Understanding Gas Price Shocks: Elasticities, Volatility, and Macroeconomic Transmission

Daniele Colombo* and Francesco Toni†

IAAE
Torino

June 25-27, 2025

*London Business School
†Université Côte d'Azur, GREDEG; Sant'Anna School of Advanced Studies

Introduction

Natural gas is a key energy source

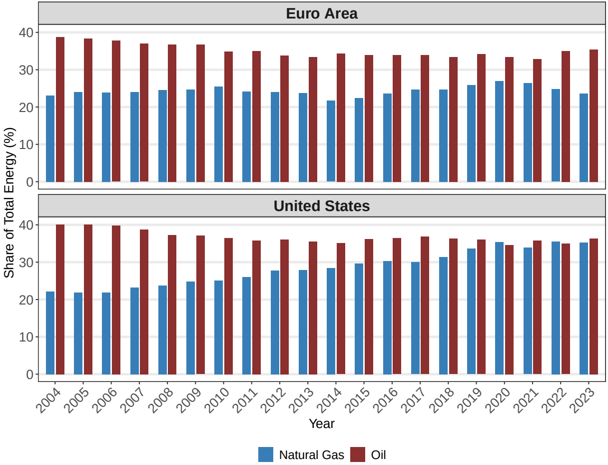


Figure: Natural gas and oil as a share of total energy supplied

Unprecedented natural gas shocks

Recent disruptions in the gas market have sparked renewed interest in the question of how energy prices affect the macroeconomy

Figure: Nord Stream Sabotage, September 2022.
Source: *Reuters*

Figure: Attacks on gas pipelines in Iran, February 2024.
Source: *Fars News*

Research Question

How do gas price shocks propagate to the macroeconomy?

Research Question

How do gas price shocks propagate to the macroeconomy?

To answer, we must address several related issues that have shaped the debate around natural gas, including:

Research Question

How do gas price shocks propagate to the macroeconomy?

To answer, we must address several related issues that have shaped the debate around natural gas, including:

- How quickly can economies adjust through fuel **substitution**? How elastic is gas demand? (Moll et al., 2023)

Research Question

How do gas price shocks propagate to the macroeconomy?

To answer, we must address several related issues that have shaped the debate around natural gas, including:

- How quickly can economies adjust through fuel **substitution**? How elastic is gas demand? (Moll et al., 2023)
- Does the **segmentation of gas markets** shape the transmission of shocks differently compared to the globally integrated crude oil market?

Research Question

How do gas price shocks propagate to the macroeconomy?

To answer, we must address several related issues that have shaped the debate around natural gas, including:

- How quickly can economies adjust through fuel **substitution**? How elastic is gas demand? (Moll et al., 2023)
- Does the **segmentation of gas markets** shape the transmission of shocks differently compared to the globally integrated crude oil market?
- To what extent are gas prices driven by **fundamentals** as opposed to **speculative** dynamics? (Knittel & Pindyck, 2016)

Research Question

How do gas price shocks propagate to the macroeconomy?

To answer, we must address several related issues that have shaped the debate around natural gas, including:

- How quickly can economies adjust through fuel **substitution**? How elastic is gas demand? (Moll et al., 2023)
- Does the **segmentation of gas markets** shape the transmission of shocks differently compared to the globally integrated crude oil market?
- To what extent are gas prices driven by **fundamentals** as opposed to **speculative** dynamics? (Knittel & Pindyck, 2016)
- How much of the recent **inflation surge** can be attributed to gas prices, as opposed to other contributing factors?

Research Question

How do gas price shocks propagate to the macroeconomy?

To answer, we must address several related issues that have shaped the debate around natural gas, including:

- How quickly can economies adjust through fuel **substitution**? How elastic is gas demand? (Moll et al., 2023)
- Does the **segmentation of gas markets** shape the transmission of shocks differently compared to the globally integrated crude oil market?
- To what extent are gas prices driven by **fundamentals** as opposed to **speculative** dynamics? (Knittel & Pindyck, 2016)
- How much of the recent **inflation surge** can be attributed to gas prices, as opposed to other contributing factors?

Key challenge: gas prices are endogenous $\Rightarrow$ construct instruments for gas demand and supply

Main Findings

- **Gas demand in the Euro Area adjusts more slowly** than in the United States.

Main Findings

- **Gas demand in the Euro Area adjusts more slowly** than in the United States.
- Supply shocks are amplified by a transmission channel through **expectations and uncertainty**.

Main Findings

- **Gas demand in the Euro Area adjusts more slowly** than in the United States.
- Supply shocks are amplified by a transmission channel through **expectations and uncertainty**.
- **Inflationary effects are sizable** in the Euro Area, while real activity impacts are limited on aggregate but display strong sectoral heterogeneity.

Main Findings

- **Gas demand in the Euro Area adjusts more slowly** than in the United States.
- Supply shocks are amplified by a transmission channel through **expectations and uncertainty**.
- **Inflationary effects are sizable** in the Euro Area, while real activity impacts are limited on aggregate but display strong sectoral heterogeneity.
- Gas price shocks **increase CO_2 emissions** in the short to medium run, due to substitution toward more carbon-intensive fuels.

Strategy and Road Map

1. Document key **stylized facts** about the natural gas market, relevant for identification

Strategy and Road Map

1. Document key **stylized facts** about the natural gas market, relevant for identification

2. Construct instruments to identify **demand and supply shocks** to the real price of natural gas in the Euro Area and the US:
   - *Demand shocks*: driven by exogenous variation in **temperature**
   - *Supply shocks*: identified via a high-frequency strategy based on **market-relevant news**

Strategy and Road Map

1. Document key **stylized facts** about the natural gas market, relevant for identification

2. Construct instruments to identify **demand and supply shocks** to the real price of natural gas in the Euro Area and the US:
   - *Demand shocks*: driven by exogenous variation in **temperature**
   - *Supply shocks*: identified via a high-frequency strategy based on **market-relevant news**

3. Estimate gas market **elasticities** and uncover key **transmission channels** to the broader macroeconomy.

Strategy and Road Map

1. Document key **stylized facts** about the natural gas market, relevant for identification
2. Construct instruments to identify **demand and supply shocks** to the real price of natural gas in the Euro Area and the US:
   - *Demand shocks*: driven by exogenous variation in **temperature**
   - *Supply shocks*: identified via a high-frequency strategy based on **market-relevant news**
3. Estimate gas market **elasticities** and uncover key **transmission channels** to the broader macroeconomy.
4. Perform a historical decomposition of the post-pandemic **inflation surge**

Related Literature

- **Temperatures and gas prices.** Mu (2007), Nick and Thoenes (2014), and Wang et al. (2019) Dubin and Gamponia (2007), Chen et al. (2023), and Baumeister and Hamilton (2024)
- **Event studies on gas news.** Gay et al. (2009), Bjursell et al. (2010), Halova et al. (2014), and Prokopczuk et al. (2021) Bartelet and Mulder (2020) and Goodell et al. (2023, 2024)
- **Elasticities of gas demand and supply.** Wiggins and Etienne (2017), Hou and Nguyen (2018), Nguyen and Okimoto (2019), and Rubaszek and Uddin (2020) Rubaszek et al. (2021), Casoli et al. (2022), and Farag (2024)
- **Macroeconomic effects of oil price shocks.** Hamilton (2003), Kilian (2009), Caldara et al. (2019), Zhou (2020), Känzig (2021), and Baumeister and Hamilton (2023)
- **Macroeconomic effects of gas shocks.** Bachmann et al. (2022), Albrizio et al. (2023), Moll et al. (2023), and Di Bella et al. (2024) Boeck et al. (2023), Adolfsen et al. (2024), and Alessandri and Gazzani (2025)
- **Energy pass-through.** Gao et al. (2014), López (2018), Känzig (2021), Kilian and Zhou (2022), Boeck et al. (2023), Joussier et al. (2023), and Adolfsen et al. (2024)

Gas markets

Euro Area and United States Gas Markets

1. **Demand composition** Energy mix Composition of demand

   Natural gas accounts for about 1/4 of all energy supplied in both regions, mainly for power generation, heating, and industry. Heating demand large ($\approx 1/3$ of total) and highly temperature-sensitive.

