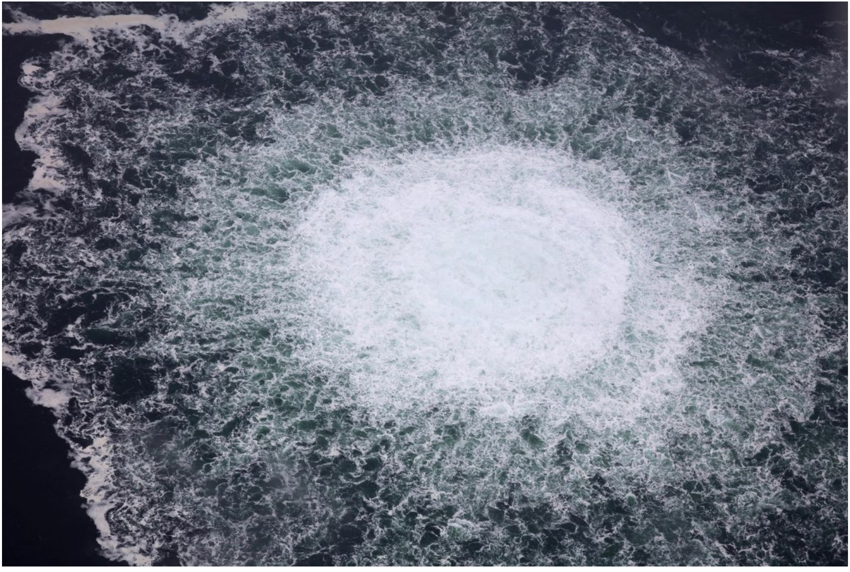
Lecture 3
The West without Russian Gas

Macroeconomics EC2B1

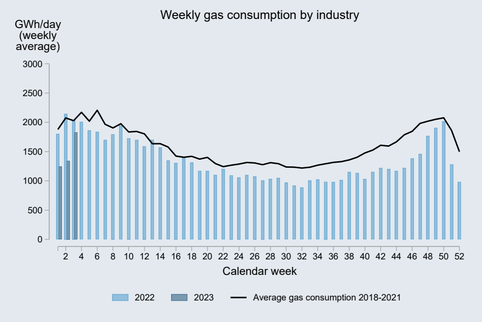
Benjamin Moll

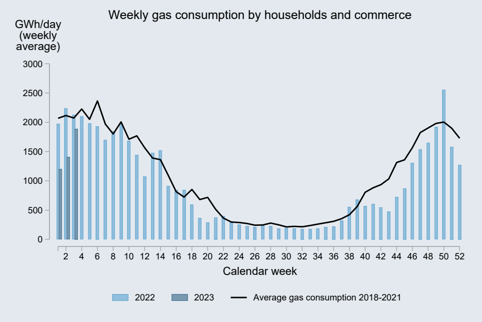
London School of Economics, Lent 2023

What today's lecture is about



Large declines in gas consumption by German industry and households





Roughly: industry 20-30%, households 10-20%, overall 20-25%

Source: https://www.bundesnetzagentur.de/DE/Fachthemen/ElektrizitaetundGas/Versorgungssicherheit/aktuelle_gasversorgung/start.html

Plan

1. Background
2. The CES production function: complementarities and substitution in production
3. What things looked like in March
4. How German industry and households adapted to Putin's energy war
5. Policies to support households in face of high energy prices

Background: huge 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

Bild HOME PAGE NEWS POLITICS REGIONAL ENTERTAINMENT SPORTS FIFA WORLD CUP 2022 STYLE COUNSELOR AUTOMOBILE DIGITAL GAMES DEAL

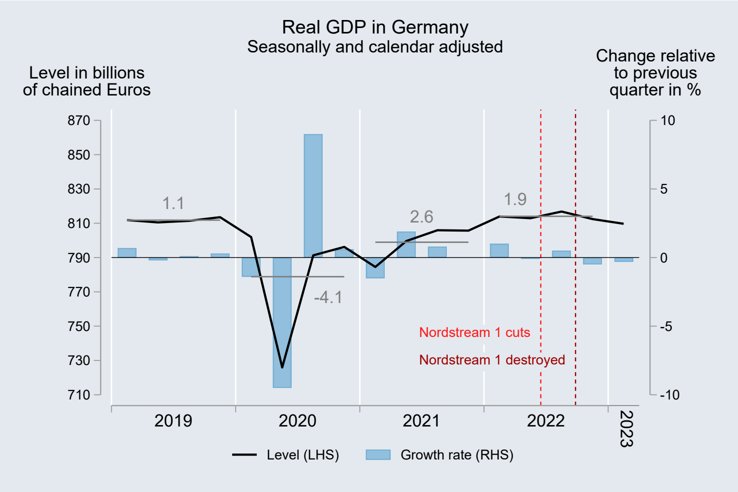
Putin is swimming in our money

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. Two last quarters together: GDP ↓ by 0.8%.

