Rapid Assessment of Economic Vulnerability using Firm-Product-Level Data

The Case of German Manufacturing and Gas Shortage during the Russian Invasion of Ukraine

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The initial situation shortly after the 2022 Russian invasion: Germany's dependence on Russian gas supplies

- Natural gas is important for electricity generation and heating and is a key input in many manufacturing sectors

- Germany depends on gas imports, before 2022 mostly **cheap pipeline gas from Russia**

- Directly after the Russian invasion, e.g., the chemical industry lobby claimed: No Russian gas → chemical industry production stops → **manufacturing collapses broadly** because basic chemicals are central to industrial supply chains

- **Problem for the German government in spring 2022:**
  - Unclear economic impacts of a sudden stop of Russian gas
  - Perceived economic vulnerability made Germany reluctant to confront Russia
  - Initial support for Ukraine was minimal

Why were the economic consequences of a sudden gas stop unclear?

- Analytical Limitations
  - Macro general equilibrium models → simplifying, aggregated and **assumption-driven** (substitution elasticities & speed of adjustment, cascade effects)
  - wide range of one-year GDP loss estimates: between 0.5 - 3% (Bachmann et al. 2022) and 12% (Krebs 2022)

- Data Limitations
  - Input-output tables are (still) far too coarse (2-digit sectors)
  - No ready-to-use micro-data on gas usage

Main micro data used

in Mertens and Mueller (2022), expertise for German Council of Economic Experts and several unpublished reports for government bodies

- German statistical office runs **surveys in the manufacturing sector;** firms are obliged to respond

- Combine two data sets covering all establishments with > 20 employees
  - **Product-level data** (9-digit, PRODCOM) including physical output (quantities) and sales
  - Energy input data **by energy carrier** in kWh
  - Unique identifiers to link these data sets

- Combined data set yields **product-level data on gas consumption and sales for manufacturing sector**

- Allows identifying for instance:
  - **Main gas using products**
  - Products with **high gas intensity**, i.e. $gas\ /sales$ (in kWh per EUR)

Supply chain vulnerability: linking German product-level data with trade data

- Use product-level data on gas consumption and output in manufacturing to estimate *direct* GDP losses in gas-intensive segments
- Problem → this **does not capture downstream cascade effects.**
- Our solution:
  - Assess whether gas-intensive products can be imported instead of produced domestically → **think about import substitution not energy input substitution**
  - UN Comtrade data provides product-level bilateral trade flows (e.g., value of ammonia shipped from U.S. to Japan)

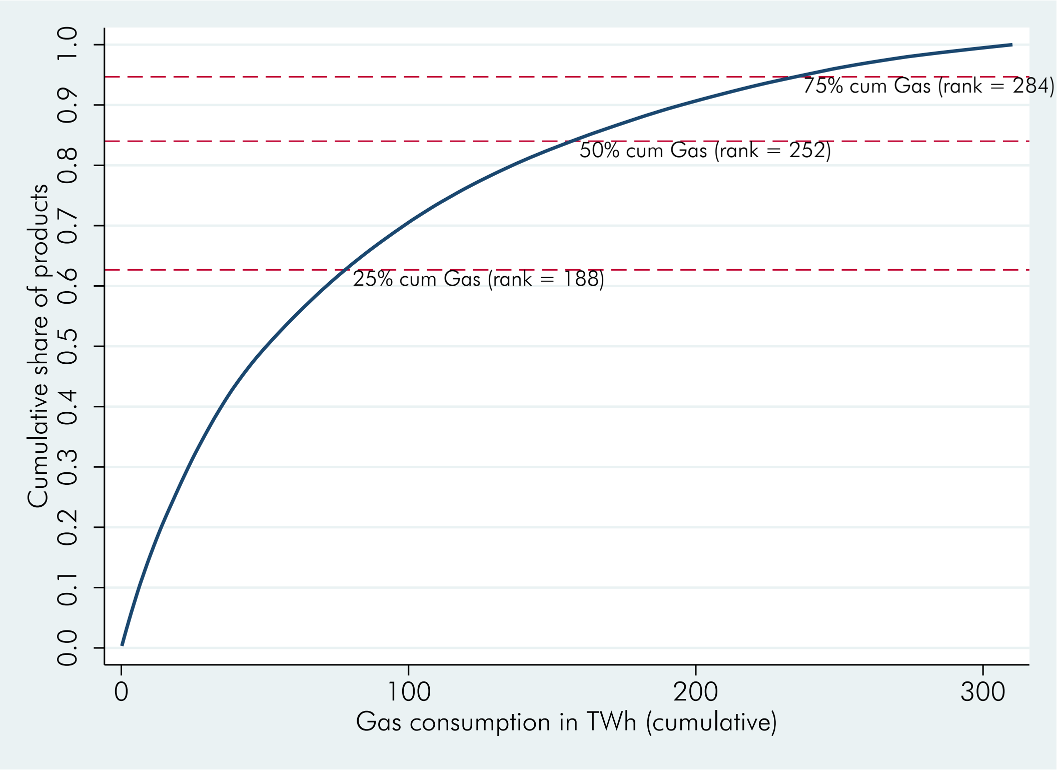
Supply chain vulnerability: linking German product-level data with trade data (ctd).