Euro Area and United States Gas Markets

1. **Demand composition** Energy mix Composition of demand

   Natural gas accounts for about 1/4 of all energy supplied in both regions, mainly for power generation, heating, and industry. Heating demand large ($\approx 1/3$ of total) and highly temperature-sensitive.

   $\Rightarrow$ Can exploit temperature shocks as a source of exogenous variation in demand

Euro Area and United States Gas Markets

1. **Demand composition** Energy mix Composition of demand

   Natural gas accounts for about 1/4 of all energy supplied in both regions, mainly for power generation, heating, and industry. Heating demand large ($\approx 1/3$ of total) and highly temperature-sensitive.

   $\Rightarrow$ Can exploit temperature shocks as a source of exogenous variation in demand

2. **Supply composition** Composition of supply
   - **Euro Area:** 90% import-dependent by 2019. Reliance on a few key suppliers makes prices highly sensitive to realized or expected disruptions.
   - **United States:** World's largest producer, with output growth driven by shale extraction. Exports LNG mainly to Europe and Asia. Prices less volatile but react to domestic disruptions.

Euro Area and United States Gas Markets

1. **Demand composition** Energy mix Composition of demand

   Natural gas accounts for about 1/4 of all energy supplied in both regions, mainly for power generation, heating, and industry. Heating demand large ($\approx 1/3$ of total) and highly temperature-sensitive.

   $\Rightarrow$ Can exploit temperature shocks as a source of exogenous variation in demand

2. **Supply composition** Composition of supply

   - **Euro Area:** 90% import-dependent by 2019. Reliance on a few key suppliers makes prices highly sensitive to realized or expected disruptions.
   - **United States:** World's largest producer, with output growth driven by shale extraction. Exports LNG mainly to Europe and Asia. Prices less volatile but react to domestic disruptions.

   $\Rightarrow$ Disruptions can be exploited via HF identification to study the effects of gas supply price shocks

EA and US Gas Markets (II)

3. **Integration** Unlike oil, the global gas market remains fragmented due to supply-side constraints and limited fungibility (e.g., reliance on pipelines, infrastructure capacity). Despite growing LNG trade, regional price differences persist. *In August 2022, EA gas prices surged 14-fold, while US prices remained much lower (IMF Blog, 2023)*

EA and US Gas Markets (II)

3. **Integration** Unlike oil, the global gas market remains fragmented due to supply-side constraints and limited fungibility (e.g., reliance on pipelines, infrastructure capacity). Despite growing LNG trade, regional price differences persist. *In August 2022, EA gas prices surged 14-fold, while US prices remained much lower (IMF Blog, 2023)*
   $\Rightarrow$ Requires region-specific analysis of gas price shocks

EA and US Gas Markets (II)

3. **Integration** Unlike oil, the global gas market remains fragmented due to supply-side constraints and limited fungibility (e.g., reliance on pipelines, infrastructure capacity). Despite growing LNG trade, regional price differences persist. *In August 2022, EA gas prices surged 14-fold, while US prices remained much lower (IMF Blog, 2023)*
   $\Rightarrow$ Requires region-specific analysis of gas price shocks

4. **Market Development** The US gas market is more mature, with HH as the benchmark since the 1990s. In Europe, a unified market is more recent, but the TTF has emerged as the reference price (Heather, 2021) TTF as European benchmark

EA and US Gas Markets (II)

3. **Integration** Unlike oil, the global gas market remains fragmented due to supply-side constraints and limited fungibility (e.g., reliance on pipelines, infrastructure capacity). Despite growing LNG trade, regional price differences persist. *In August 2022, EA gas prices surged 14-fold, while US prices remained much lower (IMF Blog, 2023)*
   ⇒ Requires region-specific analysis of gas price shocks

4. **Market Development** The US gas market is more mature, with HH as the benchmark since the 1990s. In Europe, a unified market is more recent, but the TTF has emerged as the reference price (Heather, 2021) TTF as European benchmark
   ⇒ TTF (EA) and HH (US) are the relevant prices to look at

Identification

Gas demand shock

- Residential and commercial sectors consume over 45% (EA) 35% (US) of natural gas, mainly for heating.
- **Exogenous variation:** unexpected demand of gas for heating due to anomalous temperatures.
- Unlike average seasonal temperature fluctuations, a large deviation from the average is not anticipated by economic agents.
- Can construct a *temperature shock* that is inversely correlated with the price of natural gas, and can be used as an instrument for gas-specific demand.

Constructing an instrument for gas demand

Data:

- ERA5 grid-level temperature data
- GADM spatial data
- Night lights (Li et al., 2020) or gridded population (Doxsey-Whitfield et al., 2015) to proxy economic activity

Constructing an instrument for gas demand

Data:

- ERA5 grid-level temperature data
- GADM spatial data
- Night lights (Li et al., 2020) or gridded population (Doxsey-Whitfield et al., 2015) to proxy economic activity

Daily temperature series: grid-level daily temperatures aggregated at the country level, weighting each grid by economic activity. European temperature series obtained by averaging each country weighting by gas consumption

Constructing an instrument for gas demand

Data:

- ERA5 grid-level temperature data
- GADM spatial data
- Night lights (Li et al., 2020) or gridded population (Doxsey-Whitfield et al., 2015) to proxy economic activity

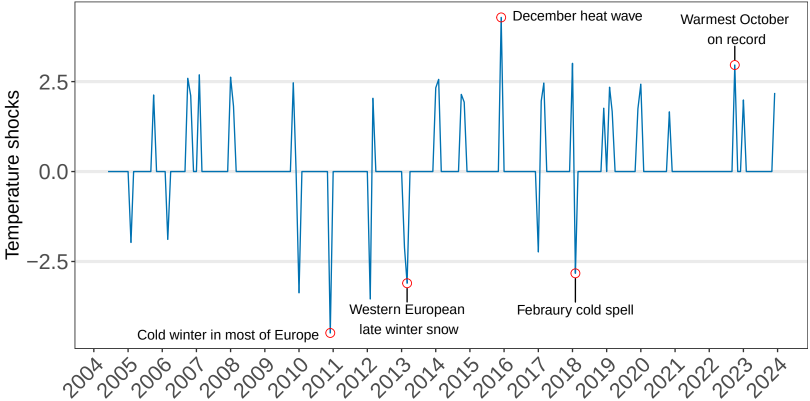
Daily temperature series: grid-level daily temperatures aggregated at the country level, weighting each grid by economic activity. European temperature series obtained by averaging each country weighting by gas consumption

Temperature shock:

1. Take deviations from average temperatures by subtracting to daily average temperatures of each calendar day the mean monthly average temperature (across all years in the sample)
2. Aggregate to monthly by taking averages across time
3. Threshold the series (below 1sd) to reduce noise
4. Exclude summer months (April to September) due to ambiguous correlation. This improves instrument relevance but does not materially affect results (further discussed in sensitivity analysis)

