Lecture 3

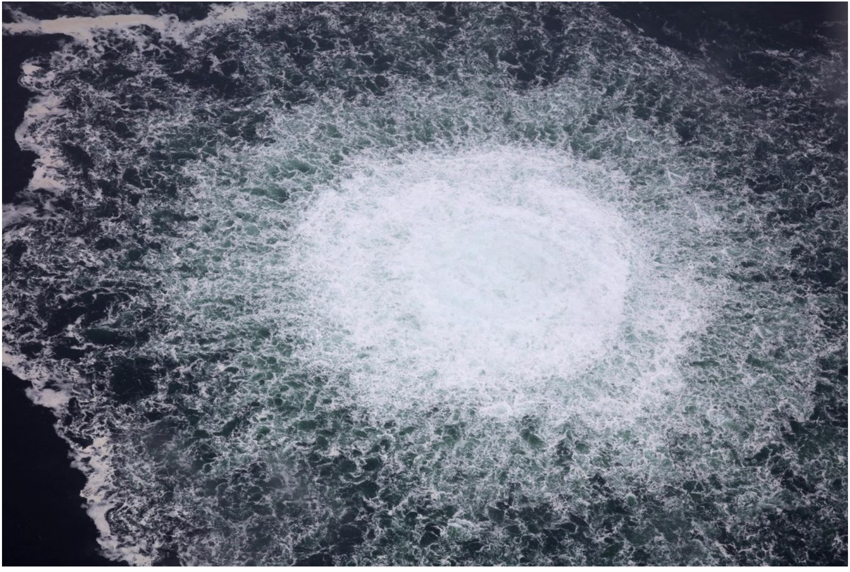
The Power of Substitution: Germany without Russian Gas

Macroeconomics EC2B1

Benjamin Moll

London School of Economics, Winter 2024

What today's lecture is about



Background: German primary energy consumption in 2021

	Oil	Gas	Coal	Nuclear	Renew.	Rest	Total
TWh	1077	905	606	209	545	45	3387
%	31.8	26.7	17.9	6.2	16.1	1.3	100
of which Russia	34%	55%	26%	0%	0%	0%	30%

Source: Bachmann et al. (2022a)

Plan

1. Background
2. The CES production function: complementarities and substitution in production
3. Back to February 2022 (Russian invasion of Ukraine)
4. After the gas cut-off: how the adjustment happened
5. Political economy of decision making in times of crisis
6. Policies to support households in face of high energy prices

Background readings: two papers (not examinable)

ECONtribute
MARKETS & PUBLIC POLICY

ECONtribute
Policy Brief No. 028

What if? The Economic Effects for Germany of a Stop of Energy Imports from Russia

Rüdiger Bachmann
Moritz Kuhn
Andreas Peichl

David Baqaee
Andreas Löschel
Karen Pittel

Christian Bayer
Benjamin Moll
Moritz Schularick

March 2022

www.econtribute.de

Brookings Papers
ON ECONOMIC ACTIVITY

BPEA Conference Draft, September 28-29, 2023

The Power of Substitution: The Great German Gas Debate in Retrospect

Benjamin Moll (London School of Economics)

Moritz Schularick (Kiel Institute for the World Economy and Sciences Po)

Georg Zachmann (Bruegel)

Other materials (not examinable)

- Marginal Revolution "Substitutes Are Everywhere" https://marginalrevolution.com/marginalrevolution/2023/05/substitutes-are-everywhere-the-great-german-gas-debate-in-retrospect.html
- Video available for Brookings presentation https://www.youtube.com/watch?v=-bs5QYr-w08&t=11295s
- Excellent discussions by Jim Hamilton and Tarek Hassan
- Q&A with lots of great questions and connection to other topics (green transition etc)
- Non-technical summary https://www.brookings.edu/articles/the-power-of-substitution-the-great-german-gas-debate-in-retrospect/
- Podcast (including transcript) https://www.brookings.edu/articles/how-did-germany-fare-without-russian-gas/
- Appendix E of Moll-Schularick-Zachmann "36 concrete cases of substitution and demand reduction" https://benjaminmoll.com/GGGD/

Embargo debate after Russian invasion of Ukraine

manager magazin

Money for Russian gas imports

660 million euros a day – this is how we finance Putin's war

Gas from Russia: For President Putin, gas exports are currently the most important source of foreign exchange Photo: Dmitry Lovetsky / dpa

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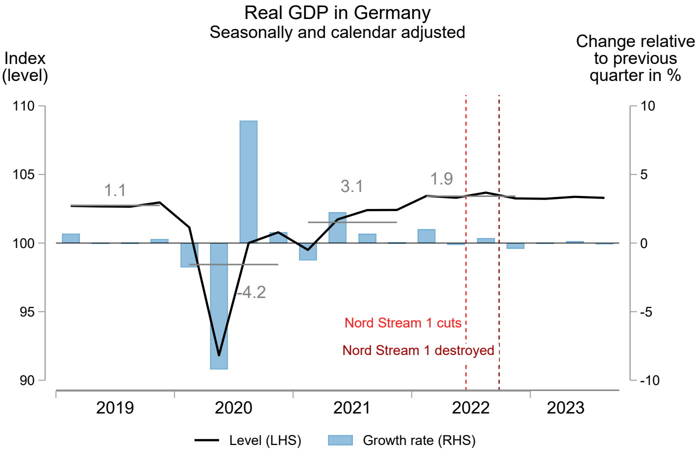
Putin is swimming in our money

embargo debate

BASF boss warns of destruction of the "entire economy"

Oil and gas are central to the chemical industry. Should their imports from Russia be stopped, BASF boss Martin Brudermüller predicts the "worst crisis since the end of the Second World War".