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."
- Itskhoki presentation from minute 6 here
  https://www.aeaweb.org/webcasts/2023/implications-russia-ukraine
- Itskhoki and Guriev op-ed linked here
  https://twitter.com/itskhoki/status/1506554394355019779?cxt=HHwWhsCt5arPregpAAAA
- Guriev op-ed: https://www.project-syndicate.org/commentary/europe-russia-oil-embargo-needs-immediate-price-cap-by-sergei-guriev-2022-06

Lecture draws on three papers – see my website

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

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March 2022

www.econtribute.de

ECONtribute
MARKETS & PUBLIC POLICY

ECONtribute
Policy Brief No. 034

How it can be done

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August 2022

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Focusing on gas storage levels distracts from what really matters: using less gas

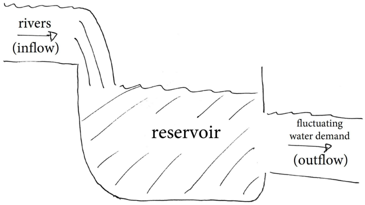
Benjamin Moll
London School of Economics and Political Science*

19 August 2022

1. The Water Reservoir Analogy

Gas storage is like a small water reservoir. This reservoir is fed by some large rivers (the inflows) and balances a large, fluctuating water demand, say for showering and irrigation (the outflows). Figure 1 illustrates such a reservoir.

Figure 1: Gas storage is like a small water reservoir



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/
- Marginal Revolution "Substitutes Are Everywhere" https://marginalrevolution.com/marginalrevolution/2023/05/substitutes-are-everywhere-the-great-german-gas-debate-in-retrospect.html

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

$$Y = A_K K + A_N N$$

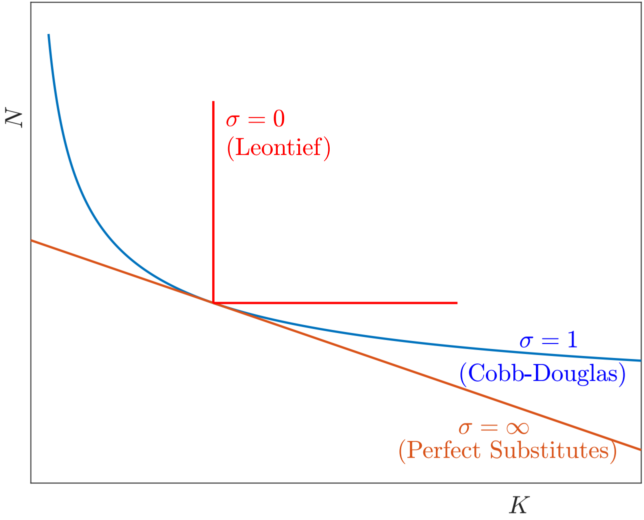
3. Case $\sigma = 0$: perfect complements, fixed proportions, or “Leontief”

$$Y = \min\left\{\frac{A_K K}{\alpha}, \frac{A_N N}{1-\alpha}\right\}$$

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:

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

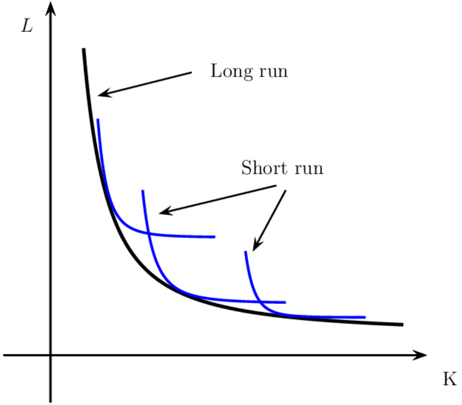
- Using expression from previous slide

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

- 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?

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

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

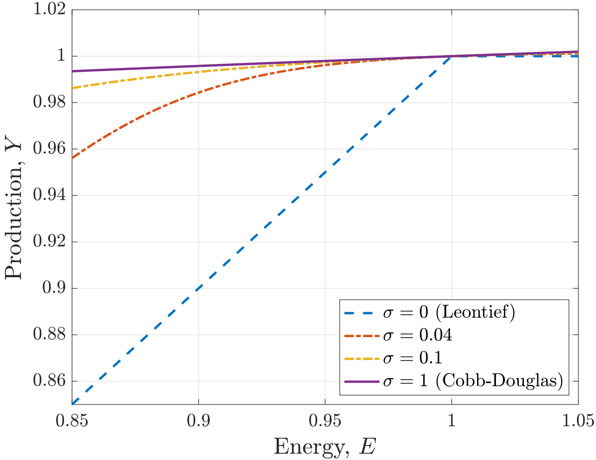
- Consider drop in E, e.g. $\Delta \log E = -30\%$. How much does Y fall?
- Gas has small expenditure share α but also small elasticity σ
- Useful benchmarks:
  1. Cobb-Douglas $\sigma = 1$: $Y = E^{\alpha} X^{1-\alpha}$ with $\alpha = 0.01$

     $$\Delta \log Y = \alpha \Delta \log E = 0.01 \times (-30\%) = -0.3\%$$

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

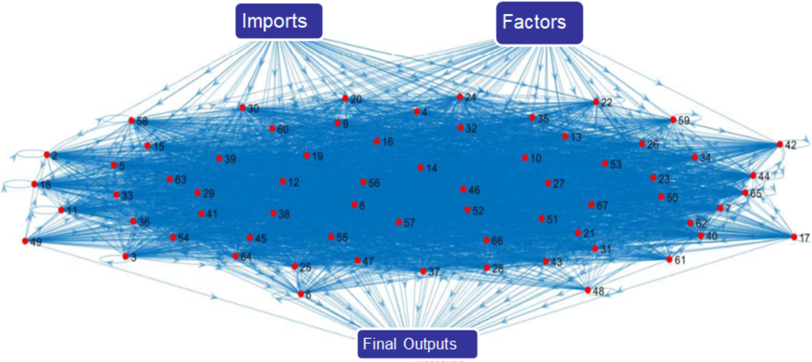
     $$\Delta \log Y = \Delta \log E = -30\% = \text{catastrophe}$$