Gas demand shock

Deviations from *normal* temperatures impact heating demand, which, in turn, influences gas prices. US demand instrument



Constructing an instrument for gas supply

Exogenous variation:

High-frequency approach, intra-day variation in gas prices following market-relevant news

Constructing an instrument for gas supply

Exogenous variation:
High-frequency approach, intra-day variation in gas prices following market-relevant news

Data:

- 72 exogenous gas supply news (27 in the US case) for the period 2004-2023 from Reuters and Factiva
- Dutch TTF gas future settlement prices (Henry Hub for the US) from Datastream

Constructing an instrument for gas supply

Exogenous variation:
High-frequency approach, intra-day variation in gas prices following market-relevant news

Data:

- 72 exogenous gas supply news (27 in the US case) for the period 2004-2023 from Reuters and Factiva
- Dutch TTF gas future settlement prices (Henry Hub for the US) from Datastream

Constructing the gas supply surprises:

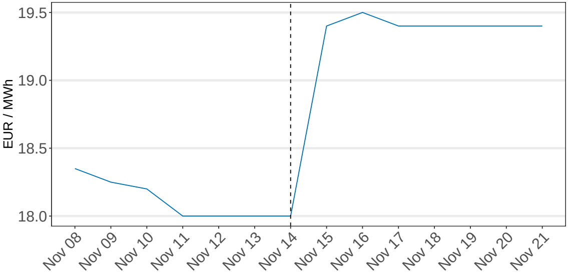
1. Compute gas supply surprises:

$$GasSurprise_d^h = F_d^h - F_{d-1}^h$$

where F_d^h is the log settlement price of the h-months ahead gas futures contract at date d

2. Take the first principal component of the gas surprises spanning the first year of the gas futures term structure
3. Aggregate to monthly by summing daily surprises

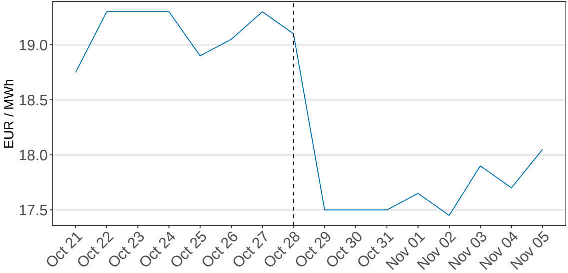
News example #1: Unexpected supply drop from Norway



Drop in Langeled flows, **2010M11**

- On November 15, 2010, Norwegian gas flows through the Langeled pipeline experienced an unexpected drop due to unforeseen technical issues
- The TTF spot price rose by about 8%

News example #2: UK expands LNG capacity



UK expands LNG capacity, **2010M10**

- On October 28, 2010, National Grid announced LNG capacity expansion at the Isle of Grain
- The TTF spot price fell by about 9%

Gas supply news

Gas supply shock

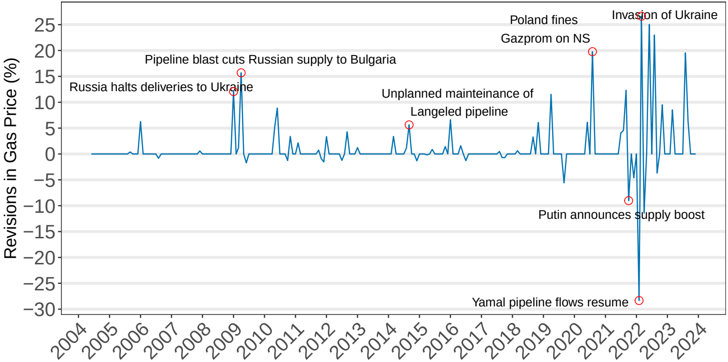


Figure: Gas price surprises series constructed from changes in gas futures prices around announcements (principal component spanning first year of TTF gas futures term structure).

- Similarly, construct a surprises series for the US US surprises series

Assessing the instruments: correlation with other shocks

Source	Shock	Europe supply		Europe demand		US supply		US demand		n
		ρ	p-value	ρ	p-value	ρ	p-value	ρ	p-value	
Kilian (2009)**	Oil supply	-0.02	0.79	-0.01	0.87	0.04	0.56	0.04	0.52	240
Kilian (2009)**	Aggregate demand	-0.07	0.31	0.01	0.83	0.02	0.77	-0.07	0.29	240
Kilian (2009)**	Oil-specific demand	0.05	0.42	-0.08	0.25	0.01	0.84	-0.05	0.44	240
Baumeister and Hamilton (2019)*	Oil supply	-0.06	0.36	0.03	0.67	-0.04	0.57	0.02	0.73	240
Baumeister and Hamilton (2019)*	Oil demand	0.00	0.99	-0.05	0.45	0.09	0.16	-0.04	0.51	240
Känzig (2021)**	Oil supply expectations	-0.08	0.20	-0.03	0.70	0.02	0.82	0.12	0.07	240
Caldara et al. (2019)*	CCI oil supply	0.02	0.77	0.01	0.87	0.01	0.87	0.01	0.88	144
Miranda-Agrippino and Nenova (2022)	Target monetary policy (EA)	0.07	0.33	0.03	0.63	-0.05	0.51	0.02	0.73	207
Jarociński and Karadi (2020)	Information median monetary policy (EA)	-0.01	0.89	0.07	0.30	0.02	0.70	0.08	0.24	234
Gertler and Karadi (2015)	FF4 monetary policy (US)	-0.13	0.20	-0.14	0.15	-0.01	0.97	0.02	0.87	102
Miranda-Agrippino and Nenova (2022)	Target monetary policy (US)	0.02	0.74	-0.02	0.75	0.01	0.88	0.02	0.82	186
Bloom (2009)**	VXO-VIX	-0.03	0.70	0.03	0.60	0.00	0.99	0.06	0.38	240
Gilchrist and Zakrajšek (2012)*	Corporate credit spread index	0.05	0.49	-0.05	0.43	-0.04	0.60	-0.06	0.33	240
Caldara and Iacoviello (2022)*	Geopolitical risk index	0.05	0.40	0.05	0.46	0.04	0.51	0.06	0.38	240

Table: Correlation with other shocks

- The supply instrument is informationally-robust when controlling for these and other potential confounding factors Info-robust
- Show that shock is not predictable via Granger's tests

* Extended by the original authors wrt the original paper sample.
** Extended by us.

Estimation

Econometric Framework and Identification

- Structural VAR

$$\begin{aligned}\mathbf{y}_t &= \mathbf{B}_0^{-1}\mathbf{B}_1\mathbf{y}_{t-1} + \cdots + \mathbf{B}_0^{-1}\mathbf{B}_p\mathbf{y}_{t-p} + \mathbf{B}_0^{-1}\mathbf{w}_t \\ &= \mathbf{A}_1\mathbf{y}_{t-1} + \cdots + \mathbf{A}_p\mathbf{y}_{t-p} + \mathbf{u}_t,\end{aligned}$$

- Identification based on external instruments (*proxy-VAR*)
- External instrument: variable correlated with the shock of interest but uncorrelated with other shocks

$$\mathbb{E}[z_t w_{1,t}] \neq \mathbf{0}$$

$$\mathbb{E}[z_t \mathbf{w}_{2:K,t}] = \mathbf{0}$$

- Since have two separate instruments can identify both shocks from price variable. Ensures exclusion restriction not violated even when prices could move independently of quantities.

Different from classic oil VARs that identify supply shock from residuals of quantity variable and demand shock from residual price variable, by imposing zero, sign or magnitude restrictions (Kilian & Murphy, 2014; Baumeister & Hamilton, 2019).