Destruction of economy? Worst crisis since end of WWII?



Instead: a mini recession followed by stagnation

Background: rationales for an energy embargo against Russia

- Oleg Itskhoki: “Each marginal euro received [by Russia] from energy exports to Europe contributes exactly one euro to the war, simple as that” https://twitter.com/itskhoki/status/1512508687641763844
- Hanno Lustig: “Suppose we did a helicopter drop of dollars in Red Square in Moscow. If no one bothers to pick them up, then export curbs are irrelevant. Not a likely outcome.”
- Guriev and Itskhoki “The Economic Rationale for Oil and Gas Embargo on Putin’s Regime” https://sanctions.kse.ua/wp-content/uploads/2022/09/The-Economic-Rationale-for-Oil-and-Gas-Embargo-on-Putins-Regime.pdf
- Guriev op-ed: https://www.project-syndicate.org/commentary/europe-russia-oil-embargo-needs-immediate-price-cap-by-sergei-guriev-2022-06
- Itskhoki presentation from minute 6 here https://www.aeaweb.org/webcasts/2023/implications-russia-ukraine

The CES production function:

Complementarities and substitution in production

Plan and useful background readings

Introduce a very useful production function: the "constant elasticity of substitution (CES) production function"

- this lecture's main application: substitution of natural gas in production
- but to underline generality: introduce with capital and labor $Y = F(K, N)$
- many other applications
- example: skill-biased technical change & skill premium $Y = F(N_s, N_u)$
- another possibility: CES utility function $\Rightarrow$ substitution in consumption

Useful background readings

- Your EC1A1 lecture notes on producer theory
- Chapter 2 here https://web2.econ.ku.dk/okocg/MAT-OEK/Mak%C3%98k2/Mak%C3%98k2-2015/Forel%C3%A6sninger/Ch1-3-M2-2015-3.pdf
- Appendix A.2 here https://benjaminmoll.com/RussianGas_Appendix/

Some production functions you should already know

Technology: output $Y = F(K, N)$ is produced using capital K and labor N

1. Cobb-Douglas

$$Y = AK^{\alpha} N^{1-\alpha}, \quad A > 0,\ 0 < \alpha < 1$$

2. Perfect substitutes

$$Y = A_K K + A_N N, \quad A_K, A_N > 0$$

3. Perfect complements, fixed proportions, or "Leontief"

$$Y = \min\{B_K K, B_N N\}, \quad B_K, B_N > 0$$

The CES Production Function

$$Y = F(K, N) = \left(\alpha^{\frac{1}{\sigma}}(A_K K)^{\frac{\sigma-1}{\sigma}} + (1-\alpha)^{\frac{1}{\sigma}}(A_N N)^{\frac{\sigma-1}{\sigma}}\right)^{\frac{\sigma}{\sigma-1}}$$

- The CES production function is a generalization of the three production functions on previous slide
- Key parameters
  - σ: elasticity of substitution, here between K and N
  - α: share parameter
  - A_K, A_N: capital- and labor productivity (factor-specific productivity)
- Will often see it written slightly differently, e.g.

$$Y = (\theta_K (A_K K)^\rho + \theta_N (A_N N)^\rho)^{1/\rho}$$

that's the same thing, e.g. $\sigma = 1/(1-\rho)$

Special cases of the CES production function

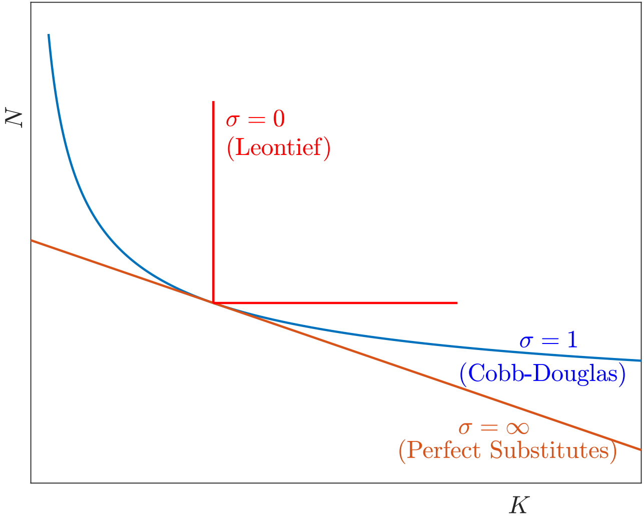
$$Y = \left(\alpha^{\frac{1}{\sigma}}(A_K K)^{\frac{\sigma-1}{\sigma}} + (1-\alpha)^{\frac{1}{\sigma}}(A_N N)^{\frac{\sigma-1}{\sigma}}\right)^{\frac{\sigma}{\sigma-1}}, \quad \sigma = \text{elasticity of substitution}$$

