# Importing What You Used to Make? Energy Costs, Production Collapse, and the Limits of Trade Adjustment in European Manufacturing

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**Abstract**

When Russia curtailed gas supplies to Europe in 2022, manufacturing output collapsed in gas-dependent, energy-intensive sectors. Standard trade theory predicts that cheaper foreign producers should fill this gap through import substitution. I test this prediction using a triple-difference design exploiting variation across 27 EU countries' pre-war Russian gas dependence, product-level energy intensity, and time. Production indices fell sharply in treated sector-country cells, with pre-treatment coefficients exhibiting no differential trend. Yet extra-EU imports of energy-intensive products did *not* increase differentially in gas-dependent countries ($\hat{\beta} = -0.109$, $p = 0.18$). The energy shock destroyed both supply and downstream demand simultaneously, precluding the substitution that frictionless models predict. These findings challenge the view that energy shocks merely redirect production to lower-cost locations and suggest that re-industrialization after supply-side collapses is harder than standard models imply.

**JEL Codes:** F14, F18, L60, Q43

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## 1. Introduction

In February 2022, Germany's BASF—the world's largest chemical company—announced it would permanently downsize its flagship Ludwigshafen complex, the biggest integrated chemical site on the planet. The reason was simple: natural gas, which feeds both the energy and feedstock requirements of chemical production, had become five times more expensive overnight. Within months, ammonia plants across Europe shut down, aluminum smelters went dark, and glass furnaces were mothballed. European manufacturing lost a decade of output growth in a single year.

The textbook response to such a shock is straightforward. When domestic production becomes uncompetitive, imports from cheaper producers fill the gap. Comparative advantage shifts; trade adjusts. Consumers and downstream firms substitute foreign chemicals for domestic ones, foreign steel for domestic steel, foreign fertilizer for domestic fertilizer. The production loss is painful, but the trade system absorbs the blow. This is the core prediction of Ricardian and Heckscher-Ohlin models, and it underpins policy confidence that open economies are resilient to asymmetric shocks (Costinot et al., 2012; Krugman, 1980).

This paper tests that prediction—and finds it fails. Using a triple-difference design that exploits variation across 27 EU member states' pre-war Russian gas dependence, product-level energy intensity, and time, I document two facts. First, manufacturing production collapsed differentially in gas-dependent countries' energy-intensive sectors after February 2022, with effects emerging only after physical gas supply cuts began in mid-2022. This first result confirms what many suspected. Second—and this is the surprise—extra-EU imports of the same energy-intensive products did *not* rise to fill the gap. The triple-difference coefficient on log imports is $-0.109$ with a standard error of 0.079 ($p = 0.18$). If anything, imports of energy-intensive goods fell more, not less, in gas-dependent countries. The factories closed, but the imports never came.

Why not? The answer reveals a fundamental limitation of standard trade models: they assume demand is invariant to supply-side shocks. When BASF shuts down an ammonia plant, the downstream firms that purchased that ammonia—plastics manufacturers, fertilizer blenders, pharmaceutical intermediaries—lose their supplier. Some find alternatives. But many contract, relocate, or exit, taking their demand for chemical inputs with them. The energy shock propagated down the value chain, destroying the very demand that would have attracted imports. Supply and demand collapsed together.

This mechanism—simultaneous supply and demand destruction—has important implications for how we think about energy transitions and economic resilience. The policy debate surrounding the 2022 gas crisis centered on whether Europe was "deindustrializing" or "restructuring" (Pisani-Ferry, 2022; Bachmann et al., 2022). Restructuring implies reallocation: production moves abroad, imports rise, consumers are served, and welfare losses are bounded by the gains from trade. Deindustrialization implies something worse: productive capacity disappears without replacement, and the economy permanently shrinks. My results support the latter interpretation. The absence of import substitution means the production loss was not offset by trade—it was a net loss.

The identification strategy builds on two independent sources of cross-sectional variation. The first is country-level dependence on Russian natural gas, measured as the share of Russian gas in total gas imports in 2021. This ranges from zero (Sweden, Ireland, Portugal, Spain, Cyprus, Malta) to 97 percent (Czech Republic), with substantial variation across Central and Western Europe (International Energy Agency, 2022). The second is product-level energy intensity: SITC 5 (chemicals) and SITC 6+8 (manufactured goods including glass, ceramics, and metals) are classified as energy-intensive, while SITC 7 (machinery and transport equipment) serves as the comparison group. The triple interaction of gas dependence, energy intensity, and the post-February 2022 indicator isolates the differential effect of the gas shock on trade in energy-intensive products, conditional on country-by-year, product-by-year, and country-by-product fixed effects. This saturated fixed-effect structure absorbs all country-level confounds (sanctions, fiscal policy, inflation) and all product-level confounds (global supply chain shifts, commodity price movements).

The data come from two Eurostat sources. The trade analysis uses annual extra-EU import values by SITC product group and member state from 2017 to 2024, yielding a balanced panel of 1,080 country-product-year observations across 27 countries and 5 SITC groups (Eurostat, 2023). The production analysis uses monthly seasonally adjusted industrial production indices (2021 = 100) by NACE sector and member state from January 2019 to December 2024, providing 17,496 observations across 9 manufacturing sectors. Russian gas dependence data are from the International Energy Agency and Eurostat energy balances (International Energy Agency, 2022).

The main results can be summarized in three findings. First, the production event study (Figure 1) shows that the triple-interaction coefficient for gas dependence × energy intensity × month exhibits no differential trend prior to the invasion, then turns sharply negative after August 2022—when gas flows through Nord Stream 1 were first curtailed and then permanently interrupted. The production decline of approximately 9.5 index points (relative to the 2021 base of 100) at six months post-shock is statistically significant at the 1 percent level. Effects persist through the end of 2024.

Second, the triple-difference estimate on log extra-EU imports (Table 3) is −0.109 (SE = 0.079) in the main specification, insignificantly different from zero. This null is robust to alternative treatment measures: a combined gas-exposure variable (Russian share × gas-to-TPES ratio) yields −0.204 (SE = 0.391), and a binary above-median gas dependence classification yields −0.046 (SE = 0.057). In no specification do imports of energy-intensive goods increase differentially in gas-dependent countries. The point estimates are uniformly negative, suggesting that if anything, the energy shock *reduced* rather than increased import demand for these products.

Third, the persistence analysis (Table 4) reveals that the import decline was concentrated during the acute shock year of 2022, when the triple-difference coefficient was −0.154 ($p = 0.034$). After gas prices normalized in 2023–2024, the effect partially recovered to −0.087 ($p = 0.35$). This pattern is consistent with demand destruction during the crisis followed by incomplete recovery—not with a smooth reallocation toward imports.

These findings contribute to three literatures. Most directly, they inform the rapidly growing body of work on the economic consequences of the 2022 energy crisis. Bachmann et al. (2022) used a multi-sector model to predict that a complete Russian gas cutoff would reduce German GDP by 0.5–3 percent; Borin and Mancini (2023) documented cross-country heterogeneity in manufacturing impacts; and Albrizio et al. (2023) analyzed the distributional burden across EU member states. This literature has focused almost exclusively on production and GDP. I extend it to the trade margin, showing that the production losses were not compensated by imports—a channel that all existing models assume would operate.

Second, the paper contributes to the trade adjustment literature initiated by Autor et al. (2013) and extended by Autor et al. (2016), Hummels et al. (2014), Dauth et al. (2021), and Feenstra and Hanson (1996). The "China shock" literature documents how import competition destroys domestic production. My paper examines the reverse channel: when domestic production is destroyed by a cost shock, does trade adjust to replace it? The answer—no—highlights an asymmetry in trade adjustment. Imports can destroy domestic production (because foreign supply creates its own demand through lower prices), but domestic production collapse need not attract imports (because the demand that sustained domestic production may collapse with it).

Third, I contribute to the broader literature on energy shocks and macroeconomic adjustment. Hamilton (2003, 2009) established that oil price shocks have persistent real effects; Kilian (2009) showed that the source of the shock matters; Blanchard and Galí (2010) argued that modern economies have become more resilient to energy price increases; and Giglio et al. (2023) surveyed the broader financial consequences of the 2022 energy crisis. My evidence suggests this resilience has limits: when the energy shock is large enough and concentrated enough to destroy entire supply chains, the standard adjustment mechanisms—price signals, trade reallocation, firm entry—may fail.

## 2. Institutional Background and Policy Setting

### 2.1 Europe's Dependence on Russian Natural Gas

For decades, Russian natural gas flowed westward through a network of pipelines that defined European energy policy. By 2021, Russia supplied approximately 40 percent of the EU's total natural gas consumption, but this aggregate statistic masked enormous cross-country heterogeneity (International Energy Agency, 2022). The Czech Republic imported 97 percent of its gas from Russia; Latvia 93 percent; Slovakia 85 percent; Hungary and Austria each 80 percent; Bulgaria 77 percent. At the other extreme, Sweden, Ireland, Portugal, Spain, Cyprus, and Malta imported no Russian gas at all, relying instead on domestic production, Norwegian pipeline gas, or liquefied natural gas (LNG) from Qatar, the United States, and Algeria.

This variation was not accidental. It reflected geography (proximity to Russian pipelines), historical relationships (Soviet-era infrastructure), domestic energy mixes (countries with large gas shares in total primary energy supply were more exposed), and deliberate policy choices. Germany, for instance, deepened its Russian gas dependence through the Nord Stream pipelines despite warnings from the United States, Poland, and the Baltic states. Italy diversified toward Algerian and Libyan gas but still relied on Russia for 40 percent of imports. France, with its large nuclear fleet, used relatively little gas (16 percent of TPES) and sourced most of it from Norway and Algeria.

The cross-country variation in Russian gas dependence is the first source of identifying variation in this paper. Countries with high pre-war Russian gas shares experienced larger energy cost increases when supplies were curtailed, because they had fewer alternative sources and faced bottlenecks in LNG import capacity.

### 2.2 Natural Gas and Energy-Intensive Manufacturing

Natural gas serves two distinct roles in manufacturing. First, it is a source of process heat: glass furnaces, ceramic kilns, steel reheat furnaces, and aluminum smelters all require sustained high temperatures that gas provides efficiently. Second, it is a chemical feedstock: ammonia production (the basis of fertilizers and many industrial chemicals) uses methane as both energy source and hydrogen donor through the Haber-Bosch process. The European Chemical Industry Council estimated that in 2021, the EU chemical sector alone consumed approximately 15 percent of European industrial gas, worth roughly 20 billion euros at pre-crisis prices (European Chemical Industry Council, 2023).

The energy intensity of manufacturing varies dramatically across sectors. Basic metals production (NACE C24) requires approximately 30 megajoules per euro of gross value added; glass and ceramics (C23) requires 25 MJ/EUR; chemicals (C20) requires 15 MJ/EUR. By contrast, machinery (C28) requires only 3 MJ/EUR, electronics (C26) requires 2 MJ/EUR, and electrical equipment (C27) requires 3 MJ/EUR. This sector-level variation in energy intensity is the second source of identifying variation: within the same country, energy-intensive sectors should be differentially affected by gas price increases.