Estimating demand and supply elasticities

Consider dynamic demand and supply equations of the form:

$$q_t^d = \alpha_{qp}^d p_t + \mathbf{x}'\boldsymbol{\beta}_d + w_t^d,$$
$$q_t^s = \alpha_{qp}^s p_t + \mathbf{x}'\boldsymbol{\beta}_s + w_t^s,$$

As shown by Baumeister and Hamilton (2024), the elasticities α_{qp}^d and α_{qp}^s-interpreted as the change in demand and supply quantities following a 1% increase in the price of natural gas, *holding all other variables constant*-are elements of the matrix $\mathbf{B}_0$, not of $\mathbf{B}_0^{-1}$.

Nevertheless, they can still be recovered even when only a single column of $\mathbf{B}_0^{-1}$ is identified:

$$\mathbf{b}_{0,j}' = \left[(\mathbf{B}_0^{-1})_{:,j}\right]' \boldsymbol{\Sigma_u}^{-1}$$

Bayesian Estimation

- Bayesian VAR with Minnesota, sum-of-coefficients and dummy-initial-observations priors (Doan et al., 1984; Sims, 1993; Sims & Zha, 1998).

- Following Kadiyala and Karlsson (1997), we specify conjugate prior distributions and implement them via dummy observations (Bańbura et al., 2007):

$$\text{vec}(\beta) \mid \Psi \sim \mathcal{N}(\text{vec}(\beta_0), \Psi \otimes \Omega_0) \quad \text{and} \quad \Psi \sim \mathcal{IW}(S_0, \alpha_0)$$

- The informativeness of the priors is determined using the hierarchical approach of Giannone et al. (2015), which selects the hyperparameters by maximizing the marginal likelihood of the data.

Results

Main Results

1. **Historical decomposition** of the real price of natural gas: identified demand and supply shocks account for much of the observed variation.
2. **Estimates of demand and supply elasticities** for natural gas in both EA and US.
3. **Propagation of shocks** via impulse response functions in both EA and US.
4. **EA focus**: sectoral analysis of price and quantity responses, and historical decomposition of inflation.

Gas shocks contribution to real gas price series

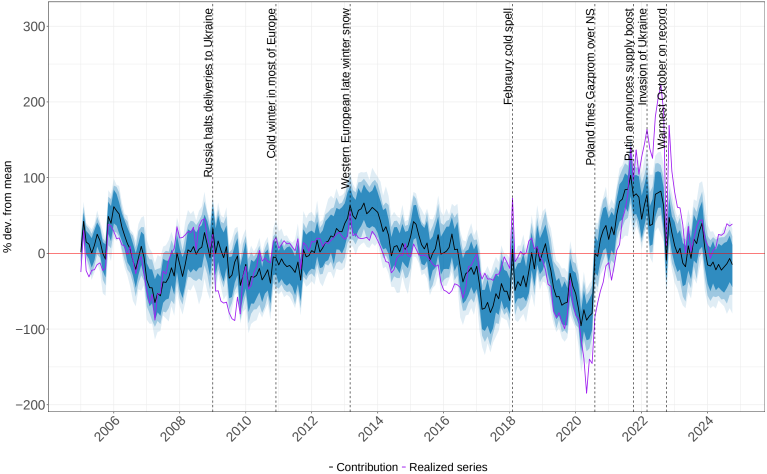
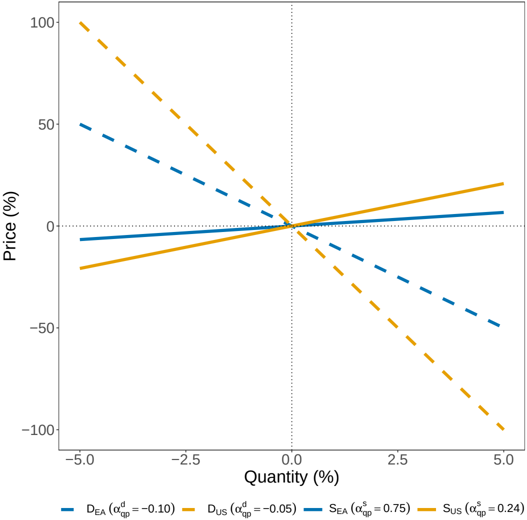


Figure: EA: Historical decomposition of the real price of gas. **2009M1** Russian halt of all gas deliveries to Ukraine; **2010M10** abnormally cold winter in Europe; **2013M3** late snow in Western Europe; **2018M2** cold spell; **2020M8** Poland fines Gazprom; **2021M10** Putin announces gas supply increases; **2023M3** supply fears following the invasion of Ukraine; Warmest October on record in **2023M10**.

Estimated elasticities of gas demand and supply



- **Euro Area**: Demand elasticity $= -0.10$, Supply elasticity $= 0.75$
- **United States**: Demand elasticity $= -0.05$, Supply elasticity $= 0.24$

Comparison with previous estimates

Our estimates:

- **Euro Area**: Demand elasticity $= -0.10$, Supply elasticity $= 0.75$
- **United States**: Demand elasticity $= -0.05$, Supply elasticity $= 0.24$

Note, we define
gas demand $=$ consumption $+$ exports
gas supply $=$ domestic production $+$ imports

Previous estimates:

Authors (year)	Region	Demand Quantity	Demand Estimate	Supply Quantity	Supply Estimate	Identification	Sample period
Casoli et al. (2022)	Europe	Consumption	-0.47	Production	0.34	Priors and sign restrictions*	2010M1–2022M7
Wiggins and Etienne (2017)	United States	Production	[-0.08; -0.18]**	Production	[0.15; 0.3]**	Sign restrictions	1976Q1–2015Q2
Rubaszek et al. (2021)	United States	Consumption	-0.42	Production	0.01	Priors and sign restrictions*	1978Q1–2020Q3
Farag (2024)	United States	Consumption	-0.177	Production + Imports	0.019	Priors and sign restrictions*	1992M1–2023M10

†* Baumeister and Hamilton (2019) identification strategy.
†** Wiggins and Etienne (2017) reports a range from a time-varying parameter model.

FEVD of gas price by shock type

Region	**Shock**	$h = 1$	$h = 6$	$h = 12$	$h = 18$	$h = 24$
Euro Area	Gas supply	0.55	0.49	0.48	0.49	0.49
	Gas demand	0.25	0.22	0.24	0.24	0.24
United States	Gas supply	0.69	0.41	0.30	0.29	0.29
	Gas demand	0.12	0.24	0.25	0.24	0.23

Note: Forecast error variance decomposition of gas prices. Values represent percentage contributions of identified supply and demand shocks.

As demand is more rigid, supply shocks explain a larger share of variation in gas prices, and vice versa.

Baseline responses: gas demand shock

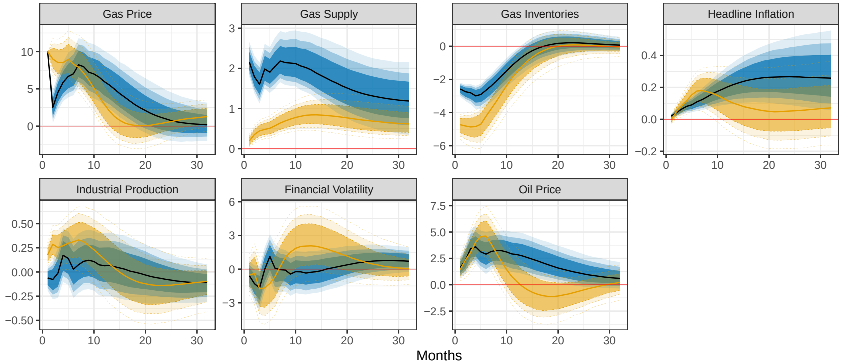


Figure: Full responses to a gas demand shock, baseline specification. Normalised to a one-time 10% increase in the real price of natural gas.