Output losses for different elasticities of substitution



- Leontief $\Rightarrow$ total production drops one-for-one with gas usage
- Even with very low σ output losses potentially far from Leontief

The worry: “cascading effects” along supply chain



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

What things looked like in March

What things looked like in March

	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)

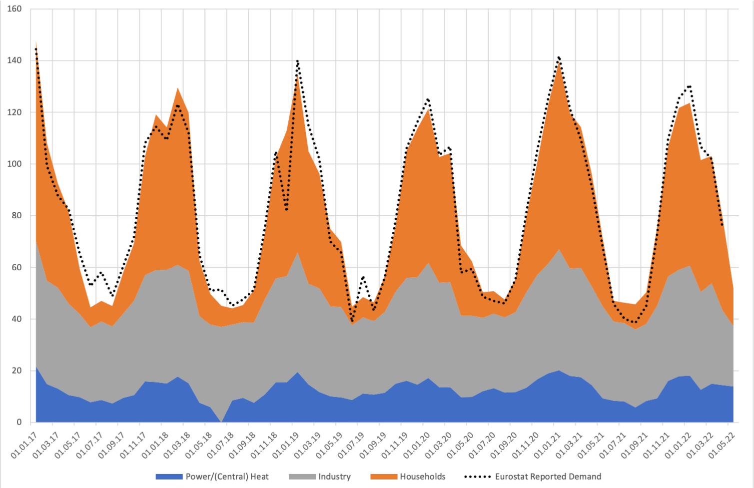
Gas trickier due to pipeline network, limited LNG supplies $\Rightarrow$ focus on gas

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

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

Important: strong seasonality of gas demand

Figure 2: German natural gas demand (TWh)



Objectives and results of March 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 assessment back in March: **GDP decline between 0.5% and 3%**

- Import stop likely somewhat less severe than Covid recession
- = recession in which we were able to provide insurance & socialize costs

July update: key table from “How it can be done” paper

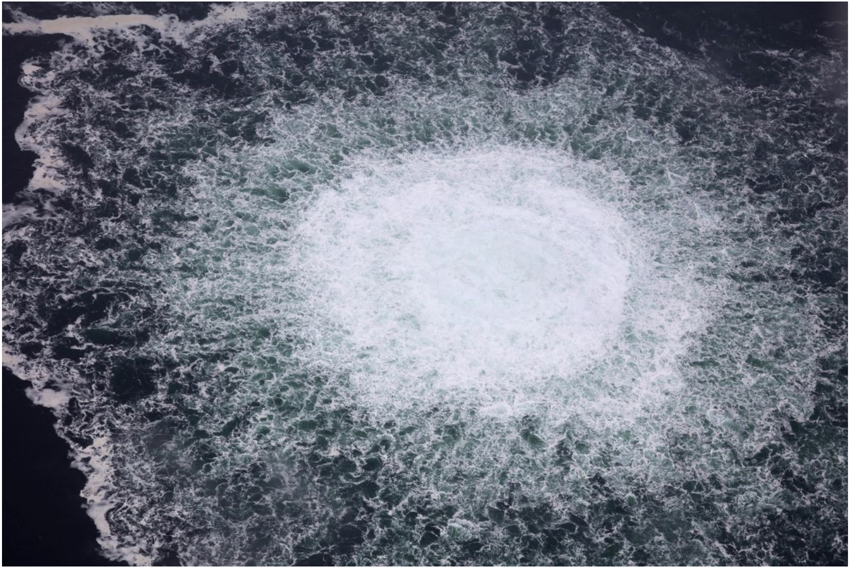
Table 1: Summary of consumption reduction by sector

Demand reduction due to	Reduction August until April (9 months)	Reduction average per month	Relative to consumption in previous years*
Electricity production (Part 1.2.1)	60 TWh	6-7 TWh	45%
Households (Part 1.2.2)	60 TWh	6-7 TWh	16%
Industry (Part 1.2.3)	90 TWh	10 TWh	26%
Sum (= Savings)	210 TWh	23 TWh	25%

* Relative to average consumption in the months of August to the end of April in 2019, 2020, 2021.