1. Case $\sigma = 1$: Cobb-Douglas
$$Y = \left(\frac{A_K K}{\alpha}\right)^{\alpha}\left(\frac{A_N N}{1-\alpha}\right)^{1-\alpha} = AK^{\alpha}N^{1-\alpha}$$
2. Case $\sigma \to \infty$: perfect substitutes
$$Y = A_K K + A_N N$$
3. Case $\sigma = 0$: perfect complements, fixed proportions, or "Leontief"
$$Y = \min\left\{\frac{A_K K}{\alpha}, \frac{A_N N}{1-\alpha}\right\}$$

Derivations (see supplement)

- proof of case 2 relatively simple: as $\sigma \to \infty$, $\frac{1}{\sigma} \to 0$, $\frac{\sigma-1}{\sigma} \to 1$, $\frac{\sigma}{\sigma-1} \to 1$
- proof of cases 1 and 3: more complicated, need to apply l'Hopital's rule

Isoquants of the CES production function



CES production function: marginal products and MRT

$$Y = \left(\alpha^{\frac{1}{\sigma}}(A_K K)^{\frac{\sigma-1}{\sigma}} + (1-\alpha)^{\frac{1}{\sigma}}(A_N N)^{\frac{\sigma-1}{\sigma}}\right)^{\frac{\sigma}{\sigma-1}}$$

- Marginal product of capital

$$\frac{\partial F(K,N)}{\partial K} = \left(\alpha^{\frac{1}{\sigma}}(A_K K)^{\frac{\sigma-1}{\sigma}} + (1-\alpha)^{\frac{1}{\sigma}}(A_N N)^{\frac{\sigma-1}{\sigma}}\right)^{\frac{\sigma}{\sigma-1}-1} \alpha^{\frac{1}{\sigma}} A_K^{\frac{\sigma-1}{\sigma}} K^{-\frac{1}{\sigma}}$$

- Marginal product of labor

$$\frac{\partial F(K,N)}{\partial N} = \left(\alpha^{\frac{1}{\sigma}}(A_K K)^{\frac{\sigma-1}{\sigma}} + (1-\alpha)^{\frac{1}{\sigma}}(A_N N)^{\frac{\sigma-1}{\sigma}}\right)^{\frac{\sigma}{\sigma-1}-1} (1-\alpha)^{\frac{1}{\sigma}} A_N^{\frac{\sigma-1}{\sigma}} N^{-\frac{1}{\sigma}}$$

- Marginal rate of transformation

$$\Rightarrow \frac{\partial F(K,N)/\partial K}{\partial F(K,N)/\partial N} = \left(\frac{\alpha}{1-\alpha}\right)^{1/\sigma} \left(\frac{A_K}{A_N}\right)^{\frac{\sigma-1}{\sigma}} \left(\frac{K}{N}\right)^{-1/\sigma}$$

Elasticity of substitution: how input mix responds to prices

- Consider profit maximizing firm: $\max_{K,N} \ F(K,N) - WN - RK$ where R and W = prices of capital and labor. Optimality:

$$\frac{\partial F(K,N)}{\partial K} = R, \qquad \frac{\partial F(K,N)}{\partial N} = W \quad \Rightarrow \quad \frac{\partial F(K,N)/\partial K}{\partial F(K,N)/\partial N} = \frac{R}{W}$$

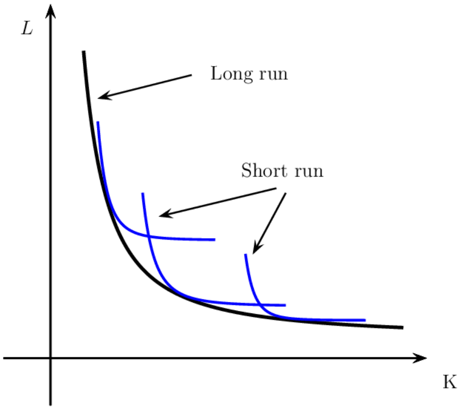
- Using expression from previous slide

$$\left(\frac{\alpha}{1-\alpha}\right)^{1/\sigma}\left(\frac{A_K}{A_N}\right)^{\frac{\sigma-1}{\sigma}}\left(\frac{K}{N}\right)^{-1/\sigma} = \frac{R}{W} \quad \Rightarrow \quad \frac{K}{N} = \text{constant} \times \left(\frac{R}{W}\right)^{-\sigma}$$

- Response of input mix K/N to factor prices R/W depends on σ
  - Leontief $\sigma = 0$: input mix does not respond to prices at all
  - Perfect substitutes $\sigma \to \infty$: input mix responds extremely strongly
  - In general

$$\frac{d \log(K/N)}{d \log(R/W)} = -\sigma$$

Le Chatelier principle: long run elasticity > short run elasticity



The LeChatelier Principle

By PAUL MILGROM AND JOHN ROBERTS*

The LeChatelier principle, in the form introduced into economics by Paul A. Samuelson, asserts that at a point of long-run equilibrium, the derivative of long-run compensated demand with respect to own price is larger in magnitude than the derivative of short-run compensated demand. We introduce an extended LeChatelier principle that applies also to large price changes and to uncompensated demand as well as to a wide range of concave and nonconcave maximization problems outside the scope of demand theory. This extension also clarifies the intuitive basis of the principle. (*JEL* C60, D10, D20).