First stage regressions: EA F: 30.13, Robust F: 12.56; US F: 10.00, Robust F: 11.04.

Baseline responses: gas supply shock

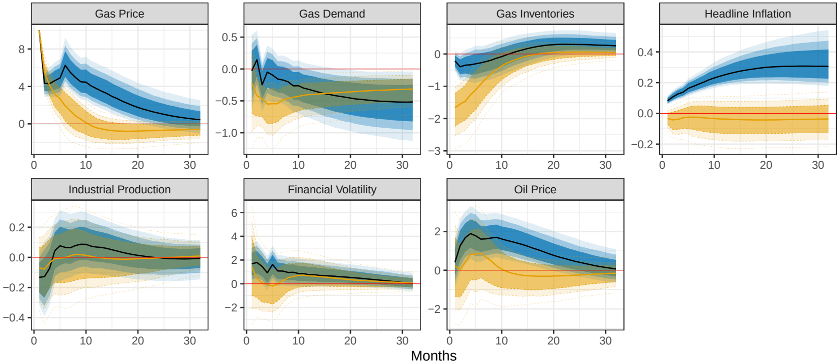
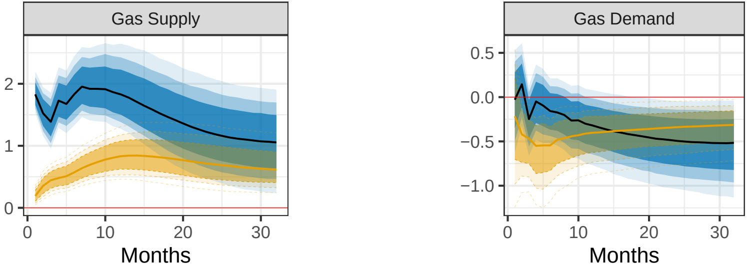


Figure: Full responses to a gas supply shock, baseline specification. Normalised to a one-time 10% increase in the real price of natural gas.

First stage regressions: EA F: 16.74, Robust F: 10.90; US F: 11.33, Robust F: 22.25.

Responses of gas quantities: supply and demand



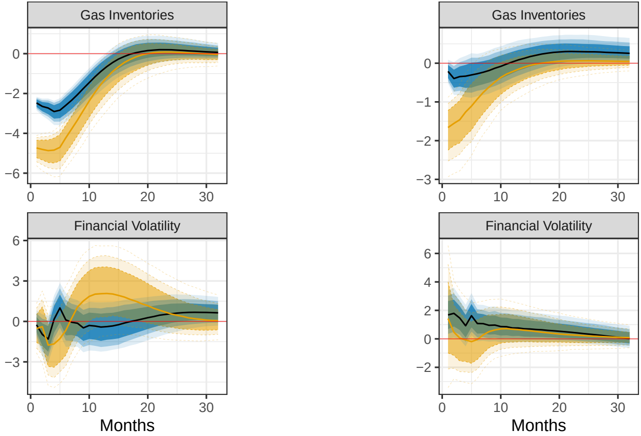
Gas Demand Shock

Gas Supply Shock

- **Supply:**
  - EA large response on impact: quick import adjustment
  - US peak at 1% after 1 year: slower production response
- **Demand:**
  - US adjusts faster (interfuel substitution in power generation, spot price indexation, specific levies)
  - Long-run adjustment ≈ -0.05 in both regions

Drivers of supply responses Composition of demand Interfuel substitution

Inventories, volatility, and uncertainty channel



Gas Demand Shock   Gas Supply Shock

- Evidence points to precautionary demand mechanism in the EA (Kilian & Murphy, 2014; Känzig, 2021)

Inventories, volatility, and uncertainty channel (EA)

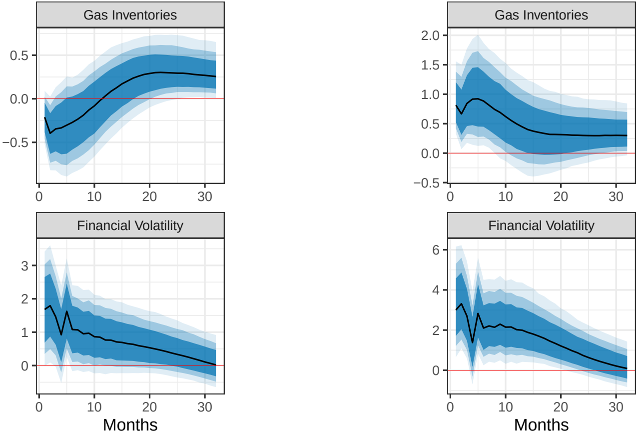
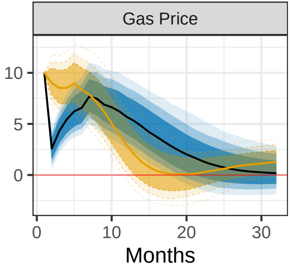
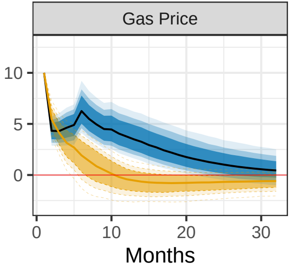


Figure: Inventories and financial volatility responses to a gas supply shock: all events (left panel), only expected events (right panel)

Gas price shock persistence



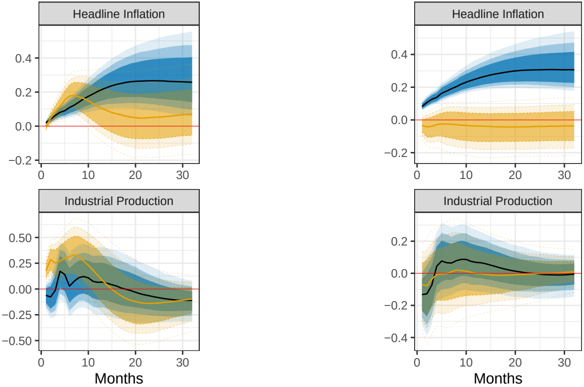
Gas Demand Shock



Gas Supply Shock

- Persistence reflects adjustments in inventories and consumption to offset the shocks
- **EA more vulnerable to supply shocks**: Inventories remain unresponsive due to precautionary demand under heightened uncertainty, while slow demand adjustment limits the system's capacity to absorb shocks

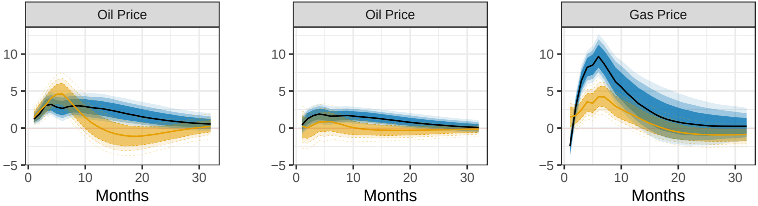
Macroeconomic impact



Gas Demand Shock   Gas Supply Shock

- In EA both shocks largely inflationary, with limited real effects (but more pronounced in Germany (Moll et al., 2023))
- In the US only modest effect of demand shocks. Real effect due to production in energy sector