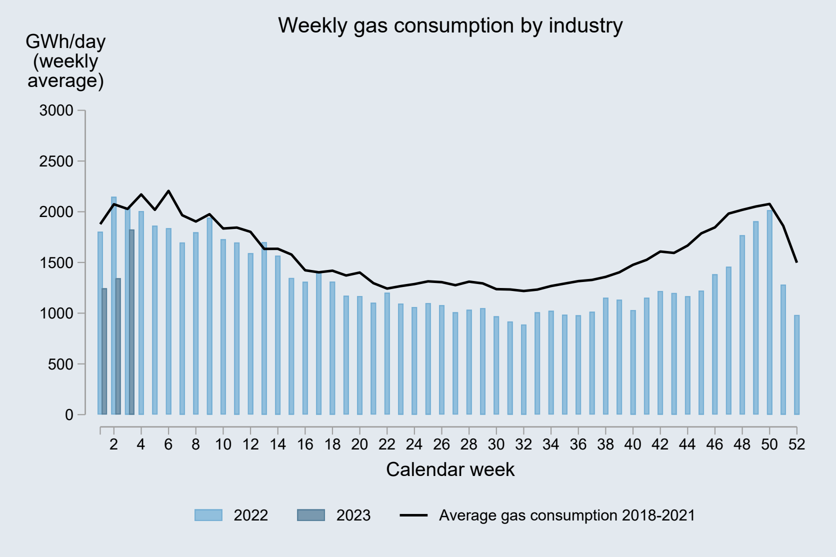
What happened next?

What happened next?

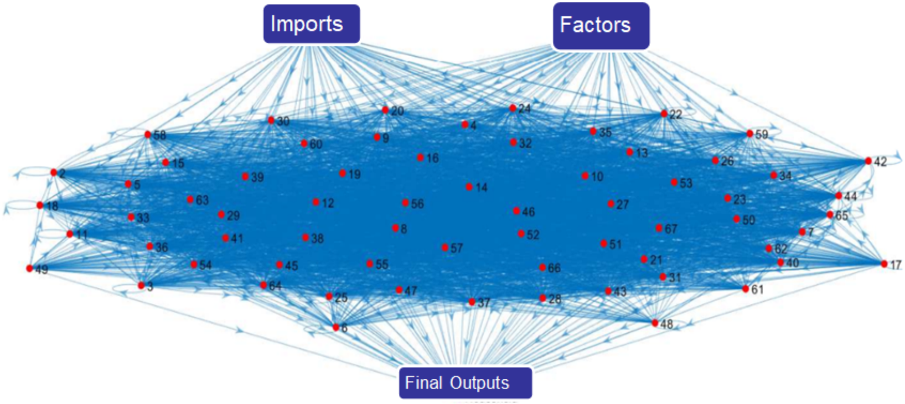


Industry

Gas consumption by industry



The worry: “cascading effects” along supply chain



Key prediction: Leontief ⇒ total production drops one-for-one with gas usage

- if true, should have seen a 20-30% drop in industrial production

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 :
  -30% at a more than 35 fold price

Modeling “cascading effects”: Baqaee-Farhi model

- Input-Output structure (allows for spill-overs and increased damages)

- But: multi country $\Rightarrow$ import energy-intense products instead of energy
  - ammonia
  - basic chemicals
  - raw metals

What did we predict back in March?

	Baqaee-Farhi suff. statistic	Baqaee-Farhi simulation	Simplest model 10% energy ↓	Simplest model 30% gas ↓
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 ⇒ round up headline to 3% (“safety margin”)

Reception by German government

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

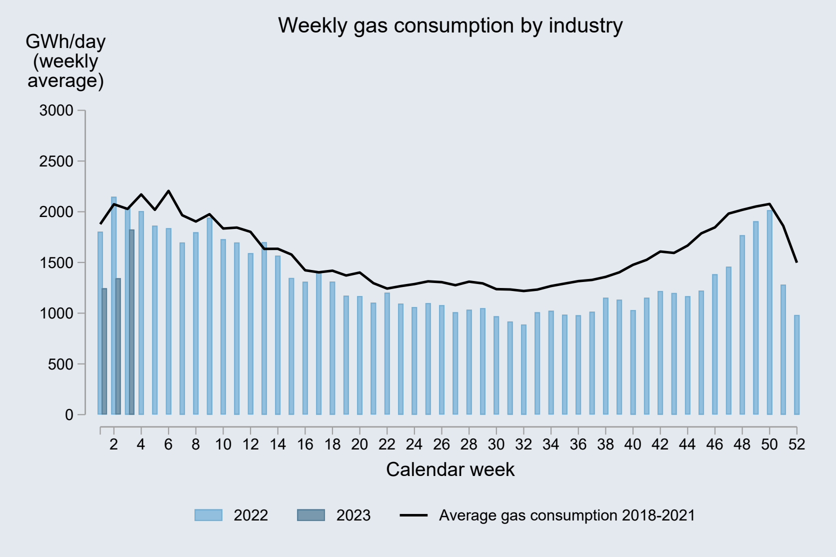
- "But they get it wrong! And it's honestly irresponsible to calculate around with some mathematical models that then don't really work."
- "I don't know absolutely anyone in business who doesn't know for sure that these would be the consequences."