- Data Integration:
  - Merge UN Comtrade data with German product-level data
  - Result: **6-digit product-level data on (i) global bilateral trade flows** (incl. German exports and imports)**, (ii) German gas consumption, and (iii) German production values**

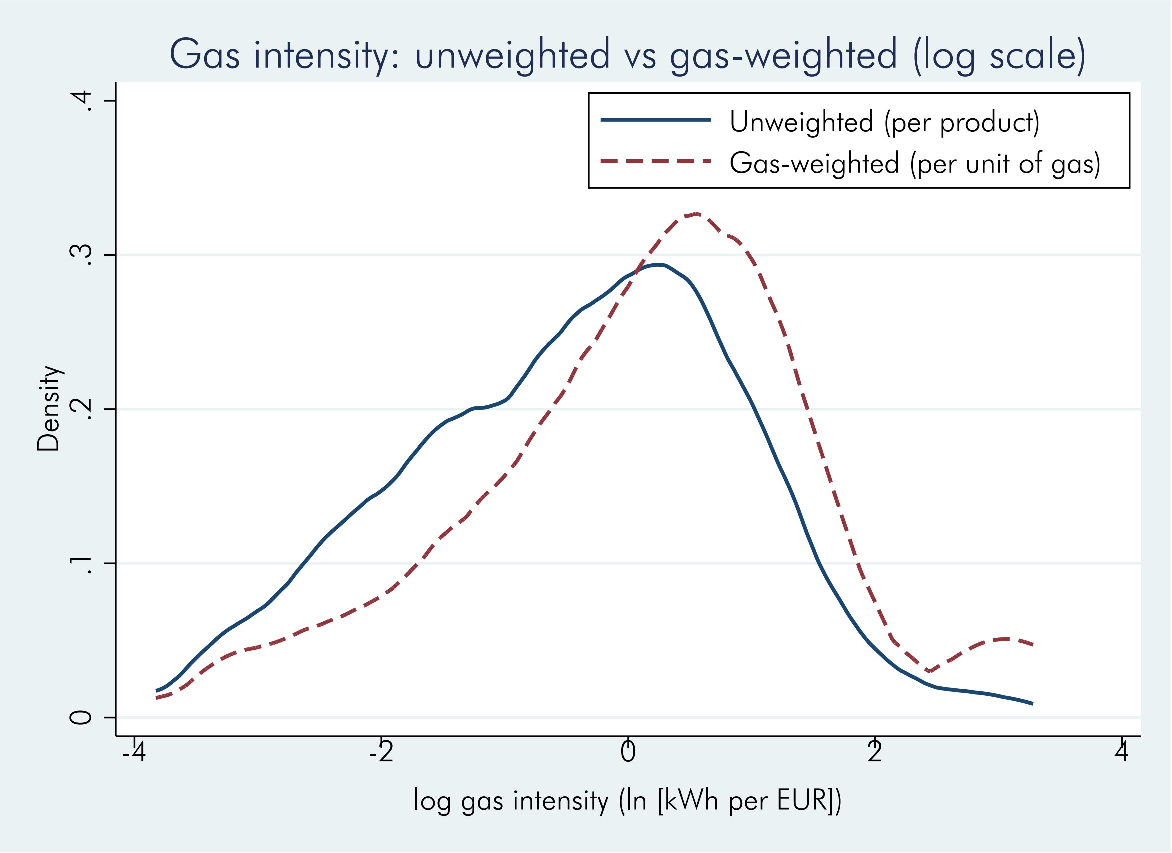
- Helps additionally identify:
  - Which gas-intensive products are tradable
  - Whether import substitution is likely to be expensive
  - Risky import sources (e.g., Russia)
  - Current export values of gas-intensive German products

Basic facts on pre-2022 Gas consumption

- Total pre-crisis gas consumption of German manufacturing was 350 TWh per year
- 310 TWh (89%) were used for the production of the 300 products (out of 1600) with the highest gas consumption
- Within those 300 products, 50% of gas consumption was accounted for by just 48 product classes



Wide distribution of gas intensity (kWh/EUR): gas-heavy products are also more gas intensive



Leontief example: Eliminating production in the 25% most gas-intensive products (72) yields **40% gas savings**, at a direct cost of €37 bn in sales (€10.6 bn in value added).