Gas and oil markets interrelation

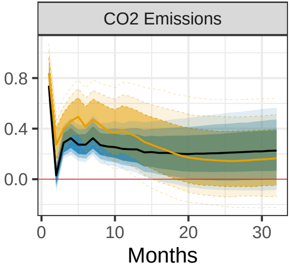


Gas demand shock | Gas supply shock | Oil supply shock

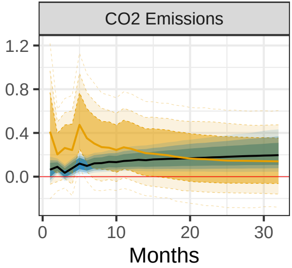
(Identified as in Känzig (2021))

- Gas and oil are imperfect substitutes
- Increasing LNG trade but constrained US export capacity (Albrizio et al., 2023) has led to higher integration in European and Asian markets
  ⇒ EA shocks impact global oil more than US shocks

Environmental impact of gas price shocks



Gas Demand Shock



Gas Supply Shock

Figure: CO_2 emissions

- **Demand shocks** increase emissions on impact by $\approx 0.8\%$: more carbon-intensive fuels are burned to satisfy demand.
- **Supply shocks** increase up to 0.2% in the EA and 0.4% in the US: gas becomes more expensive and is substituted by higher-emission fuels. Interfuel substitution

Transmission to broader energy prices (EA)

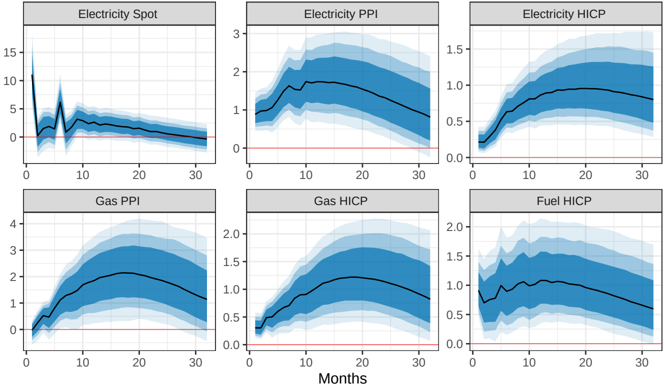


Figure: Energy prices responses to a gas supply shock

- 1-to-1 pass-through to electricity spot (marginal pricing)
- Firms face stronger price hikes than consumers (PPI response larger than HICP)
- Fuel consumer prices adjust quickly to spot market changes, while gas and power prices respond more slowly due to long-term contracts and regulation

Gas pass-through to consumer prices (EA)

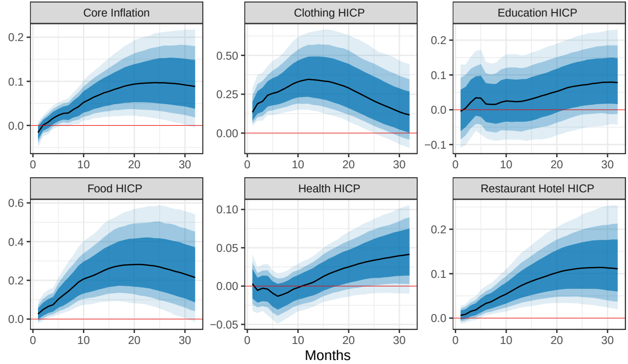


Figure: Core and HICP 2-digit sectors responses to a gas supply shock

- Gas shocks feed into core inflation
- Goods inflation (food, clothing) tends to be stronger and more persistent than services (education, healthcare)

⇒ Direct effects in sectors where energy constitutes a significant cost factor (clothing, transport) vs lagged effects in sectors impacted indirectly

Gas effects on sectoral output (EA)

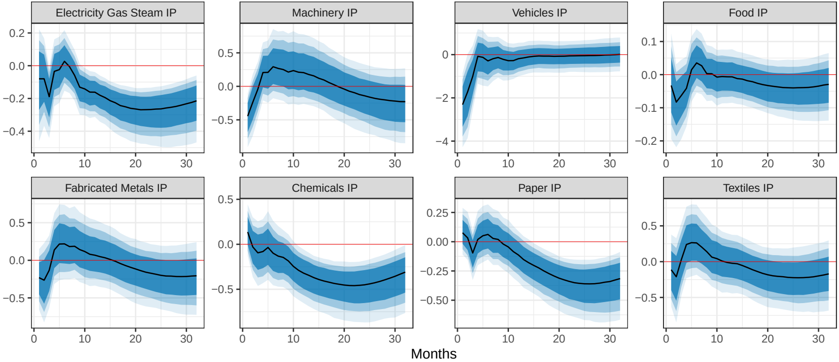


Figure: Responses of IP sectors (by value added) to a gas supply shock

- Strongest impact on gas-intensive sectors (e.g., chemicals, paper)
- Several sectors unaffected, explaining limited aggregate effects ⇒ no evidence of widespread cascading effects (Moll et al., 2023)
- Output U-shaped, inflation inverted U-shaped, and sectoral heterogeneity: cost-push shocks (Davis & Haltiwanger, 2001)

Aggregate demand channel (EA)

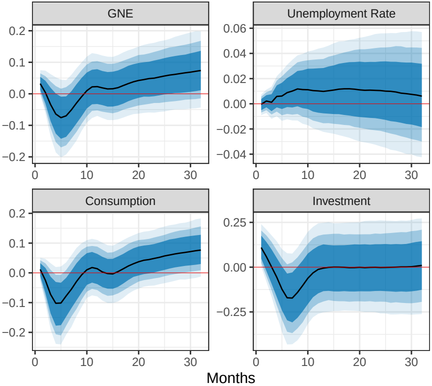


Figure: Responses of economic activity indicators to a gas supply shock. GNE, consumption, and investment are interpolated from quarterly

- Modest decline only in consumption and investment: households and firms reallocate expenditures (Hamilton, 2023)
- Oil price shocks larger effect in the literature (Hamilton, 2009; Känzig, 2021). Can be attributed to lower gas share in energy expenditure (4 to 1 ratio)

A small VAR to study the post-pandemic inflation drivers

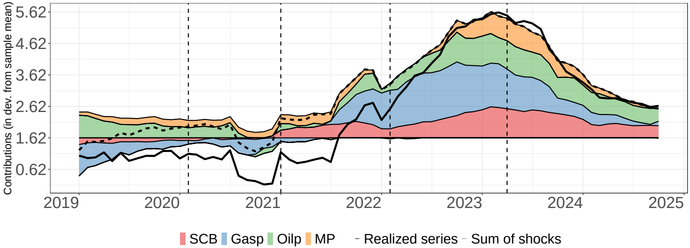
We estimate a mixed Proxy/Recursive-VAR of five variables, where we identify four structural shocks:

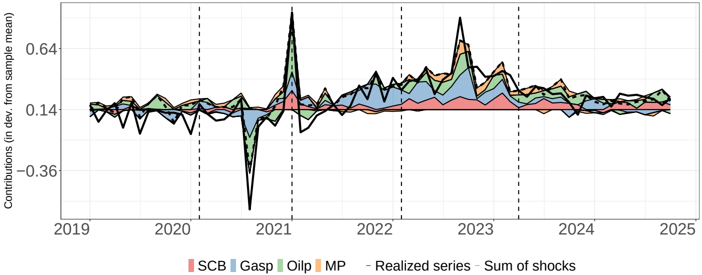
- Supply chain disruptions shock[1]: recursive identification
- Gas price shock: external instruments
- Oil price shock: external instrument from Känzig (2021) (using Brent and extended)
- MP shock: external instrument from Ricco et al. (2024)
- Inflation residuals, not identified

Use historical decompositions to assess the relevance of each series of shocks in the post-pandemic inflation surge

[1] We use the GSCPI (Benigno et al., 2022)

Historical decomposition of inflation (EA)





Historical decomposition of inflation (EA) - II

Table: Percentage contributions of the structural shocks to the realized series of inflation.