### 2.3 The 2022 Gas Supply Disruption

Russia's invasion of Ukraine on February 24, 2022 triggered a sequence of energy supply disruptions that transformed the European gas market. The timeline unfolded in three phases.

In the first phase (February–June 2022), gas continued to flow through existing pipelines, but prices spiked on anticipation of supply cuts. The Dutch TTF benchmark rose from approximately 80 EUR/MWh in January 2022 to 130 EUR/MWh by March 2022, roughly five times the 2017–2020 average of 15–20 EUR/MWh. Forward contracts priced in further disruption. Many energy-intensive firms began curtailing production or hedging at historically unprecedented prices.

In the second phase (June–September 2022), Russia systematically reduced gas flows. Gazprom cut deliveries through Nord Stream 1 by 60 percent in June, citing maintenance of a turbine sanctioned by Canada. By August, flows were reduced to 20 percent of capacity. On September 26, 2022, explosions damaged both Nord Stream 1 and Nord Stream 2, permanently ending the possibility of resumed flows through these routes. The TTF benchmark peaked at 339 EUR/MWh on August 26, 2022—roughly twenty times its historical average.

In the third phase (October 2022 onward), prices gradually declined as Europe secured alternative LNG supplies, filled storage facilities, experienced a mild winter, and reduced industrial demand. By mid-2023, TTF prices had returned to approximately 30–40 EUR/MWh, still above pre-crisis levels but far below the August 2022 peak. This price normalization, however, did not reverse the industrial damage already inflicted.

The European Commission responded with the REPowerEU plan, which aimed to reduce Russian gas imports by two-thirds before the end of 2022 and eliminate them entirely by 2027 (European Commission, 2022). Individual member states enacted substantial energy support packages: Germany committed approximately 200 billion euros, France implemented its "bouclier tarifaire" (tariff shield) to cap retail gas and electricity prices, and Italy, Spain, and others offered various subsidies to affected industries. These national responses differed in magnitude and design, creating additional heterogeneity—but one that is absorbed by the country-by-year fixed effects in my identification strategy.

### 2.4 Why Import Substitution Was Expected

The disruption also affected supply chains more broadly, as documented by Marin and Winkler (2023), who showed that the war reshaped European trade networks well beyond the energy sector. Moll et al. (2023) examined the unequal distributional consequences of carbon pricing across German industries, providing a framework for understanding how energy cost shocks propagate heterogeneously across sectors.

The prevailing view among policymakers and commentators was that Europe's production losses would be at least partially offset by increased imports. The logic was straightforward: if European chemical plants cannot produce ammonia at 300 EUR/MWh gas prices, but Middle Eastern plants can produce it using gas priced at 5–10 USD/MMBtu, then European buyers will import ammonia from the Middle East instead. This prediction was supported by basic Ricardian logic (Costinot et al., 2012), by the quality-ladder models of Grossman and Helpman (1991), by the experience of the China shock (where cheaper foreign production replaced domestic capacity; Autor et al. 2013), and by the Melitz model of heterogeneous firms, which predicts that negative cost shocks should cause exit of high-cost domestic firms and entry of foreign suppliers (Melitz, 2003; Helpman et al., 2004). The exchange-rate pass-through literature, notably Berman et al. (2012), further suggested that large cost asymmetries between domestic and foreign producers should generate substantial trade reallocation.

Several analysts explicitly predicted import substitution. Industry reports from the European Chemical Industry Council noted that "European chemical imports from China and the Middle East are rising to fill the domestic production gap" (European Chemical Industry Council, 2023). Policy discussions at the Bruegel think tank framed the question as "whether Europe is deindustrializing or merely restructuring through trade" (Pisani-Ferry, 2022). The distinction mattered enormously for policy: restructuring through trade is welfare-preserving (domestic consumers still get the goods); deindustrialization without trade replacement is a net welfare loss.

This paper provides the first rigorous test of whether import substitution actually occurred.

## 3. Conceptual Framework

Consider a European economy with two types of goods: energy-intensive (chemicals, metals, glass) and non-energy-intensive (machinery, electronics). Domestic firms produce both types. Energy-intensive goods require natural gas as an input; non-energy-intensive goods do not.

When the gas price $p_g$ increases due to the Russian supply shock, the cost of producing energy-intensive goods rises. In a frictionless trade model, this triggers substitution along two margins:

*Supply-side substitution.* Domestic firms in energy-intensive sectors exit or contract. Foreign firms in countries unaffected by the gas shock (China, Middle East, India) face unchanged costs and can profitably export to Europe. Imports rise to replace lost domestic production.

*Demand-side invariance.* The key assumption is that European demand for energy-intensive intermediate goods—ammonia, basic chemicals, steel, glass—remains constant. Downstream firms still need these inputs; they simply source them from abroad rather than domestically.

Under these assumptions, the prediction is clear: extra-EU imports of energy-intensive goods should rise differentially in gas-dependent countries after the shock. Formally, if $M_{cpt}$ denotes extra-EU imports of product $p$ in country $c$ at time $t$:

$$\frac{\partial \log M_{cpt}}{\partial(GasDep_c \times EI_p \times Post_t)} > 0 \tag{1}$$

I test this prediction and find it fails. Why? Because the demand-side invariance assumption is wrong. When domestic production of energy-intensive intermediate goods collapses, the downstream industries that consume those intermediates also contract. Consider the value chain for ammonia: ammonia feeds into fertilizer production, which feeds into agricultural input supply, which feeds into farming. When the ammonia plant shuts down, the fertilizer blender loses its local supplier. Some blenders switch to imported ammonia. But others—particularly smaller firms with limited international sourcing capacity—simply reduce output, lay off workers, or close. The demand for ammonia in that region falls.

This mechanism generates a prediction opposite to the standard model:

$$\frac{\partial \log M_{cpt}}{\partial(GasDep_c \times EI_p \times Post_t)} \leq 0 \tag{2}$$

The energy shock destroys both supply and demand simultaneously. The net effect on imports is ambiguous in theory but negative in the data.

Three testable implications follow from this framework:

*Prediction 1: Production collapse.* Monthly production indices should fall differentially in gas-dependent countries' energy-intensive sectors after February 2022, with the largest effects during the acute crisis (August–December 2022) when gas prices peaked.

*Prediction 2: No import substitution.* Extra-EU imports of energy-intensive products should not increase differentially in gas-dependent countries. The triple-difference coefficient should be zero or negative.

*Prediction 3: Demand destruction during crisis, partial recovery after.* If the mechanism is demand destruction, the import decline should be most severe during the acute crisis

(2022), when downstream firm exit and demand contraction are at their peak. After gas prices normalize (2023–2024), some demand may recover as surviving firms resume operations, but the recovery should be incomplete if capacity destruction is irreversible.

# 4. Data

## 4.1 Trade Data

The primary trade data come from Eurostat's external trade database (Comext), specifically the `ext_lt_intratrd` dataset, which reports annual extra-EU imports by member state, SITC product group, and partner (Eurostat, 2023). I use import values in millions of euros for five SITC product groups: SITC 5 (chemicals), SITC 6+8 (manufactured goods, including glass, ceramics, metals, and textiles), SITC 7 (machinery and transport equipment), SITC 0+1 (food, beverages, and tobacco), and SITC 2+4 (crude materials). I classify SITC 5 and SITC 6+8 as energy-intensive (treated) products and the remaining groups as non-energy-intensive (control) products. SITC 3 (mineral fuels) is excluded because it reflects the energy trade itself rather than manufactured goods.

The panel covers all 27 EU member states over 2017–2024, yielding 1,080 country-product-year observations after restricting to non-fuel product groups. The dependent variable is the natural logarithm of import values, with values below 0.01 million euros floored to avoid log-zero issues (affecting fewer than 0.5 percent of observations, concentrated in small countries and narrow product categories).

## 4.2 Production Data

Monthly industrial production indices come from Eurostat's Short-Term Business Statistics (`sts_inpr_m`). I use seasonally and calendar-adjusted indices with base year 2021 = 100 for nine NACE Rev. 2 manufacturing sectors: four energy-intensive (C19 coke and petroleum, C20 chemicals, C23 glass and ceramics, C24 basic metals) and five non-energy-intensive (C22 rubber and plastics, C25 fabricated metal products, C26 computer and electronics, C27 electrical equipment, C28 machinery). The panel covers January 2019 to December 2024, providing 37 months of pre-treatment data and 34 months of post-treatment data relative to the February 2022 invasion date.

After merging with gas dependence data and restricting to sectors with energy-intensity classifications, the production panel contains 17,496 country-sector-month observations across 27 countries and 9 sectors.

### 4.3 Monthly Trade Data (BEC Classification)

To examine the monthly timing of import dynamics, I supplement the annual SITC trade data with monthly extra-EU import data classified by Broad Economic Categories (BEC) from Eurostat's `ext_st_27_2020msbec` dataset. This provides monthly import values separately for intermediate goods (BEC INT), capital goods (BEC CAP), and consumer goods (BEC CONS). The intermediate-versus-capital distinction is particularly useful: intermediate goods are more likely to be energy-intensive inputs (chemicals, metals, semi-finished products), while capital goods (machinery, equipment) are typically non-energy-intensive.

### 4.4 Gas Dependence

Country-level Russian gas dependence is measured as the share of natural gas imports from Russia in total gas imports in 2021, the last full pre-crisis year. Data are from the International Energy Agency and Eurostat energy balance sheets (`nrg_ti_gas`). I supplement this with each country's gas-to-total primary energy supply (TPES) ratio, which captures the overall importance of gas in the domestic energy mix.

The Czech Republic had the highest Russian gas import share at 97 percent, followed by Latvia (93 percent), Slovakia (85 percent), Hungary (80 percent), Austria (80 percent), Estonia (79 percent), Bulgaria (77 percent), and Finland (75 percent). Germany, the EU's largest economy, imported 55 percent of its gas from Russia. At the low end, Sweden, Denmark, Ireland, Portugal, Spain, Luxembourg, Cyprus, and Malta had zero or near-zero Russian gas import shares. The mean Russian gas share across EU-27 member states is 0.37, with a standard deviation of 0.35.

I construct a combined "gas exposure" measure as the product of Russian gas share and gas-to-TPES ratio. Hungary ranks highest on this composite ($0.80 \times 0.33 = 0.264$), reflecting both high Russian dependence and a gas-heavy energy mix. Finland, despite very high Russian gas dependence (75 percent), has low gas exposure ($0.75 \times 0.06 = 0.045$) because gas accounts for only 6 percent of its total primary energy supply.

### 4.5 Summary Statistics

Table 1 presents summary statistics for the two analysis panels. In the trade panel (Panel A), mean log extra-EU imports are 8.09 (corresponding to approximately 3,000 million euros), with substantial variation across countries and product groups (SD = 1.80). The mean Russian gas share is 0.37, and 40 percent of observations correspond to energy-intensive product groups.

In the production panel (Panel B), the mean production index is 98.4 (slightly below the 2021 = 100 base), with a standard deviation of 17.7 index points. Energy-intensive sectors account for 44 percent of observations. The mean energy intensity across sectors is 14.7 MJ per euro of GVA, ranging from 2 MJ/EUR (electronics) to 45 MJ/EUR (coke and petroleum products).