The idea that long-run demand is typically more elastic than short-run demand is common in economics. The LeChatelier principle expresses this idea mathematically. The principle has its cleanest expression in the neoclassical theory of the firm, where it applies to input demand. Let there be two inputs, say capital and labor, and suppose that the price of labor falls. In the short run, if the capital input is fixed, the direct effect of the change will be to lead to (weakly) more labor being employed. In the long run, changes in capital usage may occur which alter the productivity of labor. The first formal analysis to conclude that such changes would *increase* the use of labor was offered by Paul A. Samuelson (1947), who returned to the subject frequently (Samuelson 1949, 1960a, 1960b, 1972). His original treat-

Various intuitive arguments have been offered to explain why labor demand should become (weakly) more elastic when capital is adjusted, the most accurate of which goes as follows. First suppose capital and labor are substitutes in the sense that increasing the use of one reduces the marginal product of the other. (This implies that the two are also substitutes in the demand-theoretic sense that lowering the price of one decreases the demand for the other.) Then in the long run the firm will reduce its use of capital in response to the lower price of labor. Because the inputs are substitutes, reducing the amount of capital raises the marginal product of labor, and this results in a further increase in labor's employment. Thus, the long-run adjustment is greater than the short-run one. On the other hand, if

Micro vs macro elasticities

- **Micro:** substitution within a given production process
  - often limited, production close to Leontief

- **Macro:** substitution not just within production processes / firms but also across production processes / firms (extensive margin)
  - often substantial, especially with time (le Chatelier)

- In general: macro elasticity $>$ micro elasticity

Application to gas crisis: how much does production fall when a critical input falls?

$$Y = \left[\alpha^{\frac{1}{\sigma}} G^{\frac{\sigma-1}{\sigma}} + (1-\alpha)^{\frac{1}{\sigma}} X^{\frac{\sigma-1}{\sigma}}\right]^{\frac{\sigma}{\sigma-1}}$$

where G = gas, X = other factors, e.g. $X = \tilde{F}(K, N)$

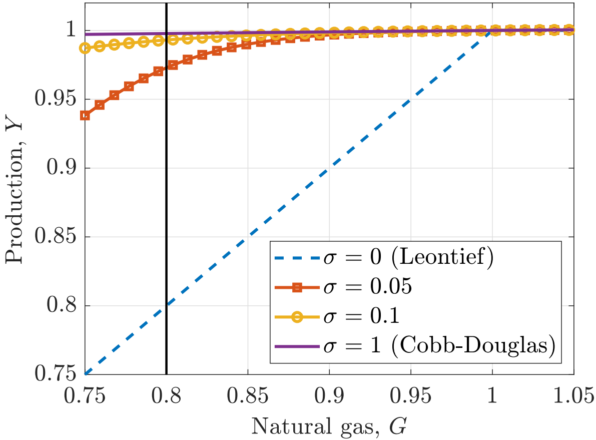
- Consider drop in G, e.g. $\Delta \log G = -20\%$. How much does Y fall?
- Gas has small expenditure share α but also small elasticity σ
- Useful benchmarks:
  1. Cobb-Douglas $\sigma = 1$: $Y = G^{\alpha} X^{1-\alpha}$ with $\alpha = 0.01$

     $$\Delta \log Y = \alpha \Delta \log G = 0.01 \times (-20\%) = -0.2\%$$

  2. Leontief $\sigma = 0$: $Y = \min\{G/\alpha, X/(1-\alpha)\}$

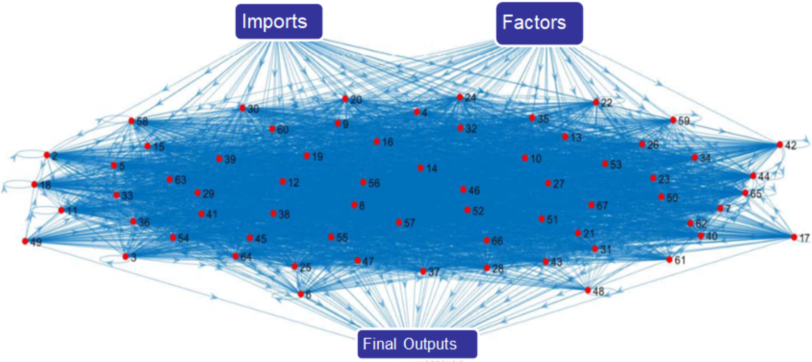
     $$\Delta \log Y = \Delta \log G = -20\% = \text{catastrophe}$$

Output losses for different elasticities of substitution



- Leontief $\sigma = 0$ $\Rightarrow$ production drops one-for-one with gas usage = 20%
- Even with $\sigma = 0.05$, output losses much smaller = 2.7% (almost 10*x*)

The worry: “cascading effects” along supply chain



- Literature on production networks, beyond scope of this course
- But same key prediction: Leontief $\Rightarrow$ total production drops one-for-one with gas usage

Back to February 2022

What things looked like in February 2022

	Oil	Gas	Coal	Nuclear	Renew.	Rest	Total
TWh	1077	905	606	209	545	45	3387
%	31.8	26.7	17.9	6.2	16.1	1.3	100
of which Russia	34%	55%	26%	0%	0%	0%	30%

Oil and coal have **global market** (+ a strategic reserve)

Gas trickier due to pipeline network, limited LNG supplies $\Rightarrow$ focus on gas

Consumption of gas (also = imports): $\approx$ 1% of GNE

- small number but energy = critical input $\Rightarrow$ amplification important

Objectives and results of March 2022 “what if?” paper

Assess consequences for Germany of cut-off from Russian energy imports

- either embargo by Germany/EU
- or stop of deliveries by Russia

Get sense of rough magnitudes of losses relative to “do nothing” baseline

1. Small GDP decline, say 0.5-1%, perhaps not even a recession?
2. Like Covid = 4.5% decline in German GDP?
3. Like Spain or Portugal during Euro crisis (5.1% & 7%)?
4. “Mass unemployment and poverty” so perhaps like Great Depression?

