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

Efficiency-Security Tradeoffs in Policy Intervention

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Outline

The Economic Security Challenge

- European policymakers increasingly worried about supply chain vulnerabilities
    - Geoeconomic fragmentation as well as pandemics and natural disasters (e.g., semiconductor bottlenecks during 2020–21).
    - Concentrated supply sources (e.g., China for REEs, Russia/US for natural gas. Taiwan/Malaysia for specific semiconductors)
    - Risk of supply disruptions
- Key question: Should governments intervene to enhance economic security?
- This paper: A framework to assess cost-benefit tradeoffs of interventions
- Different quantitative frameworks to measure GDP losses of specific case studies

Market Failure: Why Private Sector Underinvests

Private firms optimize security at their own level

But they don't internalize:

1. Aggregate macroeconomic exposure from concentrated dependencies
2. Strategic leverage afforded to foreign suppliers

Result

Decentralized equilibrium might feature **excessive reliance** on concentrated intermediate goods suppliers

$\Rightarrow$ Potential role for government intervention

The government's problem: The trade-offs between expected losses and less efficiency

Government chooses intervention rate $s \in [0,1)$ to minimize:

$$\min_{s} \quad \pi(\theta(s))\Delta Y(\theta(s)) + C(s)$$

Total cost of intervention:

$$C(s) = \underbrace{s \cdot p_D \cdot M_D(s)}_{\text{Fiscal cost}} + \underbrace{\frac{\xi}{2} s^2 \cdot p_D \cdot M_D(s)}_{\text{Deadweight loss}}$$

where $\xi = \kappa\eta\sigma^2$ captures distortionary costs

intervention s reduces effective domestic price: $p_D^s = (1-s)p_D$
$\Rightarrow$ Reduces import share $\theta(s)$

First-Order Condition

$$\underbrace{\left[\pi'(\theta)\Delta Y + \pi(\theta)\Delta Y'(\theta)\right]\frac{d\theta}{ds}}_{\text{Marginal Benefit: Reduced Vulnerability}} = \underbrace{\frac{\partial C}{\partial s}}_{\text{Marginal Cost: Fiscal + DWL}}$$

- intervention reduces dependence ($\theta'(s) < 0$)
- intervention reduces **probability** of disruption ($\pi'(\theta)\theta'(s) < 0$)
- intervention reduces **severity** of losses ($\Delta Y'(\theta)\theta'(s) < 0$)
- But at increasing fiscal and efficiency costs

Optimal Policy

Interior solution exists when marginal benefit > marginal cost at $s = 0$

How Does Optimal intervention Depend on Parameters?

Parameter	Effect on s^*	Intuition
Disruption probability (λ)	$+$	Higher risk $\Rightarrow$ more insurance
Shock size (τ)	$+$	Larger losses $\Rightarrow$ higher intervention
Substitution elasticity (σ)	$+/-$	Effectiveness vs. cost
Intermediate importance (γ)	$+$	More critical input $\Rightarrow$ higher intervention
Domestic cost rigidity (η)	$-$	Steeper costs $\Rightarrow$ less intervention
Initial dependence (θ_0)	Hump	Effective at moderate levels

Optimal intervention is **hump-shaped** in baseline import dependence

- Too low: vulnerability small
- Too high: intervention ineffective (hard to shift dependencies)

Numerical Illustration: Higher disruption probability makes intervention more attractive that lowers import dependence

Baseline Calibration:

- $\lambda = 0.15$ (15% relatively low disruption prob.)
- $\tau = 0.5$ (50% relatively high price shock)
- $\sigma = 4$ (high substitutability)
- $\gamma = 0.5$ (intermediates important)
- $\eta = 0.4$ (relatively flat supply)
- $\theta_0 = 72\%$ (high concentration)

Results:

- At $s = 0$: MB $= 0.61$, MC $= 0.29$
- $\Rightarrow$ Intervention justified!
- Optimal: $s^* = 0.18$
- Import dependence: $72\% \to 58\%$

High Risk Scenario:

- Triple disruption prob: $\lambda = 0.45$
- Optimal: $s^* = 0.75$
- Import dependence: $72\% \to 4\%$

Empirical examples: Three Sectors with Possible Supply Chain Vulnerabilities

We analyze GDP impact of disruptions in:

1. **Natural Gas**
   - Key energy input across economy
   - 60% from the US of LNG imports
2. **Semiconductors**
   - Essential input in many sectors
   - High concentration in Taiwan, Malasya
3. **Rare Earth Elements (REE)**
   - Critical for automotive, electronics, renewables, defense
   - 95% from China

Common features: **concentration**, **limited substitutability**, **critical inputs**

Case 1: Natural Gas Disruption

Market structure:

- EU is energy dependent: The EU's total natural gas imports amount to less than 0.1 percent of 2025 GDP.
- Concentration risk: US supplies 60% of LNG imports.
- Natural Gas is a key intermediate input.