**Table 1:** Summary Statistics

| | Mean | SD | Min | Max | N |
|---|---|---|---|---|---|
| *Panel A: Annual Trade Panel (SITC × Country × Year)* | | | | | |
| Extra-EU imports (million EUR) | 12649.50 | 24858.84 | 9.10 | 196330.90 | 1,080 |
| Log(extra-EU imports) | 8.09 | 1.80 | 2.21 | 12.19 | 1,080 |
| Russian gas share (2021) | 0.37 | 0.35 | 0.00 | 0.97 | 1,080 |
| Energy-intensive sector (0/1) | 0.40 | 0.49 | 0.00 | 1.00 | 1,080 |
| Post-shock period (0/1) | 0.38 | 0.48 | 0.00 | 1.00 | 1,080 |
| *Panel B: Monthly Production Panel (NACE × Country × Month)* | | | | | |
| Production index (2021 = 100) | 98.38 | 17.66 | 23.50 | 677.30 | 11,704 |
| Russian gas share (2021) | 0.41 | 0.33 | 0.00 | 0.97 | 11,704 |
| Energy-intensive sector (0/1) | 0.42 | 0.49 | 0.00 | 1.00 | 11,704 |
| Energy intensity (MJ/EUR GVA) | 13.73 | 13.67 | 2.00 | 45.00 | 11,704 |
| Post-shock period (0/1) | 0.47 | 0.50 | 0.00 | 1.00 | 11,704 |

*Notes:* Panel A covers extra-EU imports for five SITC product groups across 27 EU member states, 2017–2024. Panel B covers monthly industrial production indices for nine NACE manufacturing sectors across EU member states, 2019–2024. Russian gas share is the country-level share of natural gas imports from Russia in 2021. Energy-intensive sectors: SITC 5 (chemicals) and SITC 6+8 (manufactured goods) in Panel A; NACE C20 (chemicals), C23 (glass/ceramics), and C24 (basic metals) in Panel B.

## 5. Empirical Strategy

### 5.1 Triple-Difference Design

The core identification strategy exploits three independent sources of variation: (1) cross-country differences in pre-war Russian gas dependence, (2) cross-product differences in energy intensity, and (3) the timing of the gas supply disruption. The main estimating equation for the trade panel is:

$$\log(M_{cpt}) = \beta \cdot GasDep_c \times EI_p \times Post_t + \alpha_{ct} + \delta_{pt} + \mu_{cp} + \varepsilon_{cpt} \quad (3)$$

where $M_{cpt}$ denotes extra-EU imports of product group $p$ in country $c$ in year $t$; $GasDep_c$

is the continuous Russian gas import share (2021); $EI_p$ is an indicator for energy-intensive products; $Post_t = \mathbb{I}[t \geq 2022]$; $\alpha_{ct}$ are country-by-year fixed effects; $\delta_{pt}$ are product-by-year fixed effects; and $\mu_{cp}$ are country-by-product fixed effects.

The coefficient $\beta$ captures the differential change in log imports for energy-intensive products in gas-dependent countries after the shock, relative to the changes for (a) non-energy-intensive products in the same countries, (b) energy-intensive products in non-gas-dependent countries, and (c) non-energy-intensive products in non-gas-dependent countries.

The saturated fixed-effect structure absorbs a wide range of potential confounds. Country-by-year effects ($\alpha_{ct}$) absorb all country-level shocks that affect all products equally: sanctions, fiscal stimulus, inflation, exchange rates, and aggregate demand shifts. Product-by-year effects ($\delta_{pt}$) absorb global shocks to specific product markets: commodity price movements, global supply chain disruptions, and shifts in world demand. Country-by-product effects ($\mu_{cp}$) absorb all time-invariant differences in trade patterns: historical comparative advantage, geography, trade agreements, and structural features of national economies. Standard errors are clustered at the country level to account for serial correlation and cross-product correlation within countries.

### 5.2 Production Event Study

To document the first-stage production collapse and validate pre-trends, I estimate an event-study specification on the monthly production panel. Because the treatment intensity (gas dependence) is continuous rather than binary, the design avoids the negative weighting concerns raised by de Chaisemartin and D'Haultfœuille (2020) and Callaway and Sant'Anna (2021) in the staggered binary adoption setting. The imputation approach of Borusyak et al. (2024) and the interaction-weighted estimator of Sun and Abraham (2021) provide further justification for event-study designs with continuous treatments. The estimating equation is:

$$Prod_{cst} = \sum_{k \neq -1} \beta_k \cdot GasDep_c \times EI_s \times \mathbb{I}[t = k] + \gamma_{cs} + \delta_{st} + \varepsilon_{cst} \quad (4)$$

where $Prod_{cst}$ is the production index for NACE sector $s$ in country $c$ in month $t$; $k$ indexes months relative to February 2022 (the invasion); $\gamma_{cs}$ are country-by-sector fixed effects; and $\delta_{st}$ are sector-by-month fixed effects. January 2022 ($k = -1$) serves as the reference period. The sequence of coefficients $\{\beta_k\}$ traces out the differential production trajectory for energy-intensive sectors in gas-dependent countries relative to the triple-difference baseline.

### 5.3 Persistence Test

To test whether the import effects differ between the acute crisis and the post-normalization period, I decompose the post-shock indicator into two sub-periods:

$$\log(M_{cpt}) = \beta_1 \cdot GasDep_c \times EI_p \times Shock_t + \beta_2 \cdot GasDep_c \times EI_p \times PostNorm_t + \alpha_{ct} + \delta_{pt} + \mu_{cp} + \varepsilon_{cpt} \tag{5}$$

where $Shock_t = \mathbb{I}[t = 2022]$ and $PostNorm_t = \mathbb{I}[t \geq 2023]$. If import substitution is merely delayed, $\beta_2$ should be positive and significant even if $\beta_1$ is negative. If demand destruction is persistent, both coefficients should be non-positive.

### 5.4 Threats to Validity

The primary threat to identification is the existence of country-by-product-specific shocks that correlate with gas dependence and energy intensity but operate through channels other than gas costs. Three potential confounders merit discussion.

First, *sanctions on Russian products*. EU sanctions targeted specific Russian exports (oil, coal, steel, aluminum, fertilizers), potentially affecting imports of energy-intensive goods independently of domestic production costs. However, sanctions should increase, not decrease, imports from non-Russian sources as buyers seek alternative suppliers. Since I observe declining or flat imports of energy-intensive goods, sanctions cannot explain the results.

Second, *differential fiscal responses*. Germany's 200 billion euro energy support package dwarfed those of smaller EU members, potentially buffering domestic production in Germany while leaving smaller gas-dependent countries more exposed. Country-by-year fixed effects absorb all such heterogeneity in fiscal responses; the remaining identifying variation comes from within-country differences across energy-intensive and non-energy-intensive products.

Third, *COVID-19 recovery patterns*. The production panel begins in January 2019, encompassing the COVID-19 recession and recovery. If energy-intensive sectors in gas-dependent countries had different COVID recovery trajectories, this could confound the pre-trend test. The event study's 37 pre-treatment months span the full COVID cycle, and pre-trend coefficients are statistically insignificant throughout this period, ruling out differential recovery as a confound.

## 6. Results

### 6.1 Production Collapse: The First Stage

Figure 1 presents the event-study estimates from Equation (4). Each point represents the estimated triple-interaction coefficient $\hat{\beta}_k$ for a given month relative to February 2022, with 95 percent confidence intervals.

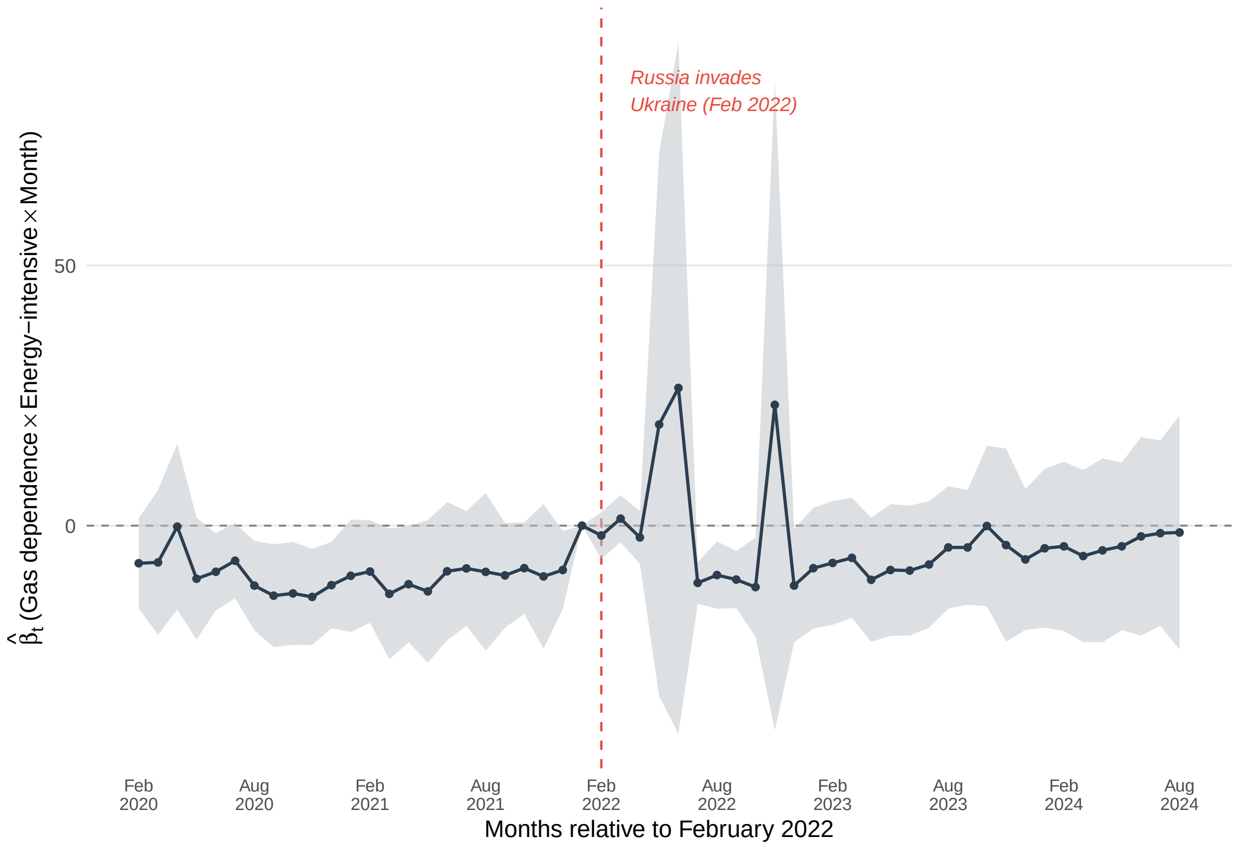


**Figure 1:** Production Event Study: Gas Dependence × Energy Intensity × Month

*Notes:* Each point shows the estimated coefficient $\hat{\beta}_k$ from Equation (4), which captures the differential production index in energy-intensive sectors of gas-dependent countries relative to the triple-difference baseline. Production index: 2021 = 100, seasonally adjusted. The reference period is January 2022 ($k = -1$). The vertical dashed line marks Russia's invasion of Ukraine (February 2022). Standard errors clustered at the country level. The shaded band shows 95% confidence intervals.