Our answer at the time: GDP decline up to 3% (“substantial but manageable”)

- Key mechanism: substitution of gas and gas-intensive inputs
- Based on model calculations of type we just discussed + relevant empirical estimates (e.g. of elasticities of substitutions)

Simplest Model

$$Y = \left[\alpha^{\frac{1}{\sigma}} Gas^{\frac{\sigma-1}{\sigma}} + (1-\alpha)^{\frac{1}{\sigma}} F(K, L)^{\frac{\sigma-1}{\sigma}}\right]^{\frac{\sigma}{\sigma-1}}$$

- Gas has small expenditure share, but substitution elasticity might be small
- Empirical estimates: **short run** ($<$12 months) demand elasticities 0.4 (Industry) and 0.2 (households)
- We assumed an elasticity of 0.1 and a -30% gas shock
- Also simulations with richer, more complicated model (Baqaee-Farhi)
  - production networks, supply chains, cascading effects
  - international trade

Table with main results of March 2022 “what if?” paper

	Baqaee-Farhi suff. statistic	Baqaee-Farhi simulation	Simplest model 10% energy $\downarrow$	Simplest model 30% gas $\downarrow$
GNE Loss, in %	< 1	< 0.3	1.5	2.3
As % of GDP	< 1	< 0.3	1.3	2.2
Per capita	€400	€100	€600	€900

- All models use conservative elasticity estimates
- Simplest model (= production fn) abstracts from trade
- The cost statements are in terms of GNE
- Some mechanisms left out $\Rightarrow$ round up headline to 3% (“safety margin”)

Reception by German government

Chancellor Scholz on TV, responding to "economists don't predict doom"

- "But they get it wrong! And it's honestly irresponsible to calculate around with some mathematical models that then don't really work."
- "I don't know absolutely anyone in business who doesn't know for sure that these would be the consequences."

Head of chancellery Wolfgang Schmidt during televised panel

- "The second thing is, what they call elasticity, the question whether you can substitute or whether you cannot substitute gas, oil, and coal."
- "And they always said in that model: 'Yeah there is elasticity, it is not zero.' But that is not true."

Transcripts: `https://benjaminmoll.com/Scholz/` and `https://benjaminmoll.com/Schmidt/`

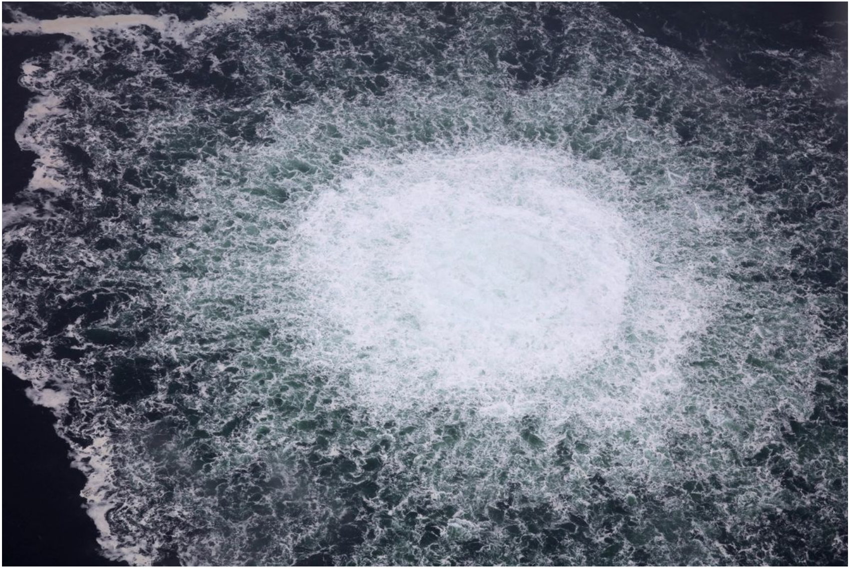
What happened next?

Soon after: **Cut-off happens** because Russia weaponizes gas supplies

- June 2022: drastically cuts supplies, particularly via Nord Stream
- August 2022: completely halt Nord Stream flows (destroyed 4 weeks later)

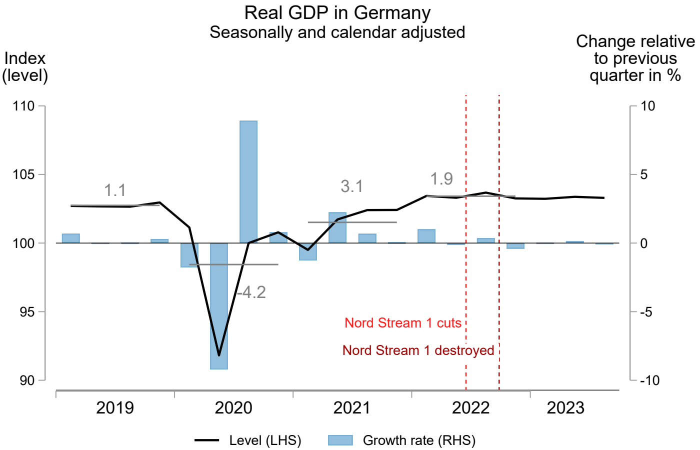
What happened next? August 2022

What happened next? September 2022



How the Adjustment Happened

Destruction of economy? Worst crisis since end of WWII?