Scenario assumption: Price shock equal to 50% of post-Ukraine invasion surge, then the price decay at the same speed as in 2023.

Methodology: Use IMF Semi-Structural Model Flexible System of Global Models (FSGM)

- Global model with: production, consumption and trade of commodities. Firms' production functions with commodities as intermediate inputs.
- FSGM is well-suited to quantify this disruption, as it features both commodity production and consumption, as well as capturing international spillovers.

Simulation results for Natural Gas Disruptions

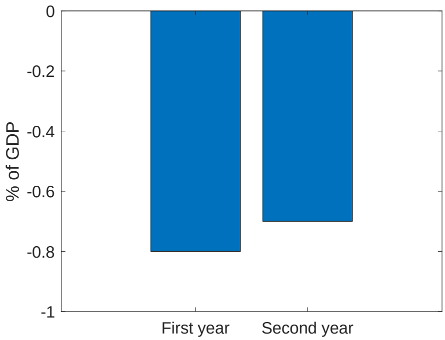

Figure: GDP impacts of LNG imports disruption

- Impact is **8× the value of gas imports**
- Inflation would shoot up by almost 3 percentage points at the impact, before turning slightly negative in the second year

Case 2: Semiconductors Disruption

Market structure:

- Total imports of legacy foundation and the "low tech memory" chips: 0.6% of GDP
- Large exposure to Taiwan and Malaysia.

Assumptions:

- Price shock equal to 80% for one year. 4 times the October 2025 Nexperia episode.
- Elasticity of substitution is assumed to be 15 times lower than the baseline calibration in the near term.

Methodology: Use IMF Structural Models GIMF

- Fully structural model with global value chain links fully modeled.
- GIMF is well suited to study the semi conductors disruption, as its production structure is rich with input-output linkages that allows the measurement of spillovers across sectors when there is limited substitutability.

Simulation results for Semiconductors Disruptions

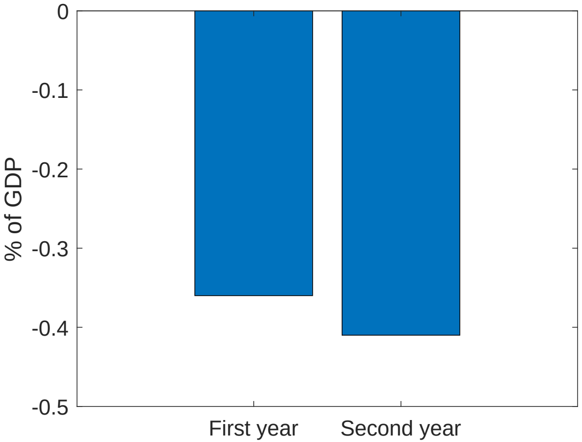

Figure: GDP impacts of semiconductor imports disruption

Case 3: Rare Earth Elements Disruption

Market structure:

- Total imports: <0.1% of GDP
- EU auto sector (2% of GDP): very large part of production is dependent on REE

Scenario: 50% reduction in REE imports gets disrupted

Methodology: Bems, Johnson, Yi (2011) input-output model

- Assumes Leontief production (no substitution in short run)
- Captures inter-sectoral and international amplification
- This methodology is used because it captures the rigid near-term responses to import disruptions, as well as real world calibration of input-output linkages. In other words, there are very limited possibilities of substitution in the near term (both in terms of different products to use and different suppliers).

Simulation results for REE Disruptions

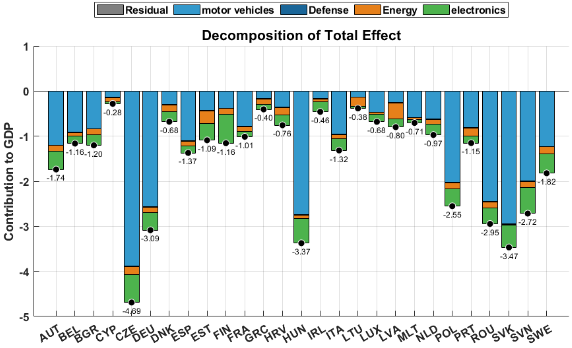

Figure: GDP impact of REE import disruption.