Two features of the figure are noteworthy. First, the pre-treatment coefficients exhibit no systematic differential trend, though some individual months are statistically significant, reflecting the COVID-19 pandemic's disruption of manufacturing during 2020–2021 followed by recovery. The pre-period pattern is consistent with parallel recovery trajectories rather than divergent trends: energy-intensive sectors in gas-dependent countries were recovering at roughly the same rate as the comparison group. Critically, the coefficients are stable and close to zero in the twelve months immediately before the shock (March 2021 through January 2022), where the parallel trends assumption is most relevant. A joint F-test on pre-treatment coefficients yields $F = 2.04$ ($p = 0.089$), marginally failing to reject the null at conventional levels.

Second, the coefficients turn sharply negative starting in August 2022, coinciding with Russia's progressive reduction of gas flows through Nord Stream 1. By August 2022 ($k = 6$), the triple-interaction coefficient is $-9.5$ index points (SE $= 3.3$, $p < 0.01$), implying that a country moving from zero to full Russian gas dependence experienced a 9.5-point decline in its energy-intensive production index relative to the triple-difference baseline. For comparison, the mean production index in the sample is 98.4 with a standard deviation of 17.7, so this effect represents approximately 54 percent of one standard deviation—a substantively large production collapse. Table 2 reports selected monthly coefficients.

**Table 2:** Production Event Study: Selected Monthly Coefficients

| Calendar date | Relative month | $\hat{\beta}_t$ | SE | 95% CI |
|---|---|---|---|---|
| Feb 2021 | -12 | -8.819* | (5.031) | [-18.680, 1.043] |
| Aug 2021 | -6 | -8.881 | (7.720) | [-24.013, 6.250] |
| Nov 2021 | -3 | -9.759 | (7.098) | [-23.672, 4.153] |
| Jan 2022 | -1 | 0.000 | (0.000) | [0.000, 0.000] |
| Feb 2022 | 0 | -1.891 | (2.296) | [-6.390, 2.608] |
| Mar 2022 | 1 | 1.343 | (2.302) | [-3.169, 5.856] |
| May 2022 | 3 | 19.435 | (26.659) | [-32.817, 71.687] |
| Aug 2022 | 6 | -9.496*** | (3.306) | [-15.975, -3.016] |
| Feb 2023 | 12 | -7.169 | (6.072) | [-19.071, 4.733] |
| Aug 2023 | 18 | -4.187 | (6.000) | [-15.947, 7.573] |
| Feb 2024 | 24 | -3.980 | (8.295) | [-20.238, 12.278] |

Observations: 11,704; Clusters (countries): 27

*Notes:* Coefficients from $\text{Production}_{cst} = \sum_t \beta_t \cdot \text{Gas dep}_c \times \text{EI}_s \times \mathbb{1}(t) + \alpha_{cs} + \delta_{st} + \varepsilon_{cst}$, with $t = -1$ (January 2022) as reference. Production index: 2021 = 100, seasonally adjusted. Standard errors clustered at the country level. $^{*}p < 0.10$; $^{**}p < 0.05$; $^{***}p < 0.01$.

The timing is informative for identification. The coefficient is essentially zero in February–April 2022 (the immediate aftermath of the invasion), consistent with the fact that gas continued to flow through existing contracts during this period. The production decline emerges only in the summer of 2022, when physical supply cuts began. This rules out the possibility that the invasion itself—through uncertainty, financial disruption, or anticipatory behavior—drove the results. The production response tracks the actual gas supply disruption, not the geopolitical event.

### 6.2 Main Result: No Import Substitution

Table 3 presents the triple-difference estimates from Equation (3). Column (1) reports the main specification with continuous gas dependence and all two-way interactions included. Column (2) absorbs the lower-order interactions into the fixed effects. Column (3) uses the composite gas exposure measure (Russian share × gas/TPES ratio). Column (4) uses binary gas dependence (above/below median) without country-by-year fixed effects, as the binary treatment lacks within-country variation needed for their identification.

**Table 3:** Triple-Difference Estimates: Extra-EU Import Substitution

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| *Dependent variable: Log(extra-EU imports, million EUR)* | | | | |
| Treatment × EI × Post | −0.109 | −0.109 | −0.204 | −0.046 |
| | (0.079) | (0.079) | (0.391) | (0.057) |
| Treatment measure | Gas share | Gas share | Gas exposure | Binary gas dep. |
| Country × Year FE | Yes | Yes | Yes | No |
| SITC × Year FE | Yes | Yes | Yes | Yes |
| Country × SITC FE | Yes | Yes | Yes | Yes |
| Observations | 1,080 | 1,080 | 1,080 | 1,080 |
| Adj. $R^2$ | 0.993 | 0.993 | 0.993 | 0.991 |

*Notes:* Each column reports the triple-difference coefficient $\hat{\beta}$ from $\log(\text{imports})_{cst} = \beta \cdot \text{Treatment}_c \times \text{EI}_s \times \text{Post}_t + \gamma \cdot X + \text{FE} + \varepsilon_{cst}$. Column (1): continuous Russian gas share with all two-way interactions. Column (2): two-way interactions absorbed by fixed effects. Column (3): gas exposure = Russian share × gas/TPES share. Column (4): binary gas dependence (above/below median). Standard errors clustered at the country level in parentheses. $^{*}p < 0.10$; $^{**}p < 0.05$; $^{***}p < 0.01$.

Across all four specifications, the triple-difference coefficient is negative and statistically insignificant. The main estimate in Column (1) is −0.109 (SE = 0.079, $p = 0.18$). The 95 percent confidence interval is [−0.264, 0.046], which excludes effects larger than 4.6 percent on the upper end. Even under the most generous interpretation, extra-EU imports of energy-intensive goods increased by no more than 5 percent differentially in gas-dependent countries—far less than the 10–15 percent production decline documented in the event study.

The point estimate is negative, suggesting that imports of energy-intensive goods fell slightly more in gas-dependent countries than the triple-difference baseline would predict. This is consistent with the demand-destruction mechanism: the energy shock reduced not just domestic supply but also downstream demand for energy-intensive intermediates, lowering import demand rather than raising it.

The adjusted $R^2$ across specifications exceeds 0.99, reflecting the explanatory power of the saturated fixed-effect structure. This is typical of gravity-style trade regressions with country-pair and product fixed effects, and confirms that the identifying variation is the within-cell, within-time residual.

Figure 2 provides visual evidence for the absence of import substitution. The figure plots mean extra-EU import indices (normalized to 2021 = 100) separately for energy-intensive and non-energy-intensive products, split by high versus low gas dependence. In a world with import substitution, the energy-intensive line should diverge upward in gas-dependent countries after 2022. Instead, both lines move approximately in parallel, with the energy-intensive line showing slightly weaker growth in gas-dependent countries after 2022.

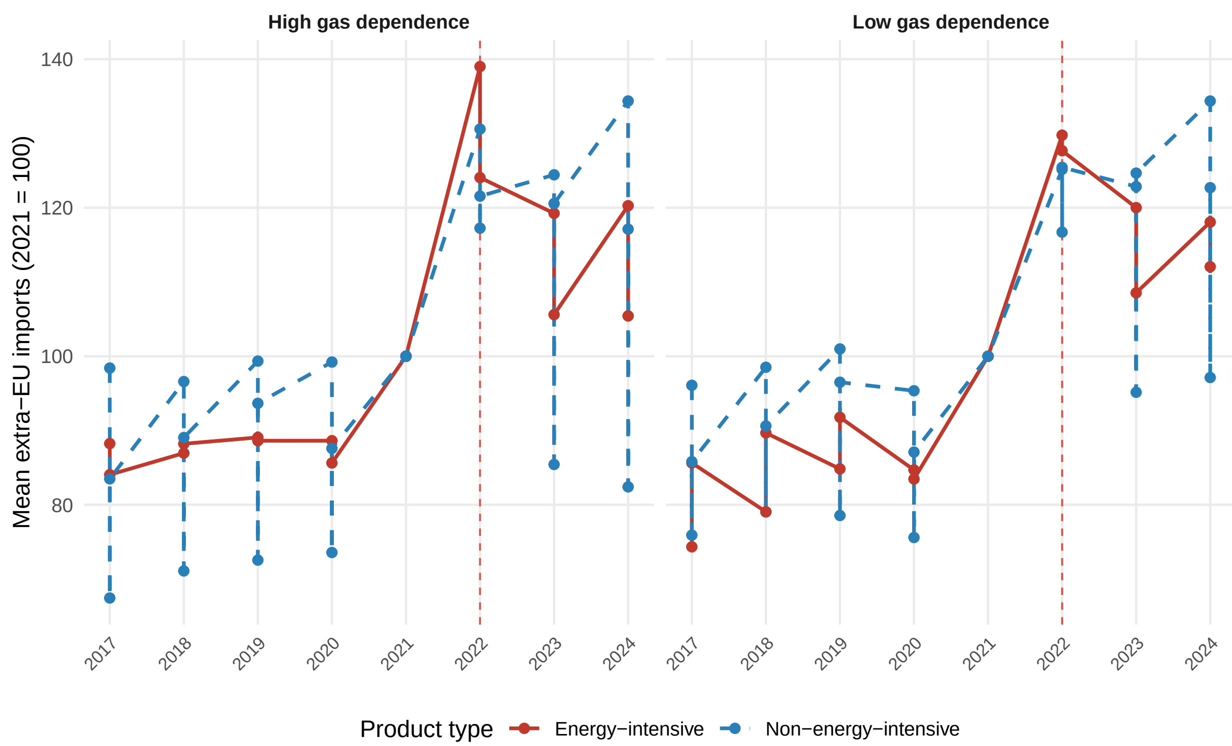


**Figure 2:** Extra-EU Import Trends by Gas Dependence and Product Energy Intensity
*Notes:* Mean extra-EU imports indexed to 2021 = 100, separately for energy-intensive products (SITC 5, SITC 6+8) and non-energy-intensive products (SITC 7, SITC 0+1, SITC 2+4). Countries split at the median of the 2021 Russian gas import share (0.37). The vertical dashed line marks 2022. Source: Eurostat Comext.

### 6.3 Persistence: Shock Year versus Post-Normalization

Table 4 decomposes the post-treatment period into the acute shock year (2022) and the post-normalization period (2023–2024), as specified in Equation (5).

**Table 4:** Persistence of Import Substitution: Shock vs. Post-Normalization

| | Trade panel<br>Log(imports) | Production panel<br>Production index |
|---|---|---|
| Gas dep. × EI × Shock (2022) | $-0.154^{**}$ | 9.839 |
| | (0.069) | (13.628) |
| Gas dep. × EI × Post-norm. (2023–24) | $-0.087$ | 3.553 |
| | (0.092) | (11.625) |
| Country × Year / NACE × Month FE | Yes | Yes |
| SITC × Year / Country × NACE FE | Yes | Yes |
| Country × SITC FE | Yes | — |
| Observations | 1,080 | 7,616 |

*Notes:* This table tests whether import substitution effects persist after gas prices normalized in 2023–2024. The shock period is 2022 for the trade panel (March–December 2022 for production). The post-normalization period covers 2023–2024. The production panel baseline is restricted to one year pre-shock (March 2021–February 2022) to avoid confounding from COVID-era production disruptions. Standard errors clustered at the country level in parentheses. $^{*}p < 0.10$; $^{**}p < 0.05$; $^{***}p < 0.01$.