Head of chancellery Wolfgang Schmidt during televised panel

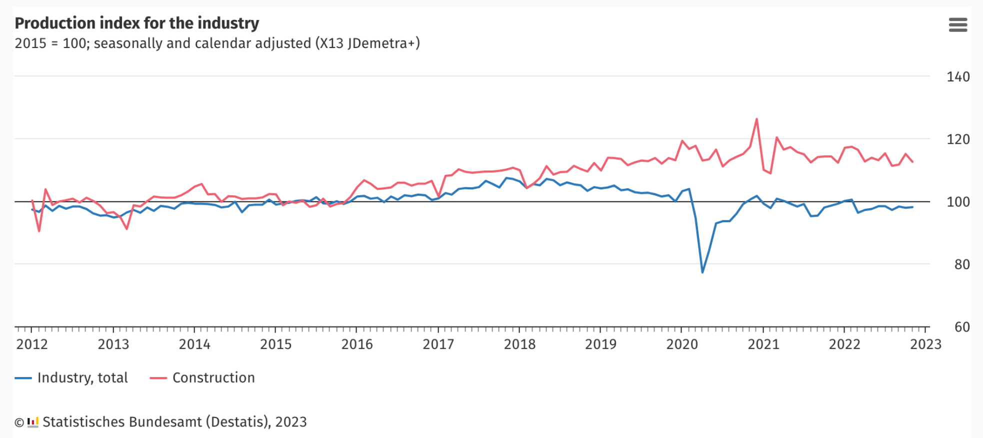
- "The second thing is, what they call elasticity, the question whether you can substitute or whether you cannot substitute gas, oil, and coal."
- "And they always said in that model: 'Yeah there is elasticity, it is not zero.' But that is not true."

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

What has happened so far?

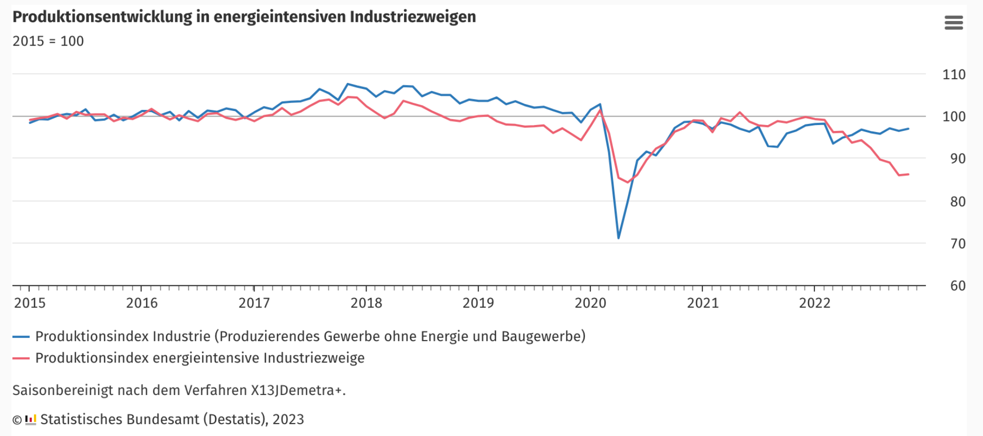


So far industrial production looks nothing like Leontief



Source: https://www.destatis.de/EN/Press/2023/01/PE23_008_421.html

Cuts in energy-intensive sectors but decoupling from rest



Source: https://www.destatis.de/DE/Themen/Branchen-Unternehmen/Industrie-Verarbeitendes-Gewerbe/produktionsindex-energieintensive-branchen.html

How so? Substitution along supply chain

- See examples in this twitter thread
https://twitter.com/ben_moll/status/1548004135294754817?s=20&t=78Fe5LKpYYWtxmfMD-To-w
- ... and Section 2 of "How it can be done"

- **BASF**[20] "in Ludwigshafen can replace [with] heating oil about 15 percent of the natural gas needed for electricity and steam generation." Gas for electricity and steam generation accounted for about half of the gas consumed in Ludwigshafen in 2021.[21] **BASF** is also substituting in ammonia production. The company has reduced the production of ammonia at its Ludwigshafen site because of high gas prices and supplemented it with purchases: "this substitution via the world market [is] relatively easy."[22] The company can substitute some by producing ammonia in the U.S. instead of at the Ludwigshafen site.[23] This is a good example of substitution through imports, which we emphasized in our earlier study, in this case even within the same company. A study by Stiewe et al. (2022) examines German fertilizer production, for which **ammonia** is an important precursor, which in turn is produced with gas. The study concludes "that increased ammonia imports have caused domestic fertilizer production to remain remarkably stable." Consistent with these examples, data from Oxford Economics show that chemical imports have surged in recent months.[24]
- Glass manufacturer **Wiegand Glas** will be able to "heat its furnaces with light fuel oil in the future instead of only natural gas as before."[25]
- Car manufacturer **Mercedes-Benz** sees a reduction potential for natural gas of 50% in Germany "if regional pooling is made possible." "For example, at the Sindelfingen site [...] the paint shop can be operated in emergency mode without gas supply."[26]
- Car manufacturer **Audi** says it can get by with 20 percent less gas. Only about 10 percent of normal gas demand, the company says, is "the minimum amount of gas needed."[27]

… true despite German industry lobby claiming opposite

BDI | *article*

menu Pres

Substance of the industry threatened

After taking part in the cabinet retreat in Meseberg, BDI President Siegfried Russwurm said: "The substance of the industry is under threat."