Shock contribution		**SCB**	**Gasp**	**Oilp**	**MP**	**Residual**
Pre-COVID	*2019M01* *2020M01*	6%	15%	17%	8%	54%
Phase I	*2020M02* *2020M12*	8%	22%	24%	8%	38%
Phase II	*2021M01* *2023M03*	18%	33%	21%	12%	16%
Phase III	*2023M04* *2024M10*	24%	19%	30%	14%	13%
All phases	*2020M02* *2024M10*	18%	27%	24%	12%	19%

Robustness

Perform several checks

- **Identification**:
  - Background noise and placebo Details on noise and placebo
  - Informationally robust instrument Info robust IRFs
  - Granger tests on instrument Granger tests
  - Demand instrument including summer months Demand with summer IRFs
  - Mertens and Ravn (2013) joint identification strategy Instrumenting price and quantity
- **Model specification and estimation**:
  - Controls/extended specification
  - Extended sample for US (HH starts in 1997) US extended IRFs
  - Estimation by VAR-OLS Frequentist VAR IRFs

$\Longrightarrow$ Results are robust

Conclusions

Conclusions

- Proposed a novel identification strategy to separately identify demand and supply shocks to the real price of natural gas

Conclusions

- Proposed a novel identification strategy to separately identify demand and supply shocks to the real price of natural gas
- Estimated gas demand and supply elasticities for EA and US

Conclusions

- Proposed a novel identification strategy to separately identify demand and supply shocks to the real price of natural gas
- Estimated gas demand and supply elasticities for EA and US
- Found that gas shocks have significant macroeconomic effects, with notable regional differences

Conclusions

- Proposed a novel identification strategy to separately identify demand and supply shocks to the real price of natural gas
- Estimated gas demand and supply elasticities for EA and US
- Found that gas shocks have significant macroeconomic effects, with notable regional differences
- Results show that expectation-driven mechanism amplifies inflationary pressures in EA via precautionary demand and heightened uncertainty

Conclusions

- Proposed a novel identification strategy to separately identify demand and supply shocks to the real price of natural gas
- Estimated gas demand and supply elasticities for EA and US
- Found that gas shocks have significant macroeconomic effects, with notable regional differences
- Results show that expectation-driven mechanism amplifies inflationary pressures in EA via precautionary demand and heightened uncertainty
- Aggregate real effects are limited, though in the EA significant sectoral heterogeneity and larger impact on Germany

Conclusions

- Proposed a novel identification strategy to separately identify demand and supply shocks to the real price of natural gas
- Estimated gas demand and supply elasticities for EA and US
- Found that gas shocks have significant macroeconomic effects, with notable regional differences
- Results show that expectation-driven mechanism amplifies inflationary pressures in EA via precautionary demand and heightened uncertainty
- Aggregate real effects are limited, though in the EA significant sectoral heterogeneity and larger impact on Germany
- Gas price shocks increase CO_2 emissions in the short to medium run, due to substitution toward more carbon-intensive fuels.

Conclusions

- Proposed a novel identification strategy to separately identify demand and supply shocks to the real price of natural gas
- Estimated gas demand and supply elasticities for EA and US
- Found that gas shocks have significant macroeconomic effects, with notable regional differences
- Results show that expectation-driven mechanism amplifies inflationary pressures in EA via precautionary demand and heightened uncertainty
- Aggregate real effects are limited, though in the EA significant sectoral heterogeneity and larger impact on Germany
- Gas price shocks increase CO_2 emissions in the short to medium run, due to substitution toward more carbon-intensive fuels.
- Gas one of the main drivers of the post-pandemic inflation surge in the EA

Concluding Remarks: Policy Implications

Concluding Remarks: Policy Implications

- Interfuel substitution and low response of demand reduce the effectiveness of price-based mechanisms in driving the energy transition (though sustained long-run price increases may have stronger effects...)

Concluding Remarks: Policy Implications

- Interfuel substitution and low response of demand reduce the effectiveness of price-based mechanisms in driving the energy transition (though sustained long-run price increases may have stronger effects...)
- Strengthening energy security remains a key priority for the Euro Area (Draghi, 2024)
  - Deepen partnerships with reliable and diversified suppliers
  - Promote joint procurement initiatives

Concluding Remarks: Policy Implications

- Interfuel substitution and low response of demand reduce the effectiveness of price-based mechanisms in driving the energy transition (though sustained long-run price increases may have stronger effects...)
- Strengthening energy security remains a key priority for the Euro Area (Draghi, 2024)
  - Deepen partnerships with reliable and diversified suppliers
  - Promote joint procurement initiatives
- Reforming the electricity market in the Euro Area could reduce the outsized impact of marginal pricing from high-cost energy sources

Appendix A - Euro Area and United States energy statistics

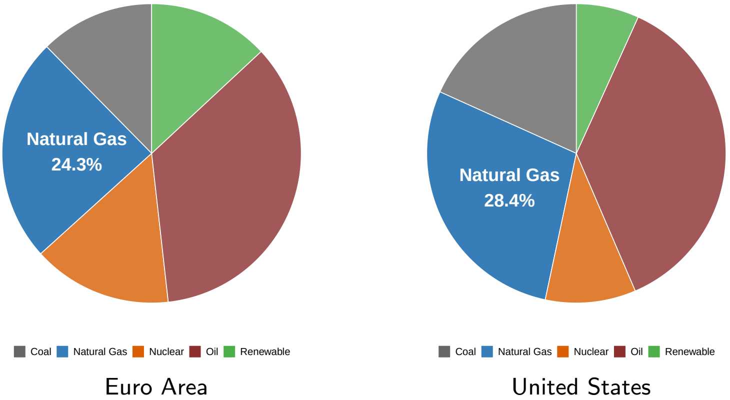
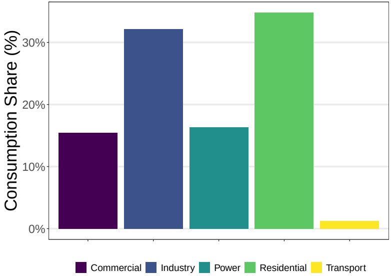


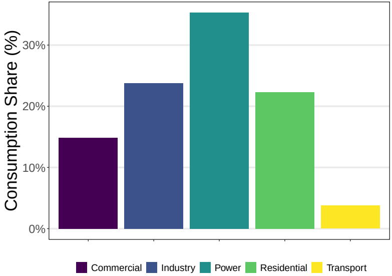
Figure: Total energy supplied by source

Back to gas markets

Appendix A - Euro Area and United States energy statistics (II)



Euro Area



United States

Figure: Natural gas consumption share by sector

Back to gas markets Back to supply and demand responses

Appendix A - Euro Area and United States energy statistics (III)