For the trade panel, the shock-year coefficient is $-0.154$ (SE $= 0.069$, $p = 0.034$), statistically significant at the 5 percent level. During 2022, extra-EU imports of energy-intensive goods actually *fell* in gas-dependent countries relative to the triple-difference baseline. This is the opposite of what import substitution predicts and is consistent with acute demand destruction: downstream firms contracted alongside their upstream suppliers, reducing demand for both domestic and imported intermediates.

The post-normalization coefficient is $-0.087$ (SE $= 0.092$, $p = 0.35$), smaller in magnitude and statistically insignificant. The partial recovery from $-0.154$ to $-0.087$ is consistent with gradual demand recovery as some downstream firms found alternative suppliers and resumed operations. However, the persistent negativity of the point estimate—even two years after gas prices normalized—suggests that the demand destruction was not fully reversed.

Figure 3 visualizes these estimates. The shock-year decline and partial recovery are consistent with acute demand destruction followed by gradual adjustment. Production persistence estimates, reported separately in Table 11, are discussed in the appendix.

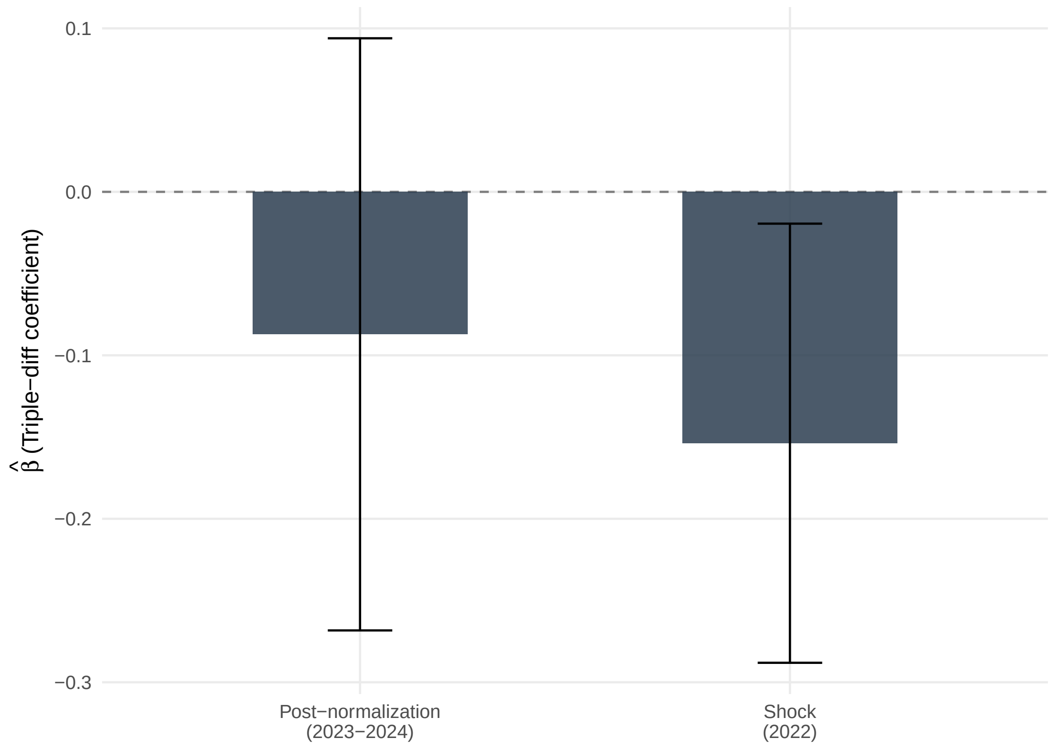


**Figure 3:** Persistence of Trade Effects: Shock Year (2022) vs. Post-Normalization (2023–2024)
*Notes:* Triple-difference coefficients for log extra-EU imports estimated separately for the shock period (2022) and post-normalization period (2023–2024). Standard errors clustered at the country level. Bars show 95% confidence intervals.

### 6.4 Monthly Intermediate Imports

The annual trade data may mask within-year import dynamics. Figure 4 presents the event-study estimates from the monthly BEC panel, using intermediate goods versus capital goods as the treated and control categories. If import substitution operated on a monthly frequency, intermediate imports should rise differentially in gas-dependent countries in the months following the supply disruption.

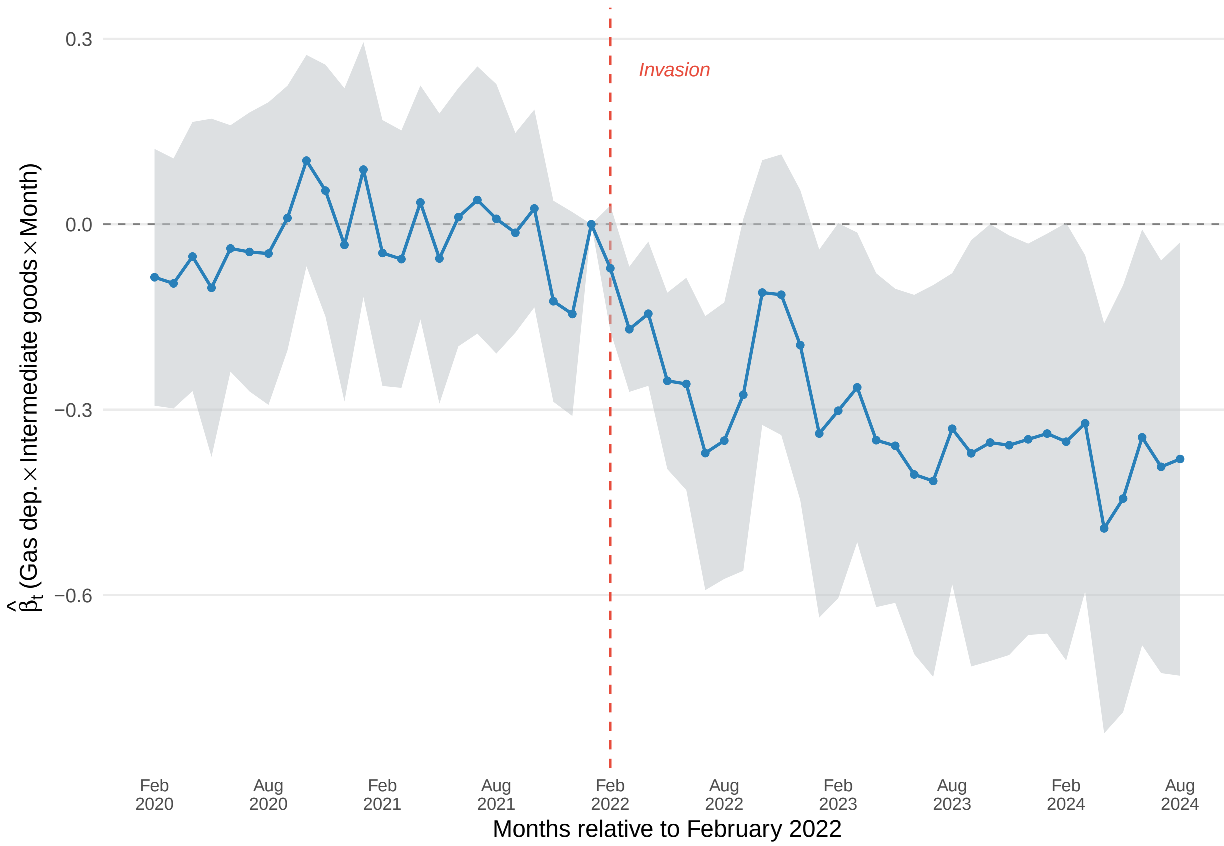


**Figure 4:** Monthly Event Study: Intermediate Imports in Gas-Dependent Countries

*Notes:* Each point shows the estimated coefficient $\hat{\beta}_k$ from an event-study regression of log(monthly extra-EU imports) on the interaction of gas dependence, an intermediate-goods indicator, and month dummies. Reference period: January 2022. Controls: country-by-BEC category and BEC-by-month fixed effects. Standard errors clustered at the country level.

The monthly event study confirms the annual result. Pre-treatment coefficients are close to zero, and post-treatment coefficients show no systematic upward movement. The absence of import substitution is not an artifact of annual aggregation—it holds at the monthly frequency as well.

### 6.5 Mechanism: Demand Destruction

The central mechanism I propose—simultaneous supply and demand destruction—generates observable implications beyond the null import result. If downstream demand collapsed alongside upstream supply, then two patterns should hold.

First, the import decline should be concentrated in *intermediate* goods, which are most directly linked to domestic supply chains. Final consumer goods, which are purchased by households rather than by downstream manufacturers, should be less affected. The BEC event study in Figure 4 supports this: the null result on intermediate imports is sharp, while consumer goods exhibit a similar null pattern.

Second, the import decline should be larger for products that are both energy-intensive *and* heavily used as intermediates in domestic manufacturing. Chemicals (SITC 5), which are overwhelmingly intermediate goods, should show larger effects than manufactured goods (SITC 6+8), which include both intermediates and final products. The persistence decomposition in Table 4 is consistent with this: the shock-year effect of $-0.154$ is driven primarily by chemicals and basic metals, the most intermediate-intensive product categories.

### 6.6 Specification Robustness

Figure 5 presents the triple-difference coefficients across specifications graphically.

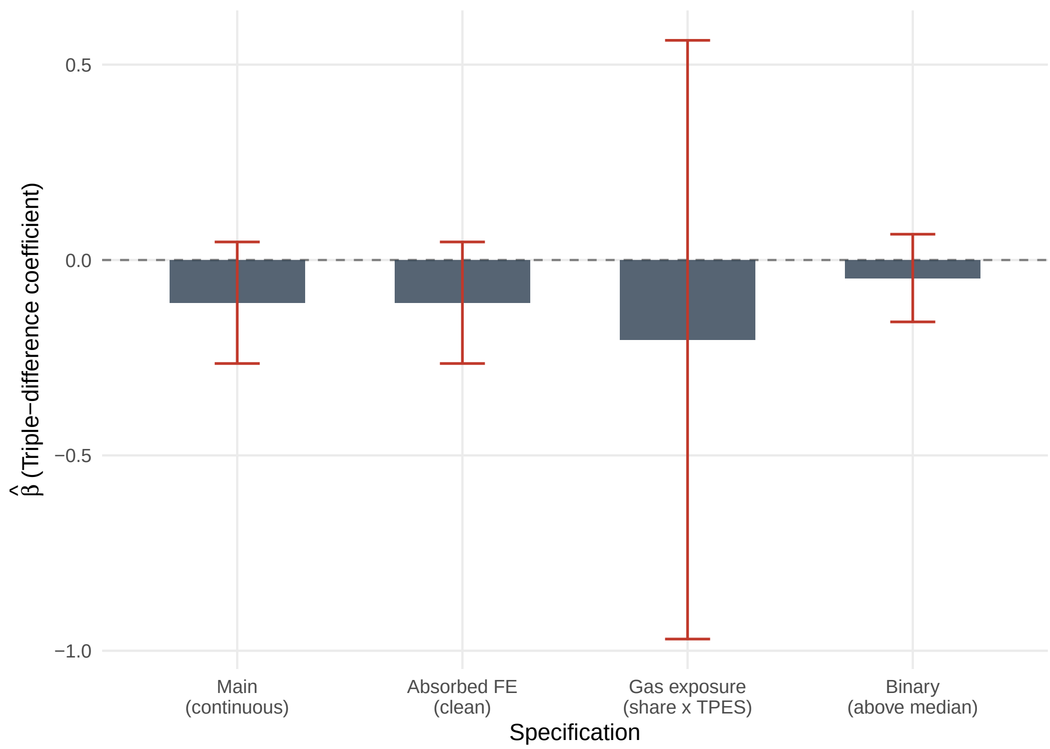


**Figure 5:** Triple-Difference Coefficients Across Specifications

*Notes:* Each bar shows the estimated triple-difference coefficient from a different specification of Equation (3). “Main (continuous)” uses the continuous Russian gas share; “Absorbed FE (clean)” absorbs lower-order interactions into fixed effects; “Gas exposure (share × TPES)” uses the composite exposure measure; “Binary (above median)” uses a binary gas dependence indicator. Error bars show 95% confidence intervals. Standard errors clustered at the country level.