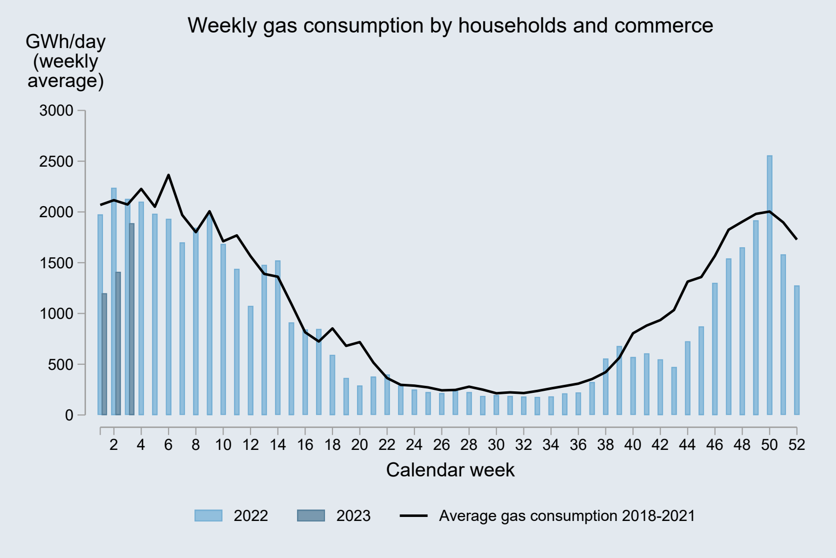
The substance of the industry is under threat. The reduction in gas costs through a reduced VAT rate alone reaches all private households, while industry has to bear the full amount of the gas surcharge as an additional burden.

Gas consumption in industry in July was 21 percent below consumption in the same month of the previous year, but beware of false conclusions: this is often not due to efficiency gains, but to a dramatic drop in production. This is not a success, but an expression of a massive problem.

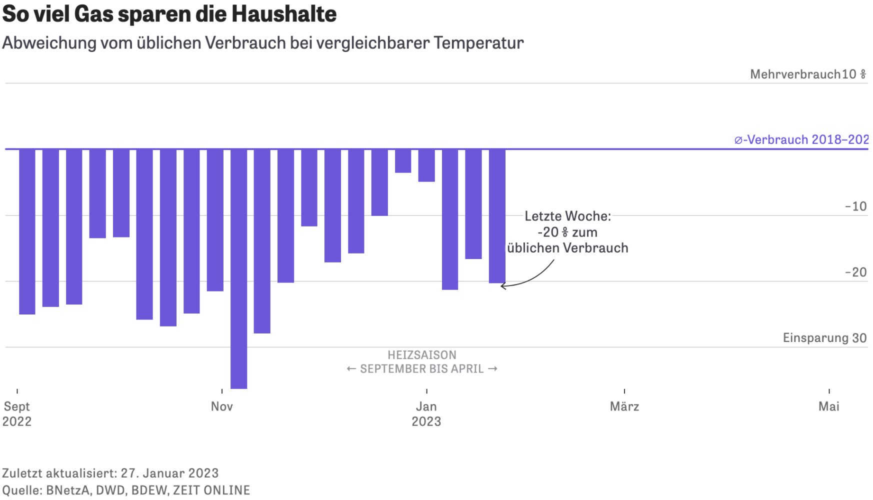
Source: `https://bdi.eu/artikel/news/substanz-der-industrie-bedroht/`

Households

Gas consumption by households: large demand reduction



... true even when controlling for temperature



Prices (Dutch TTF Gas Futures)

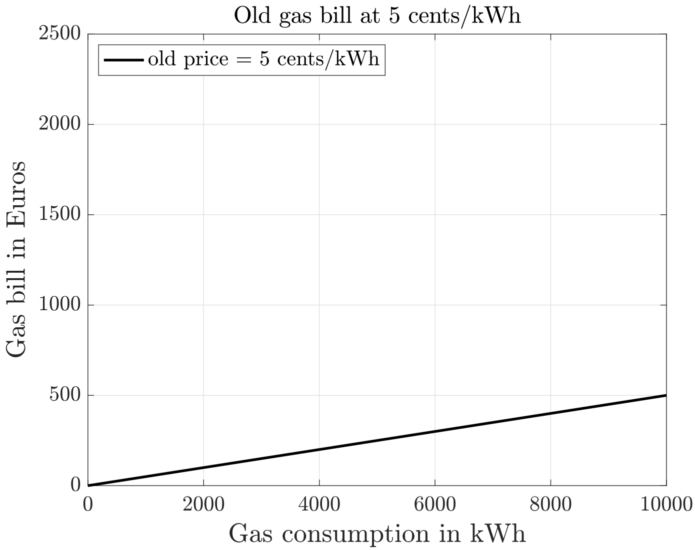
Source: https://www.theice.com/products/27996665/Dutch-TTF-Gas-Futures/data?marketId=5460494&span=2