- First year average euro area GDP loss: **-1.6%**
- Most exposed (Czech Republic, Slovakia, Hungary and Germany): **-3 to -5% of GDP**

Highlights in the Simulations of the three scenarios

Amplification Matters

Small import shares can generate large GDP effects due to:

- Inter-sectoral linkages (downstream $\leftrightarrow$ upstream)
- Limited short-run substitutability
- Criticality of inputs in production

When government intervention achieves a better cost-benefit trade-off

1. **High vulnerability:** Critical inputs with few substitutes
2. **High strategic risk:** Concentrated suppliers, geopolitical tensions
3. **Large potential losses:** Sectors central to production networks
4. **Low intervention costs:** Elastic domestic supply, limited distortions

Intervention is less effective and with a higher trade-off:

- Dependencies already very low (small marginal benefit)
- Dependencies already very high (intervention ineffective)
- Domestic production extremely costly (steep supply curve)
- Low disruption probability

Policies to Enhance Resilience

"Win-Win" Policies

No efficiency loss:

- Deepen single market integration
- Remove barriers to cross-border activity
- Trade diversification agreements
- Digital euro for payments
- EU Savings & Investment Union

$\Rightarrow$ Boost efficiency AND security

Targeted Interventions

Efficiency-security tradeoff:

- intervention for domestic production
- Local content requirements
- Strategic stockpiling
- R&D support for alternatives

$\Rightarrow$ Requires careful cost-benefit analysis

Other direct and indirect costs of targeted interventions

1. **Fiscal burden**
   - Direct intervention costs can be substantial
   - Opportunity cost of public funds
2. **Deadweight loss**
   - Resource misallocation from distorting prices
   - Reduced overall efficiency
3. **Global inefficiency**
   - If many countries self-insure simultaneously, the inefficiencies compound.
   - Loss of gains from trade and specialization
4. **Retaliation risk**
   - Trading partners may respond with own restrictions
   - Escalation of protectionism

$\Rightarrow$ Multilateral coordination valuable when possible

Conclusion

Main contributions:

1. Framework to assess efficiency-security tradeoffs of targeted interventions
2. Formal model showing when private sector underinvests in security
3. Comparative statics guide policy design
4. Empirical simulations quantify vulnerabilities

Key insights:

- Market failures can justify intervention in critical supply chains
- Optimal policy depends on: disruption risk, substitutability, domestic costs
- Small import shares can generate large GDP effects via amplification
- "Win-win" horizontal policies preferable when available

Modeling framework: Production Technology

Final goods production (Cobb-Douglas):

$$Y = AM^{\gamma}K^{\beta}L^{1-\gamma-\beta}$$

Intermediate composite (CES):

$$M = \left[\alpha^{1/\sigma}M_F^{(\sigma-1)/\sigma} + (1-\alpha)^{1/\sigma}M_D^{(\sigma-1)/\sigma}\right]^{\sigma/(\sigma-1)}$$

where:

- M_F = foreign (imported) intermediate
- M_D = domestic intermediate
- σ = elasticity of substitution
- α = baseline import dependence parameter

Import Dependence

Equilibrium import share of intermediate expenditure:

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

- Higher σ (substitutability) $\Rightarrow$ small price differences lead to high import dependence
- Lower foreign prices p_F $\Rightarrow$ higher equilibrium reliance on imports

Supply Disruptions and Output Loss

Disruption: Foreign price shock $p_F \to p_F(1+\tau)$, where $\tau > 0$

Output loss:

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

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

Expected loss:

$$\mathbb{E}\mathcal{L}(s) = \pi(\theta(s)) \cdot \Delta Y(\theta(s))$$

where $\pi(\theta)$ = probability of disruption (increasing in θ)

Backup: Model Derivation - Output Loss

Starting from the CES price index under disruption:

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

Define $\Psi(\theta) = \theta(1+\tau)^{1-\sigma} + (1-\theta)$
Then:

$$\frac{p_M(\tau)}{p_M} = \Psi(\theta)^{\frac{1}{1-\sigma}}$$

From the production function:

$$Y = A\left(\frac{\gamma}{p_M}\right)^{\gamma} K^{\beta} L^{1-\gamma-\beta}$$

The output loss is:

$$\Delta Y = Y\left(1 - \Psi(\theta)^{\frac{\gamma}{1-\sigma}}\right)$$

Backup: Deadweight Loss Derivation

Total cost with intervention:

$$C(s) = s \cdot p_D \cdot M_D(s) + \text{Resource cost}$$

Taylor expansion around efficient allocation M_D^*:

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

At efficient allocation: $c_D(M_D^*) = p_D$ (first-order term cancels)
With $c_D'(M_D) = \kappa M_D^{\eta}$ and $\Delta M_D \approx \sigma M_D^* \frac{s}{1-s}$:

$$\text{DWL}(s) \approx \frac{1}{2}\kappa\eta\sigma^2 \cdot s^2 \cdot p_D \cdot M_D$$

Backup: Parameter Calibration Details

Parameter	Value	Source/Justification
Y	50	Normalized economy size
α	0.6	High import bias (REE case)
σ	4	Literature on CES substitution
γ	0.5	Intermediate share in production
τ	0.5	50% price shock (Ukraine precedent)
λ	0.15-0.45	Low to high geopolitical risk
κ	0.4	Domestic production cost scale
η	0.4	Supply elasticity
p_d/p_f	1.2	20% cost disadvantage