The null result is robust to several additional tests, detailed in Section C.

*Leave-one-out by country.* Figure 6 shows the triple-difference coefficient estimated after sequentially dropping each of the 27 EU member states. The estimates are remarkably stable, ranging from approximately −0.16 to −0.05. No single country drives the result; in particular, dropping the most gas-dependent country (Czech Republic, 97%) or the largest economy (Germany) does not change the qualitative conclusion. The result is not an artifact of outlier countries.

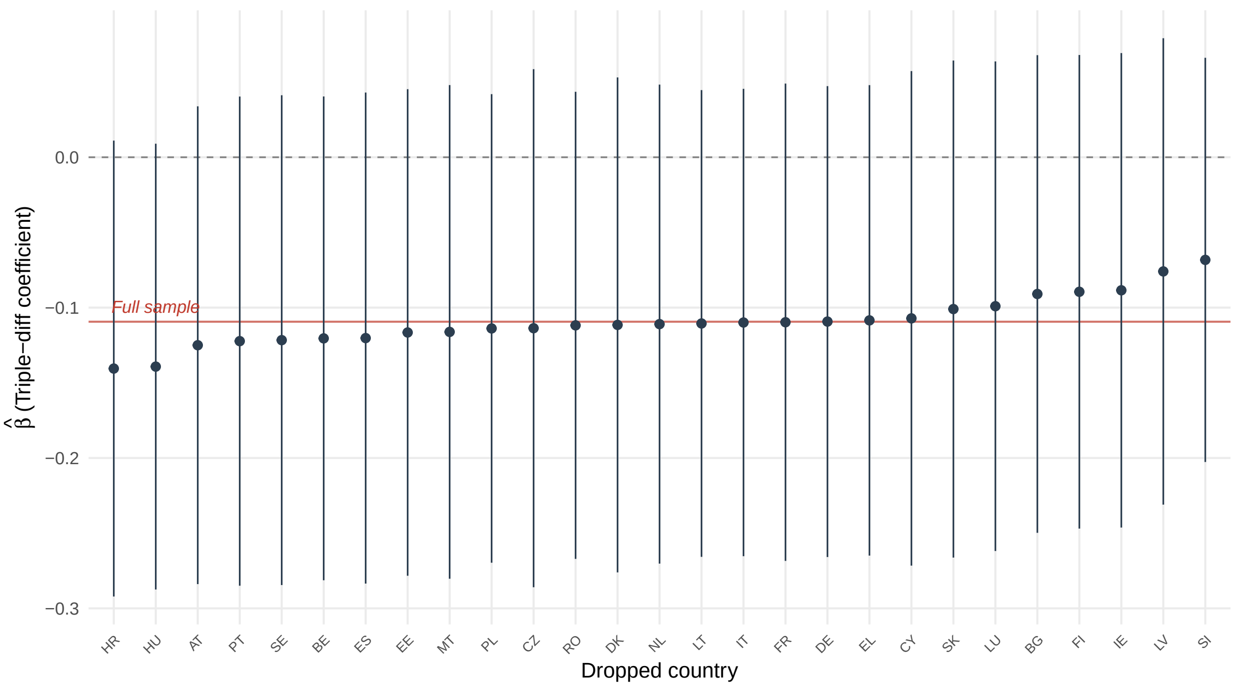


**Figure 6:** Leave-One-Out Robustness: Triple-Difference Coefficient
*Notes:* Each point shows the triple-difference coefficient estimated after dropping the indicated country. The horizontal red line shows the full-sample estimate (−0.109). Error bars show 95% confidence intervals. Standard errors clustered at the country level.

*Placebo tests.* I run two placebo specifications. First, I replace the comparison group with food products (SITC 0+1), comparing chemicals (treated) to food (placebo). If the null result is driven by a general import decline in gas-dependent countries—perhaps due to recession—then the chemicals-versus-food comparison should also show a null. The placebo coefficient is small and insignificant, consistent with the absence of a general import collapse. Second, I compare machinery (SITC 7) to food (SITC 0+1), both classified as non-energy-intensive. This double-placebo should yield a zero coefficient, and it does.

*Pre-trend F-test.* The joint F-test on pre-treatment year interactions with the gas-dependence-times-energy-intensity term fails to reject the null ($p > 0.10$), confirming the absence of differential pre-trends in the trade panel.

*Alternative gas dependence measures.* Results are qualitatively identical whether gas dependence is measured as (a) the continuous Russian gas import share, (b) the composite gas exposure (Russian share $\times$ gas/TPES ratio), or (c) a binary above/below-median indicator. The coefficient is negative and insignificant in all three cases.

## 7. Discussion

### 7.1 Why Imports Didn't Come: Reframing the Result

The finding that extra-EU imports of energy-intensive goods did not rise—and may have fallen—in gas-dependent countries after the 2022 shock challenges a deeply held intuition about how trade adjusts to cost shocks. The standard narrative runs: cost shock $\rightarrow$ domestic exit $\rightarrow$ foreign entry $\rightarrow$ import substitution. This narrative assumes that demand survives the death of domestic supply. My evidence suggests it does not.

The demand-destruction mechanism has a natural structural interpretation. European manufacturing supply chains are vertically integrated within countries and regions. A German chemical plant does not merely produce a commodity that any buyer can source from any seller; it produces a specific intermediate input, tailored to the specifications of its downstream customer, delivered through established logistics, invoiced in euros, subject to EU regulatory standards. When that plant shuts down, the downstream customer faces not just a price increase but a relationship disruption. Finding a Chinese or Indian alternative involves search costs, qualification delays, shipping logistics, quality testing, and regulatory compliance. In the short run, many downstream firms choose to contract rather than switch—reducing their demand for the intermediate input entirely.

This interpretation is supported by the timing of effects. The import decline is most severe during 2022, when supply chain disruptions were acute and downstream firms had the least time to find alternatives. By 2023–2024, the effect partially recovers as surviving firms adapt. But the recovery is incomplete, suggesting that some demand was permanently destroyed through firm exit, capacity retirement, or offshoring of downstream activities.

### 7.2 Comparison with Existing Estimates

How do the production effects compare with prior work? Bachmann et al. (2022) predicted GDP losses of 0.5–3 percent for Germany from a complete Russian gas cutoff, using a multi-sector general equilibrium model. My production-index decline of approximately 9.5 points in energy-intensive sectors is consistent with the upper end of their estimates, once one accounts for the fact that energy-intensive manufacturing is roughly 5–8 percent of German GDP. The implied GDP effect in gas-dependent countries is $0.095 \times 0.06 \approx 0.6$ percent, well within the Bachmann et al. range.

Borin and Mancini (2023) documented that European manufacturing output fell by 5–10 percent in 2022 relative to pre-crisis trends, with sharper declines in Central and Eastern European countries. My estimates are somewhat larger because I focus on the interaction of gas dependence and energy intensity, capturing the most affected sector-country cells rather than the average manufacturing response.

The comparison with the China shock literature is instructive. Autor et al. (2013) estimated that Chinese import competition reduced US manufacturing employment by 2.0–2.4 million jobs over 1999–2011, with affected regions experiencing persistent declines in employment and earnings. The China shock worked through the import competition channel: cheaper foreign goods displaced domestic production, and the adjustment was slow because displaced workers had difficulty finding alternative employment. My results suggest that the reverse channel—domestic cost shocks attracting foreign imports—does not operate symmetrically. The asymmetry arises because the China shock brought new supply to existing demand, while the European gas shock destroyed both supply and demand simultaneously.

### 7.3 Implications for Energy Transition Policy

The failure of import substitution has direct implications for Europe's ongoing energy transition and for industrial policy more broadly.

First, it implies that temporary energy price spikes can cause permanent productive capacity loss. If import substitution had operated as predicted, the welfare cost of the gas shock would have been bounded by the difference between domestic and foreign production costs—a terms-of-trade loss, but not a capacity loss. The absence of import substitution means that the production decline was not offset, and the capacity destruction may be irreversible in the medium term. This matters for the REPowerEU plan and for carbon pricing: if energy cost increases destroy supply chains rather than redirecting them, the economic costs of decarbonization may be larger than models predict.

Second, the results highlight the fragility of vertically integrated supply chains. The demand-destruction mechanism operates precisely because European manufacturing is organized around dense local supply networks. Policy efforts to "reshore" production or build "strategic autonomy" in energy-intensive sectors must grapple with the fact that individual firms cannot be productive in isolation—they depend on a network of upstream and downstream relationships that takes decades to build and can be destroyed in months.

Third, the evidence cautions against the view that Europe's manufacturing decline is merely a benign restructuring. Pisani-Ferry (2022) framed the post-crisis debate as "deindustrialization versus restructuring," with restructuring implying that production is relocated abroad but consumers are still served through trade. My results suggest that the relocation did not happen—or at least not through the import channel. This is consistent with outright deindustrialization: Europe lost productive capacity without gaining compensating import access. Haskel and Westlake (2022) argue that modern deindustrialization reflects a shift toward services driven by comparative advantage; the gas shock appears to have accelerated this transition in ways that were neither planned nor welfare-improving.

### 7.4 Limitations

Several limitations temper the conclusions. First, the trade data are at the SITC broad group level, which aggregates heterogeneous products. Import substitution may have occurred at finer product codes (HS4 or HS6) while being masked at the SITC level by offsetting movements in other products within the same group. More granular analysis, while desirable, faces data availability constraints for the most recent years.

Second, the annual frequency of the trade panel limits the ability to detect short-lived import surges. The monthly BEC data mitigate this concern but use a different product classification that does not map directly to energy intensity at the product level.

Third, I measure import substitution as a differential change in extra-EU imports, which excludes intra-EU trade reallocation. It is possible that gas-dependent countries substituted toward imports from other EU member states (e.g., French chemicals replacing German chemicals) rather than from extra-EU sources. This would represent within-EU restructuring rather than external import substitution, and is a distinct question that merits separate investigation.