Policies to Support Households

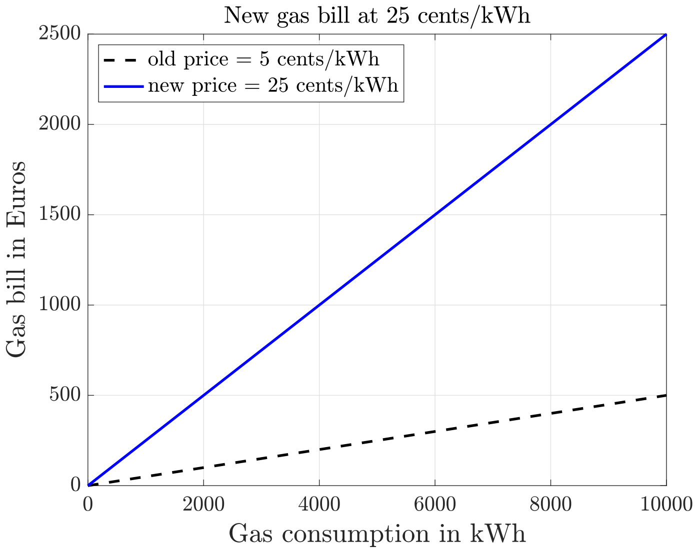
Good and bad policies to support households

- 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

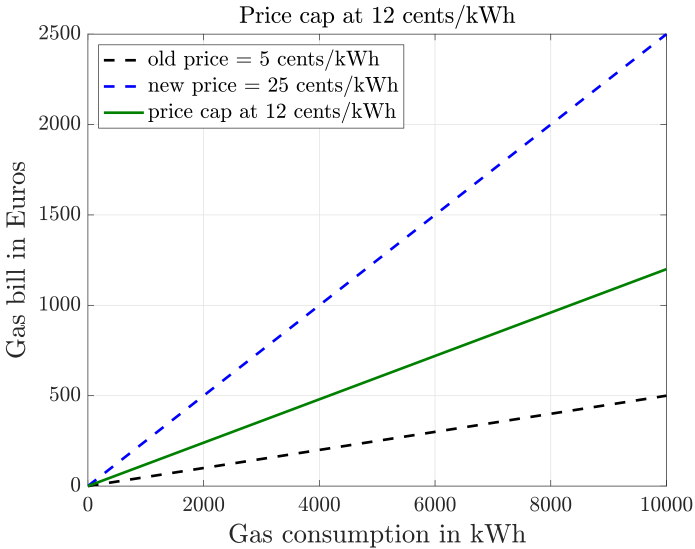
Gas commission: lump sum, not price subsidy or cap



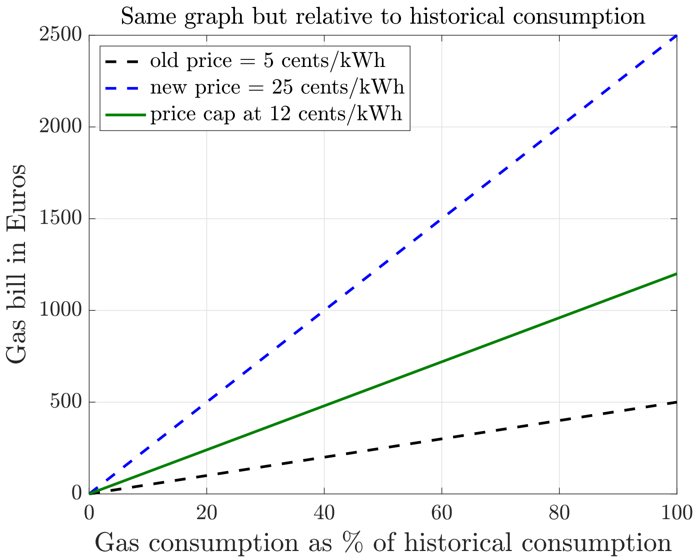
Gas commission: lump sum, not price subsidy or cap



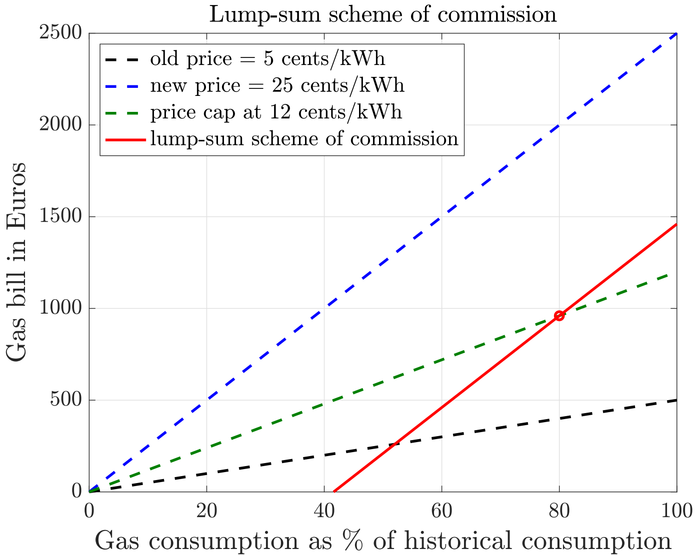
Price cap: diminished incentives for reducing consumption