Instead: a mini recession followed by stagnation

Large adjustments on both demand- and supply side

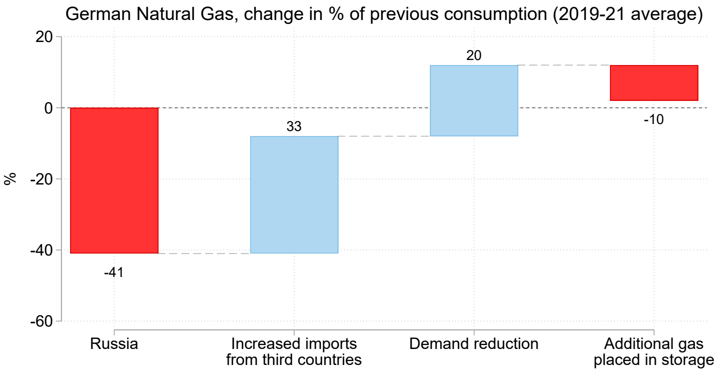


Figure 4: Germany's changing gas balance

Notes: The figure compares German natural gas imports, consumption, and storage change for the period July 2022 - March 2023, to the corresponding average from 2019 to 2021 using data from Eurostat (database code nrg_ti_gasm), McWilliams and Zachmann (2023), and AGSI. On the supply side, we take into account not only direct imports to Germany but also indirect imports via third countries as well as re-exports within Europe. More details, including on sources, are in appendix B.

Large demand reduction by industry and households

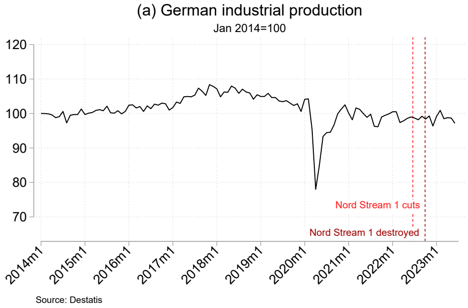
	2022/23 consumption	Baseline consumption	Reduction rel. to baseline	Percentage reduction	Bachmann et al. (August 2022)
Total	642 TWh	799 TWh	157 TWh	20%	25%
Industry	276 TWh	373 TWh	98 TWh	26%	26%
Households	281 TWh	339 TWh	58 TWh	17%	16%
Power	85 TWh	87 TWh	1 TWh	2%	45%

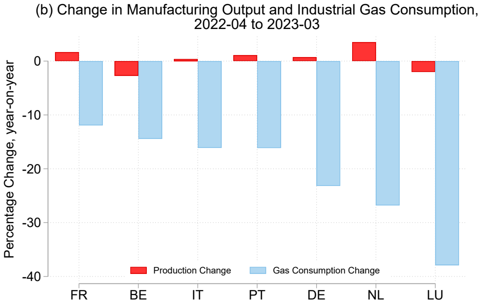
Table 2: Large demand reduction by industry and households

Notes: The table summarizes gas consumption over the period July 2022 to March 2023 ("2022/23 consumption") and compares it to average consumption in the same months in the years 2019 to 2021 ("baseline consumption").

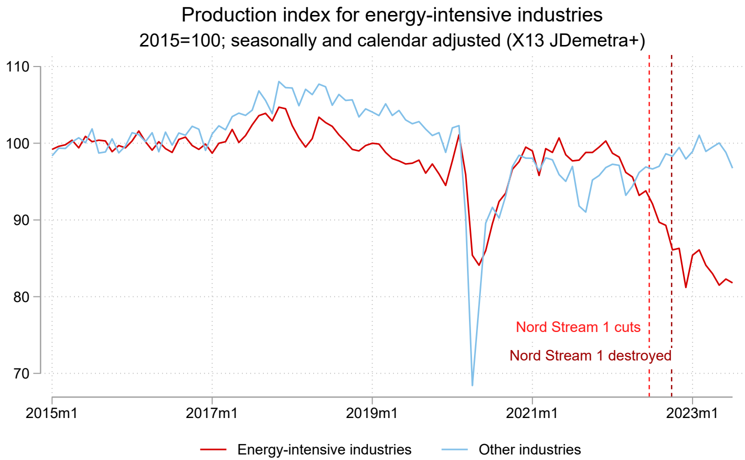
Industrial production in Germany and Europe looks nothing like Leontief

Recall: Leontief $\Rightarrow$ should have seen 20-30% drop in industrial production



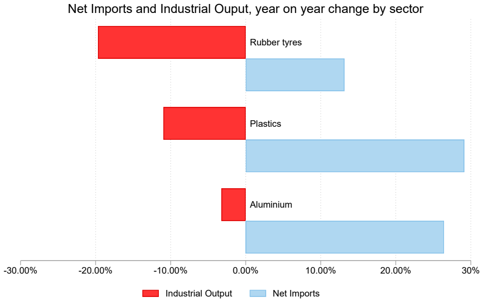


Decoupling: large cuts in energy-intensive sectors but not rest = polar opposite of “cascading effects”



