta} \begin{cases} > 0 & \text{for } \theta < \bar{\theta}, \\ < 0 & \text{for } \theta > \bar{\theta}. \end{cases}}$$

For low to moderate dependence, higher θ increases vulnerability and raises the optimal intervention. For very high dependence, the term $\theta(1-\theta)$ becomes small, which means that the sensitivity of import dependence to subsidies collapses, making policy ineffective.

Thus, the optimal intervention is generally *hump-shaped* in baseline import dependence.

5. Elasticity of substitution (σ) σ affects both sides:

- raises the sensitivity of dependence ($\sigma - 1$ term) $\Rightarrow$ increases marginal benefit;
- raises fiscal convexity through $a = \sigma(1+\eta)$ and DWL.

Under standard parameter values where substitution effects dominate distortionary amplification,

$$F_\sigma > 0, \tag{63}$$

so

$$\boxed{\frac{\partial s^*}{\partial \sigma} > 0.} \tag{64}$$

Note that the effect may be ambiguous in extreme cases. In general, optimal intervention given elasticity of substitution reflects two competing effects:

Vulnerability effect (+++): Higher σ implies larger effects on output. Effectiveness effect (+++): Higher σ implies that subsidies more effective at reducing dependencies. Cost effect (—-—): Higher *sigma* implies steeper cost curve $\rightarrow$ subsidies more expensive.

6. Domestic cost parameter (κ) κ increases both fiscal cost and deadweight loss:

$$F_\kappa < 0, \tag{65}$$

thus

$$\boxed{\frac{\partial s^*}{\partial \kappa} < 0.} \tag{66}$$

7. Domestic supply rigidity (η) Higher η increases marginal cost convexity:

$$F_\eta < 0, \tag{67}$$

hence

$$\boxed{\frac{\partial s^*}{\partial \eta} < 0.} \tag{68}$$

Summary of Signs

$$\frac{\partial s^*}{\partial \lambda} > 0, \qquad \frac{\partial s^*}{\partial \tau} > 0, \qquad \frac{\partial s^*}{\partial Y} > 0, \tag{69}$$

$$\frac{\partial s^*}{\partial \gamma} > 0, \qquad \frac{\partial s^*}{\partial \sigma} \gtreqless 0, \tag{70}$$

$$\frac{\partial s^*}{\partial \kappa} < 0, \qquad \frac{\partial s^*}{\partial \eta} < 0. \tag{71}$$

Finally note that $\frac{\partial s^*}{\partial \theta}$ is hump-shaped.
Thus, optimal subsidies increase with strategic vulnerability and output sensitivity, and decrease with domestic production rigidity and fiscal distortion.

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