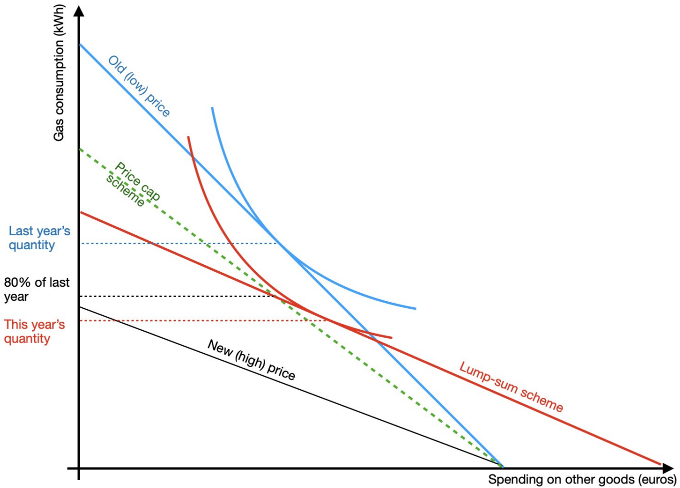
Useful momentarily: as % of previous consumption



Gas commission: lump sum, not price subsidy or cap

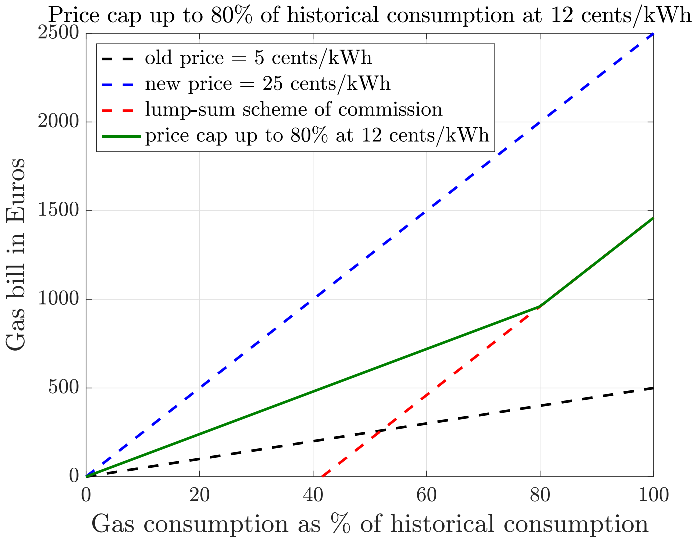


Target income effect but leave substitution effect intact

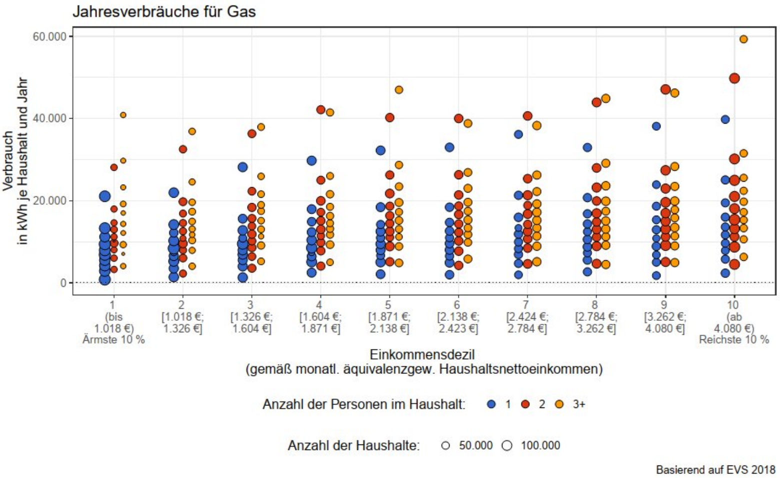


https://twitter.com/maxgoedl/status/1583350372110045185?s=20&t=mNKsTyfX2KRLfpj-Fxrz1g

For comparison: price cap up to 80%



Reason not to target by income



Source: EVS, https://twitter.com/LionHirth/status/1582618195063492608

Challenge: average vs marginal prices

Do Consumers Respond to Marginal or Average Price? Evidence from Nonlinear Electricity Pricing†

By Koichiro Ito*

Nonlinear pricing and taxation complicate economic decisions by creating multiple marginal prices for the same good. This paper provides a framework to uncover consumers' perceived price of nonlinear price schedules. I exploit price variation at spatial discontinuities in electricity service areas, where households in the same city experience substantially different nonlinear pricing. Using household-level panel data from administrative records, I find strong evidence that consumers respond to average price rather than marginal or expected marginal price. This suboptimizing behavior makes nonlinear pricing unsuccessful in achieving its policy goal of energy conservation and critically changes the welfare implications of nonlinear pricing. (*JEL* D12, L11, L94, L98, Q41)

- But information campaign could change this (e.g. Kahn and Wolak, 2013)

Conclusion

- Western economies have adapted remarkably well to Putin's energy war
  - Germany: not even a recession
- Key = demand reduction because full gas storage alone not enough to get through winter without Russian gas (see storage paper)
- New examples of substitution in industry on daily basis but have seen production cuts in some sectors
- In retrospect, even immediate gas import stop (embargo) looks feasible
- Household demand reduction in winter has been critical
  - key: alleviate hardship but without destroying incentives
  - example of good policy: Germany "gas cost break"
  - example of bad policy: UK price cap