Source: Destatis

Substitution of gas-intensive products via imports



BASF's ammonia production (= very gas-intensive): when gas prices ↑

- drastically cut ammonia production in Luwigshafen, Germany
- But BASF has plant in U.S. ⇒ produce ammonia there, ship it to Germany

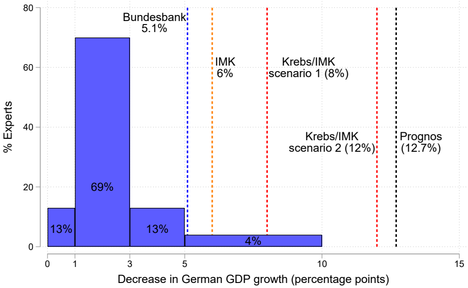
Substitution via imports can happen even within same company

Bad for German ammonia production but kills cascading effects

Political economy of decision making in times of crisis

Two political problems with lessons for future crises

1. Policymakers turned to business leaders & their associations for advice
    - “expertise on the ground” but also clear incentive to talk up dependence
    - striking divergence: claimed dependence vs observed substitution (BASF)
2. Strategic use of special-interest-financed think-tanks to increase uncertainty



Source: The April 2022 CfM survey

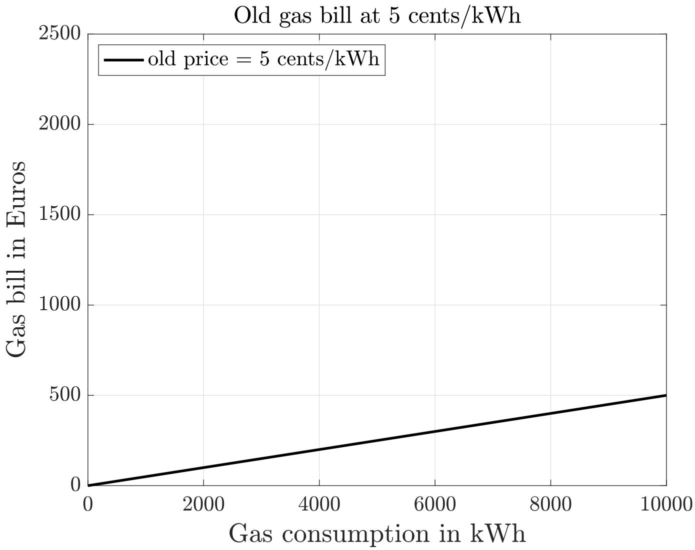
Head of Chancellery Econ Division: “We will never ever be able to determine whether this has a 2% or 10% GDP impact. We are simply trying to take the pragmatic middle course.”

Policies to Support Households

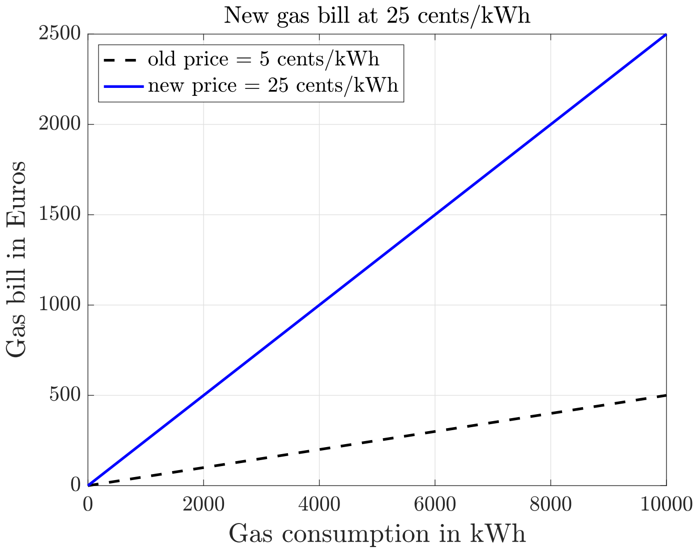
Good and bad policies to support households

- Absolutely crucial to support households, especially economically weaker ones, in the face of rising gas prices
- Should be done by means of transfers that are not directly tied to gas consumption and that preserve incentives for reducing gas demand
- Good policy: German "gas cost break" (commission incl Bayer & Pittel)
  - importantly, not price subsidy / cap but lump-sum transfers
  - compensation based on historical consumption = Bayer's idea featured in "what if" and "how it can be done" papers
  - https://www.bmwk.de/Redaktion/DE/Dossier/Gas-Kommission/zwischenbericht-expert-innen-kommission-gas-warme.html
  - https://www.bmwk.de/Redaktion/DE/Publikationen/Energie/abschlussbericht.html

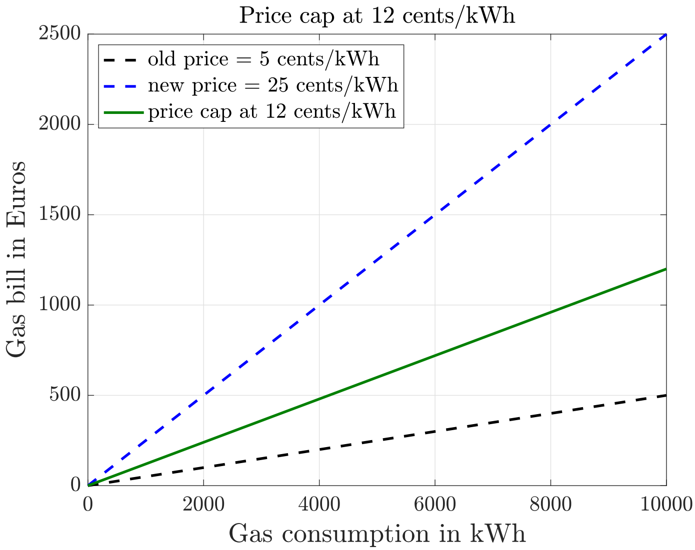
Gas commission: lump sum, not price subsidy or cap