Import Substitutability (pre-crisis)

- At the product level, we define the (inverse) import substitutability as the **ratio of domestic consumption to global trade volume**, i.e.

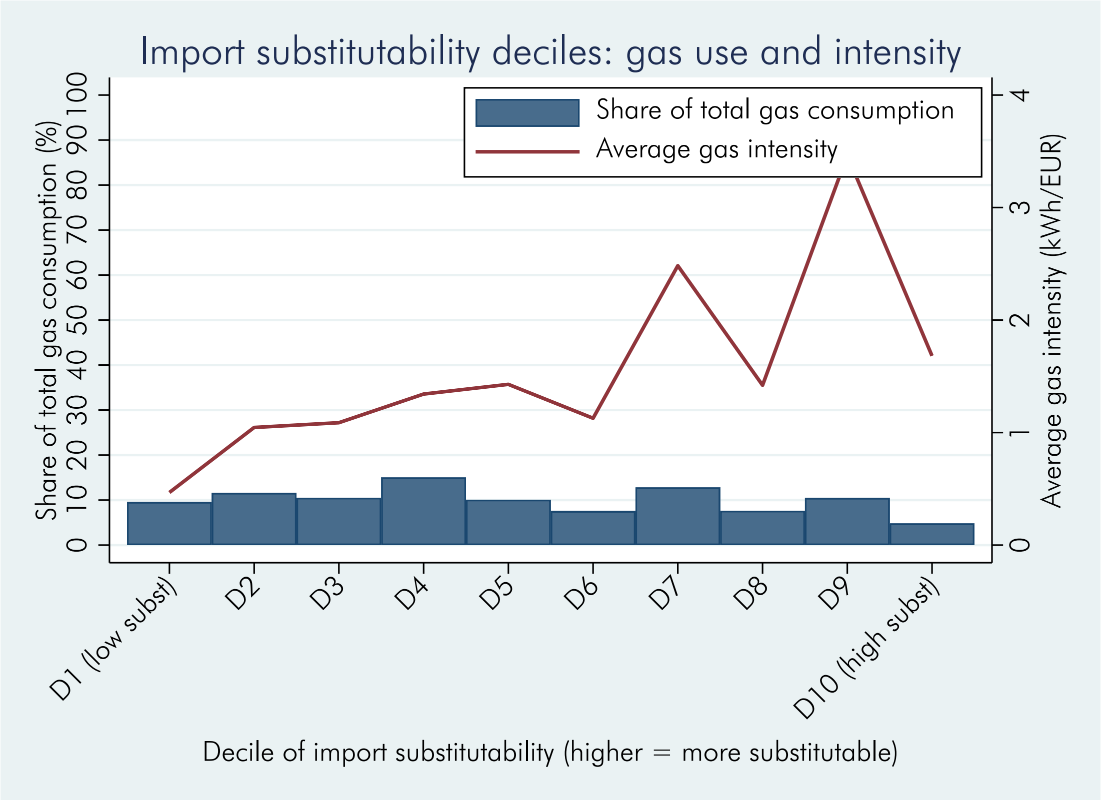
$$import\ substitutability = \frac{domestic\ production + imports\ -\ exports}{global\ trade\ volume}$$

- Global trade volume is exports minus re-exports.
  - We exclude German exports.
  - We exclude Russia, and it is possible to adjust this for further risky countries.
  - We exclude European exports, as Europe was hit by the same gas shock.

- At the median, domestic consumption accounts for 13% of global trade volume.

Mean: 0.428	25^{th}: 0.012	50^{th}: 0.131	75^{th}: 0.282

Substitutable products have very high gas intensity but below average gas use



Leontief example: Eliminating production in the 72 products that exceed the median in both gas intensity and import substitutability yields **26% gas savings**, at a cost of €36 bn in sales (≈ €11 bn in value added).

Policy Advice based on linked product-level Data

(Mertens and Mueller (2022), expertise for German Council of Economic Experts and several unpublished reports for government bodies)

- **Use the advantages of granular data**: identify the gas-heavy products.

- This will likely be a **small number of products**, allowing the government/researcher to examine them closely. Of particular interest is:
  1. How much value is added per unit of gas? ✓
  2. Can the products be substituted by imports? ✓
  3. Can gas be substituted by other energy carriers?
     - *Impossible* for some industrial processes, e.g. in ammonia synthesis, where gas is not an energy carrier but a raw material.
     - *Possible but difficult* in very heat-intensive industrial processes (e.g. steel production).
  4. If substitution is difficult, identify the precise downstream sectors.
     - Could downstream products be imported themselves?
  5. Could exports be (temporarily) restricted?

- **Based on this knowledge, prepare an emergency plan that saves gas where costs are minimal - rather than using a "one-size-fits-all" approach.**