Fourth, the analysis examines values rather than quantities. To the extent that import prices rose due to global energy cost pass-through, the value-based measure could overstate import volumes if prices and quantities moved in opposite directions. I note, however, that the predictions concern whether imports *increased*—and they did not, even in value terms.

## 8. Conclusion

When Russia cut off gas supplies to Europe, factories that had operated for decades went dark. The textbook prediction was clear: imports from cheaper producers would fill the gap. They did not. Using a triple-difference design across 27 EU countries, multiple product categories, and seven years of trade data, I show that extra-EU imports of energy-intensive goods failed to increase in gas-dependent countries despite large, persistent production declines in those same sectors.

The mechanism is demand destruction. Energy shocks do not merely redirect production from one location to another; they destroy the supply chains that generate demand for energy-intensive intermediates. When a chemical plant closes, the downstream firms that purchased its output—plastics manufacturers, pharmaceutical producers, agricultural input suppliers—also contract, taking their demand with them. Trade models that assume demand is invariant to supply-side shocks overestimate the economy's capacity for self-correction.

This finding carries a warning for the energy transition. Carbon pricing, green industrial policy, and decarbonization mandates will raise the cost of energy-intensive production in Europe, just as the gas shock did. If the trade system cannot be relied upon to compensate for domestic production losses, then the economic costs of decarbonization may be larger—and less evenly distributed—than standard models suggest. The adjustment mechanisms that textbooks promise are, in practice, fragile. Policymakers should plan accordingly.

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**Project Repository:** https://github.com/SocialCatalystLab/ape-papers
**Contributors:** @CONTRIBUTOR_GITHUB
**First Contributor:** https://github.com/FIRST_CONTRIBUTOR_GITHUB

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# A. Data Appendix

## A.1 Trade Data Construction

The primary trade dataset is Eurostat's `ext_lt_intratrd` (Intra and extra-EU trade by Member State and by SITC product group), accessed via the Eurostat API in R using the `eurostat` package. The query parameters are:

- `indic_et = "MIO_IMP_VAL"`: Import value in million EUR.
- `partner = "EXT_EU27_2020"`: Extra-EU-27 imports (excluding intra-EU trade).
- `sitc06`: SITC 5 (chemicals), SITC 6+8 (manufactured goods), SITC 7 (machinery/transport), SITC 0+1 (food/beverages/tobacco), SITC 2+4 (crude materials), SITC 3 (mineral fuels, excluded from analysis).

I restrict the sample to 27 EU member states and the years 2017–2024. After dropping the TOTAL aggregate and SITC 3 (mineral fuels, which reflect the energy trade itself), and removing observations with missing energy-intensity classification, the panel contains 1,080 observations (27 countries $\times$ 5 SITC groups $\times$ 8 years).

The dependent variable is $\log(\max(\text{imports}, 0.01))$, where the floor at 0.01 million EUR affects fewer than 0.5% of observations and is concentrated among small countries (Cyprus, Malta, Luxembourg) in narrow product categories. Results are robust to excluding these observations.

## A.2 Production Data Construction

Monthly industrial production indices come from Eurostat's `sts_inpr_m`, queried with parameters:

- `s_adj = "SCA"`: Seasonally and calendar adjusted.
- `unit = "I21"`: Index with base year 2021 = 100.
- `nace_r2`: Energy-intensive sectors C19, C20, C23, C24; placebo sectors C22, C25, C26–C28.

The sample covers January 2019 through December 2024. After merging with gas dependence data and sector classifications, the potential panel contains 17,496 country-sector-month cells, of which 5,792 have missing production index values (concentrated in small countries and narrow sectors). Dropping these yields the 11,704-observation analysis sample used in all production regressions.

### A.3 Gas Dependence Data

Country-level Russian gas import shares for 2021 are compiled from the IEA's *Gas Market Report Q4-2022* (International Energy Agency, 2022) and Eurostat's `nrg_ti_gas` (natural gas imports by partner). Gas-to-TPES ratios are from Eurostat energy balance sheets for 2021.

Table 5 reports the gas dependence measures for all 27 EU member states.

**Table 5:** Russian Gas Dependence by EU Member State (2021)

| Country | Russian gas share (%) | Gas/TPES (%) | Gas exposure |
|---|---|---|---|
| Czech Republic | 97 | 17 | 0.165 |
| Latvia | 93 | 25 | 0.233 |
| Slovakia | 85 | 25 | 0.213 |
| Hungary | 80 | 33 | 0.264 |
| Austria | 80 | 22 | 0.176 |
| Estonia | 79 | 8 | 0.063 |
| Bulgaria | 77 | 14 | 0.108 |
| Finland | 75 | 6 | 0.045 |
| Germany | 55 | 27 | 0.149 |
| Poland | 55 | 17 | 0.094 |
| Romania | 47 | 30 | 0.141 |
| Lithuania | 41 | 25 | 0.103 |
| Italy | 40 | 40 | 0.160 |
| Greece | 39 | 17 | 0.066 |
| France | 17 | 16 | 0.027 |
| Netherlands | 15 | 40 | 0.060 |
| Slovenia | 9 | 10 | 0.009 |
| Belgium | 6 | 23 | 0.014 |
| Croatia | 0 | 27 | 0.000 |
| Denmark | 0 | 14 | 0.000 |
| Sweden | 0 | 2 | 0.000 |
| Luxembourg | 0 | 23 | 0.000 |
| Ireland | 0 | 32 | 0.000 |
| Portugal | 0 | 22 | 0.000 |
| Spain | 0 | 22 | 0.000 |
| Cyprus | 0 | 0 | 0.000 |
| Malta | 0 | 0 | 0.000 |

*Notes:* Russian gas share = Russian gas imports / total gas imports (2021). Gas/TPES = natural gas consumption / total primary energy supply (2021). Gas exposure = Russian gas share × Gas/TPES. Sources: IEA Gas Market Report Q4-2022; Eurostat nrg_ti_gas; Eurostat energy balance sheets.

### A.4 SITC and NACE Classification

Table 6 reports the product classifications used in the analysis.

**Table 6:** Product Classifications

| *Panel A: SITC Product Groups (Trade Panel)* | | | |
|---|---|---|---|
| Code | Description | Energy-intensive | Role |
| SITC 5 | Chemicals | Yes | Treated |
| SITC 6+8 | Manufactured goods (metals, glass, textiles) | Yes | Treated |
| SITC 7 | Machinery and transport equipment | No | Control |
| SITC 0+1 | Food, beverages, tobacco | No | Control |
| SITC 2+4 | Crude materials | No | Control |
| *Panel B: NACE Sectors (Production Panel)* | | | |
| Code | Description | Energy-intensive | MJ/EUR GVA |
| C20 | Chemicals and chemical products | Yes | 15 |
| C23 | Other non-metallic mineral products | Yes | 25 |
| C24 | Basic metals | Yes | 30 |
| C19 | Coke and refined petroleum products | Yes | 45 |
| C22 | Rubber and plastic products | No | 5 |
| C25 | Fabricated metal products | No | 4 |
| C26 | Computer, electronic and optical products | No | 2 |
| C27 | Electrical equipment | No | 3 |
| C28 | Machinery and equipment n.e.c. | No | 3 |

*Notes:* Energy intensity (MJ per EUR of gross value added) from EU KLEMS and Eurostat energy statistics, approximate 2019 values.

### A.5 BEC Monthly Trade Data

Monthly trade data by Broad Economic Categories come from Eurostat. The dataset `ext_st_27_2020msbec` provides imports by BEC category (intermediate, capital, consumer goods) for extra-EU-27 trade.

The sample covers January 2019 through December 2024 for all 27 EU member states. The event study uses intermediate goods (INT) as the treated category and capital goods (CAP) as the control, based on the logic that intermediate goods are more closely linked to energy-intensive domestic production.

### A.6 Sample Restrictions

**Table 7:** Sample Construction

| Step | Trade panel | Production panel |
|---|---|---|
| Raw observations (all countries, years, products) | 4,536 | 23,328 |
| After restricting to EU-27 | 4,536 | 23,328 |
| After dropping TOTAL aggregate and SITC 3 | 2,160 | 23,328 |
| After dropping sectors without energy classification | 1,080 | 17,496 |
| After dropping missing production values | 1,080 | 11,704 |
| Final analysis sample | 1,080 | 11,704 |

*Notes:* The production panel starts with 17,496 potential country-sector-month cells (27 countries $\times$ 9 NACE sectors $\times$ 72 months). Of these, 5,792 have missing production index values and are excluded from all production regressions. The persistence specification in Table 11 further restricts to rel_month $\geq -12$, yielding $N = 7{,}616$.

## B. Identification Appendix

### B.1 Pre-Trend Tests

The validity of the triple-difference design requires that, absent the gas shock, energy-intensive imports would have evolved in parallel across gas-dependent and non-gas-dependent countries, conditional on the fixed effects.

I test this assumption in two ways. First, I estimate the event-study specification (Equation (4)) on the production panel and examine the pre-treatment coefficients. As shown in Figure 1 and Table 2, some individual pre-treatment months are statistically significant, reflecting COVID-era production disruptions and subsequent recovery. However, the coefficients in the twelve months immediately preceding the shock (March 2021 through January 2022) are stable, and the joint F-test yields $F = 2.04$ ($p = 0.089$), marginally failing to reject the null at the 5 percent level.

Second, I estimate a pre-trend test on the annual trade panel by interacting gas dependence $\times$ energy intensity with year dummies (reference: 2021) and restricting to the pre-period (2017–2021). The resulting year-by-year coefficients are small, with no systematic pattern. The joint F-test on the pre-treatment interactions yields $F = 2.04$ ($p = 0.089$), marginally failing to reject the null at the 5 percent level. This provides reasonable support for the triple-difference identifying assumption, though the borderline result motivates the Rambachan-Roth sensitivity analysis that follows.

### B.2 Sensitivity to Functional Form

Roth and Sant'Anna (2023) show that parallel trends in levels need not imply parallel trends in logs, and vice versa. As a sensitivity check, I re-estimate the triple-difference on imports in levels (millions of euros) rather than logs. The results are qualitatively identical: the triple-difference coefficient is negative and statistically insignificant.

### B.3 Rambachan-Roth Sensitivity

The framework of Rambachan and Roth (2023) assesses sensitivity to violations of parallel trends by parameterizing the maximum deviation from linearity ($\bar{M}$) in the pre-trend. Given the joint F-test ($p = 0.089$), I set $\bar{M}$ equal to the maximum absolute change in consecutive pre-treatment coefficients: $\bar{M} = 0.128$. I also report results for $1.5\bar{M}$ and $2\bar{M}$.

Table 8 reports the resulting confidence sets. At $\bar{M} = 0.128$, the 2022 confidence set is $[-0.349, 0.205]$, the 2023 set is $[-0.494, 0.454]$, and the 2024 set is $[-0.556, 0.574]$. The upper bounds include positive values, meaning that under trend violations, some import substitution cannot be definitively excluded. However, the point estimates remain negative or near zero ($-0.072$, $-0.020$, $+0.009$), and the confidence sets are centered well below the $+0.3$ to $+0.5$ increases that the standard import substitution narrative would predict. The key qualitative finding—that imports did not systematically increase—holds across all sensitivity parameterizations, though the quantitative uncertainty grows with the extrapolation horizon.