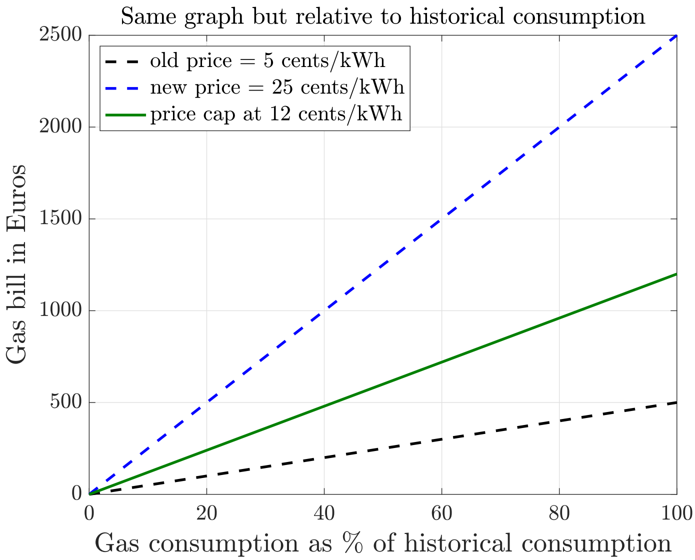
Gas commission: lump sum, not price subsidy or cap



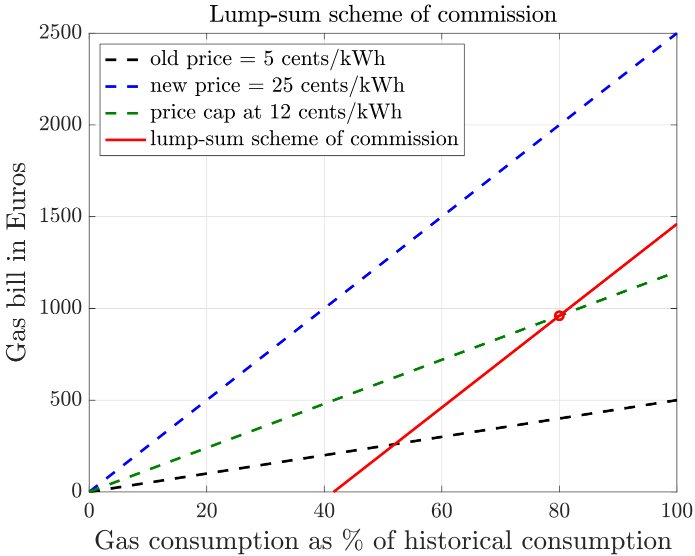
Price cap: diminished incentives for reducing consumption



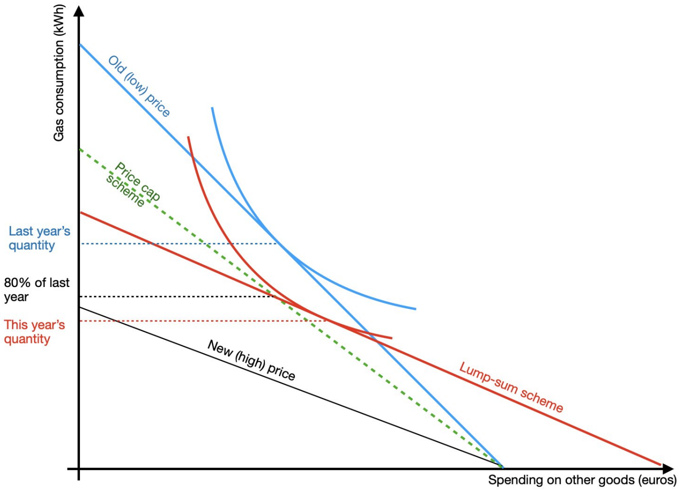
Useful momentarily: as % of previous consumption



Gas commission: lump sum, not price subsidy or cap



Target income effect but leave substitution effect intact



https://twitter.com/maxgoedl/status/1583350372110045185?s=20&t=mNKsTyfX2KRLfpj-Fxrz1g

Key Takeaways

Germany blunted Putin's energy weapon using two margins of adjustment:

- Supply side: gas imports from 3rd countries $\uparrow$ (insurance through trade)
- Demand side: demand $\downarrow$ 20% driven by industry (26%), households (17%)

Key lesson: the power of substitution

- A bit of substitution goes a long way: $\sigma = 0.05$ very different from $\sigma = 0$
- Large number of examples how this works in practice – see appendix

Decoupling from energy-intensive industries rather than cascading effects

In retrospect, even immediate gas import stop (embargo) was feasible

Not implementing sanctions against Russia sooner and more decisively
= major missed opportunity to help avert enormous human suffering in Ukraine