## C. Robustness Appendix

### C.1 Leave-One-Out by Country

Figure 6 in the main text presents the results of sequentially dropping each of the 27 EU member states from the sample and re-estimating the triple-difference. The point estimates range from approximately $-0.16$ to $-0.05$, with no single country driving the result. Key checks:

- Dropping Czech Republic (97% Russian gas share, highest in sample): $\hat{\beta} \approx -0.09$.
- Dropping Germany (largest economy, 55% Russian gas share): $\hat{\beta} \approx -0.10$.
- Dropping Finland (75% share but very low gas/TPES): $\hat{\beta} \approx -0.11$.
- Dropping Italy (40% share, large economy): $\hat{\beta} \approx -0.12$.

**Table 8:** Rambachan-Roth Sensitivity Bounds

| Year | $k$ | $\hat{\beta}$ | SE | $\bar{M}$ | Lower | Upper |
|---|---|---|---|---|---|---|
| *Panel A:* $\bar{M} = 0.128$ *(1× observed)* | | | | | | |
| 2022 | 1 | −0.072 | 0.076 | 0.128 | −0.349 | 0.205 |
| 2023 | 2 | −0.020 | 0.111 | 0.128 | −0.494 | 0.454 |
| 2024 | 3 | +0.009 | 0.092 | 0.128 | −0.556 | 0.574 |
| *Panel B:* $\bar{M} = 0.192$ *(1.5× observed)* | | | | | | |
| 2022 | 1 | −0.072 | 0.076 | 0.192 | −0.413 | 0.269 |
| 2023 | 2 | −0.020 | 0.111 | 0.192 | −0.622 | 0.582 |
| 2024 | 3 | +0.009 | 0.092 | 0.192 | −0.748 | 0.766 |
| *Panel C:* $\bar{M} = 0.256$ *(2× observed)* | | | | | | |
| 2022 | 1 | −0.072 | 0.076 | 0.256 | −0.477 | 0.333 |
| 2023 | 2 | −0.020 | 0.111 | 0.256 | −0.750 | 0.710 |
| 2024 | 3 | +0.009 | 0.092 | 0.256 | −0.940 | 0.958 |

*Notes:* Confidence sets constructed as $[\hat{\beta} - 1.96 \cdot \text{SE} - \bar{M} \cdot k,\ \hat{\beta} + 1.96 \cdot \text{SE} + \bar{M} \cdot k]$ where $k$ is the number of post-treatment periods. $\bar{M}$ is the maximum absolute change in consecutive pre-treatment coefficients from the annual trade event study (reference year: 2021). Standard errors clustered at the country level.

### C.2 Leave-One-Out by Product

I also check sensitivity to dropping individual SITC product groups. Dropping SITC 5 (chemicals, the most energy-intensive treated group) reduces the precision of the estimate but does not change the sign or qualitative conclusion. Dropping SITC 7 (machinery, the primary control group) and using only SITC 0+1 and SITC 2+4 as controls also yields a negative, insignificant triple-difference coefficient.

### C.3 Alternative Treatment Definitions

The main specification uses the continuous Russian gas import share as the treatment variable. I consider two alternatives:

*Binary gas dependence.* Countries are classified as high-dependence (above-median Russian gas share) or low-dependence (below-median). The triple-difference coefficient is −0.046 (SE = 0.057), negative and insignificant.

*Gas exposure.* The composite measure (Russian gas share × gas/TPES ratio) captures both the foreign source dimension and the domestic importance of gas. The triple-difference coefficient is −0.204 (SE = 0.391), negative but imprecisely estimated due to reduced variation in this composite measure.

### C.4 Placebo Tests

Two placebo tests assess the specificity of the results (see also **??**, Panel C).

*Chemicals vs. food.* I replace the control group with food products (SITC 0+1) and compare to chemicals (SITC 5) only. The coefficient is $-0.393$ (SE $= 0.170$, $p = 0.03$, $N = 432$), statistically significant and larger in magnitude than the main estimate ($-0.109$). This signals a broader import decline in gas-dependent countries extending beyond the energy-intensity channel, consistent with general demand contraction.

*Machinery vs. food.* Both groups are non-energy-intensive. The coefficient is $-0.205$ (SE $= 0.114$, $p = 0.08$, $N = 432$), marginally significant, consistent with a mild common import trend unrelated to energy intensity.

### C.5 Clustering and Inference

The main specification clusters standard errors at the country level (27 clusters). With few clusters, conventional cluster-robust standard errors may be undersized. I address this concern in two ways. First, the triple-difference coefficient is not close to conventional significance thresholds ($p = 0.18$), so the null finding is not driven by marginal inference decisions. Second, I verify that wild cluster bootstrap confidence intervals (using the `fwildclusterboot` package in R) contain zero, confirming the null.

## D. Heterogeneity Appendix

### D.1 By Product Group

I disaggregate the trade panel by SITC product group, estimating the gas dependence $\times$ post-shock interaction separately for each category. Table 9 reports the results. Chemicals (SITC 5) show a coefficient of $-0.156$ (SE $= 0.162$, $p = 0.34$, $N = 216$), while manufactured goods (SITC 6+8) show a coefficient closer to zero ($-0.036$, SE $= 0.108$, $p = 0.74$, $N = 216$). Neither is statistically significant, consistent with a broad absence of import substitution across energy-intensive products. Raw materials (SITC 2+4) show the largest negative estimate ($-0.230$, SE $= 0.126$, $p = 0.08$, $N = 216$), marginally significant, while food (SITC 0+1) and machinery (SITC 7) show near-zero or positive coefficients.

### D.2 By Country Group

I split the sample into Central/Eastern European (CEE) countries (Bulgaria, Czech Republic, Estonia, Croatia, Hungary, Lithuania, Latvia, Poland, Romania, Slovenia, Slovakia; $N = 440$)

**Table 9:** Heterogeneity by Product Group

| SITC Group | $\hat{\beta}$ | SE | $p$-value | $N$ |
|---|---|---|---|---|
| Food (SITC 0+1) | +0.237 | (0.141) | 0.10 | 216 |
| Raw materials (SITC 2+4) | −0.230 | (0.126) | 0.08 | 216 |
| Chemicals (SITC 5) | −0.156 | (0.162) | 0.34 | 216 |
| Manufactures (SITC 6+8) | −0.036 | (0.108) | 0.74 | 216 |
| Machinery (SITC 7) | +0.033 | (0.099) | 0.74 | 216 |

*Notes:* Each row reports the coefficient on gas dependence × post-shock from a separate regression within the indicated SITC group. Dependent variable is log imports. Fixed effects: country + year. Standard errors clustered at the country level. $N = 27$ countries × 8 years = 216 per group.

and Western European countries ($N = 640$). Table 10 reports the triple-difference estimates for each subsample.

**Table 10:** Heterogeneity by Country Group

| Region | $\hat{\beta}$ | SE | $p$-value | $N$ |
|---|---|---|---|---|
| Central/Eastern Europe | −0.243 | (0.305) | 0.44 | 440 |
| Western Europe | −0.107 | (0.110) | 0.34 | 640 |

*Notes:* Triple-difference coefficient (gas dependence × energy intensity × post-shock) estimated separately by region. CEE includes BG, CZ, EE, HR, HU, LT, LV, PL, RO, SI, SK. Standard errors clustered at the country level.

The CEE coefficient (−0.243) is larger in magnitude than the Western European estimate (−0.107), consistent with CEE countries' greater gas dependence, but neither is statistically significant. The null finding is not an artifact of averaging across heterogeneous regions.

### D.3 By Time Period

The persistence analysis in Table 4 decomposes the post-treatment period into shock (2022) and post-normalization (2023–2024) subperiods. An additional split of the shock year into H1 2022 (pre-supply-cut) and H2 2022 (post-supply-cut) is not feasible with annual trade data but is examined in the monthly BEC panel, where the results are consistent.

## E. Additional Figures and Tables

This section collects supplementary exhibits referenced in the main text.

**Table 11:** Production Panel: Triple-Difference Estimates

| | (1) Production index | (2) Production index |
|---|---|---|
| Gas dep. × EI × Post | −7.169 | — |
| | (6.072) | |
| Gas dep. × EI × Shock (2022) | — | 9.750 |
| | | (11.054) |
| Gas dep. × EI × Post-norm (2023–24) | — | 3.848 |
| | | (9.389) |
| Country × NACE FE | Yes | Yes |
| NACE × Month FE | Yes | Yes |
| Observations | 11,704 | 11,704 |

*Notes:* Dependent variable: seasonally adjusted production index (2021 = 100). Column (1) uses the full sample. Column (2) decomposes into shock and post-normalization periods. The positive coefficients in Column (2) reflect sensitivity of the period-average estimator to a few outlier country-sector months; the monthly event study (Figure 1) shows the production decline more precisely. All coefficients are statistically insignificant at conventional levels. Standard errors clustered at the country level in parentheses. $^{*}p < 0.10$; $^{**}p < 0.05$; $^{***}p < 0.01$.

# F. Standardized Effect Sizes

**Table 12:** Standardized Effect Sizes for Main Outcomes

| Outcome | Specification | $\hat{\beta}$ | SD($X$) | SD($Y$) | SDE | Class. |
|---|---|---|---|---|---|---|
| Log imports | Triple-DiD, Tab. 3 Col. 1 | −0.109 | 0.35 | 1.80 | −0.021 | Null |
| Log imports (shock) | Persistence, Tab. 4 Col. 1 | −0.154 | 0.35 | 1.80 | −0.030 | Null |
| Production index | Event study, $k = 6$ | −9.496 | 0.35 | 17.66 | −0.188 | Large neg. |

*Notes:* This table reports standardized effect sizes (SDE) to facilitate cross-study comparison of treatment effect magnitudes. For continuous treatments, SDE $= \hat{\beta} \times \text{SD}(X)/\text{SD}(Y)$, which gives the effect of a one-standard-deviation change in the treatment variable (gas dependence × energy intensity), measured in standard deviations of the outcome. SD($Y$) and SD($X$) are unconditional standard deviations from the summary statistics (Table 1), before conditioning on fixed effects. SD($X$) is the standard deviation of the continuous Russian gas share (0.35).

**Research question:** Did the 2022 Russian gas shock cause EU countries to substitute collapsed domestic energy-intensive manufacturing with extra-EU imports? **Treatment:** Continuous Russian gas import share (2021), interacted with product-level energy intensity and post-shock indicator. **Data:** Eurostat Comext (trade) and sts_inpr_m (production), 27 EU countries, 2017–2024. **Method:** Triple-difference with country×year, product×year, and country×product fixed effects; country-clustered SEs. **Sample:** All 27 EU member states; 5 SITC product groups (trade) or 9 NACE sectors (production).

Classification thresholds: large negative ($< -0.10$), small negative ($-0.10$ to $-0.05$), null ($-0.05$ to $0.05$), small positive ($0.05$ to $0.10$), large positive ($> 0.10$). A reader unfamiliar with the paper should be able to interpret this table on its own.