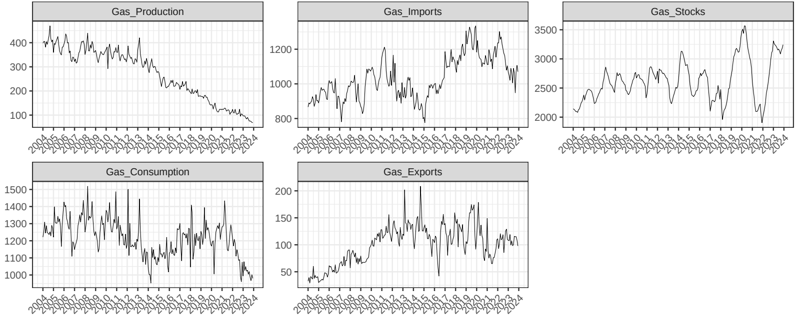


Figure: Gas Balances for the Euro Area

Appendix A - Euro Area and United States energy statistics (IV)

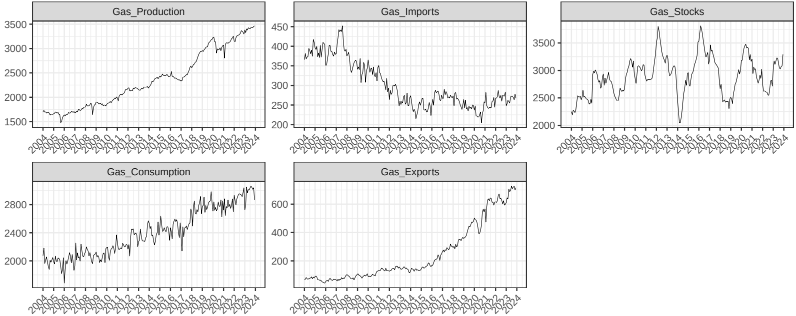


Figure: Gas Balances for the United States

Appendix A - EA and US energy statistics (V)

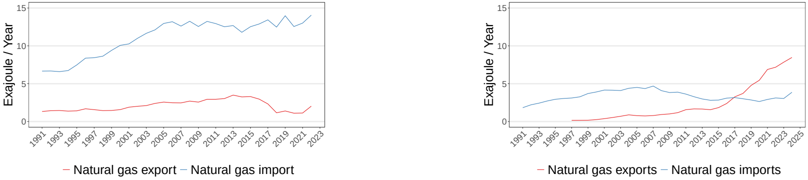
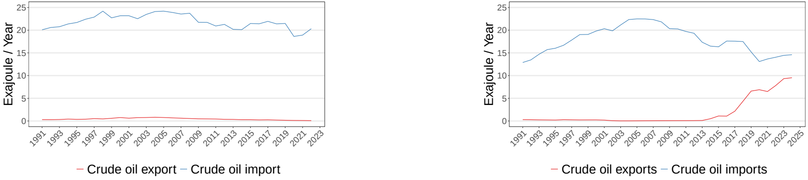


Figure: Natural gas imports and exports

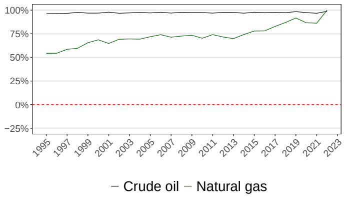


European Union United States

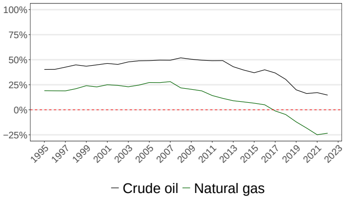
Figure: Crude oil imports and exports

Back to gas markets

Appendix A - EA and US energy statistics (VI)



European Union



United States

Figure: Gas and oil import dependency

Back to gas markets

Appendix B - TTF as the European benchmark for gas

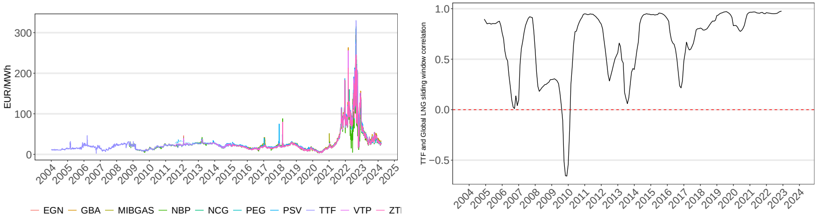


Figure: Left panel: TTF and other European gas hub prices. Right panel: rolling-window correlation between TTF and Global LNG price.

	NCG	VTP	PSV	ZTP	EGN	NBP	GBA	PEG	MIBGAS
TTF	1.00	1.00	1.00	0.97	0.98	0.93	1.00	0.97	0.97

Table: Correlation between TTF and other gas prices.

Back to gas markets

Appendix C - Gas supply instrument for the US

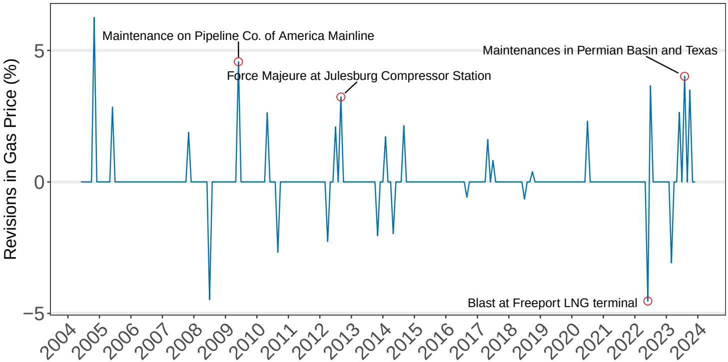


Figure: Gas price surprise series constructed from changes in gas futures prices around announcements (principal component spanning first year of HH gas futures term structure).

Back to gas supply shock

Appendix C - Gas demand instrument for the US

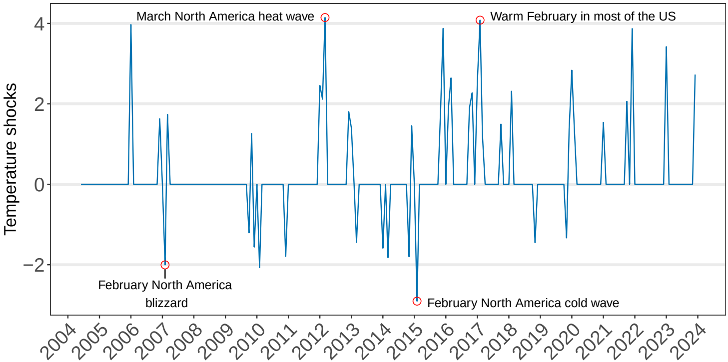


Figure: Temperature shocks series for the US.

Back to gas demand shock

Appendix D - Gas supply news

Date	Event	daily %Δ (PC)
EA		
2009-01-06	Russia halts gas deliveries to Ukraine amid escalating gas dispute.	12.1
2010-10-28	UK expands LNG Capacity at the Isle of Grain terminal.	-1.3
2010-11-15	Unexpected drop in flows from Norway through the Langeled pipeline.	3.4
2014-03-03	Gazprom threatens to cut gas exports amid the Crimea crisis.	5.7
2019-04-05	Pipeline blast reduces Russian gas supplies to Bulgaria by 60%	11.5
2020-08-03	Polish anti-monopoly UOKiK fines Gazprom over Nord Stream.	19.8
2021-10-28	Putin announces Gazprom ready to start pumping natural gas into European gas storage.	-9.9
2022-02-25	Auction result shows flows might resume via the Yamal pipeline.	-28.3
2022-03-02	Supply fears peak amid Russia-Germany dispute over NS2, following invasion of Ukraine.	26.6
2022-06-14	Gazprom announces reduced supply through Nord Stream 1 due to repair works.	12.8
2022-06-15	Gazprom announces further reduction in gas flows through Nord Stream 1.	12.2
US		
2009-06-15	Kinder Morgan announces maintenance on natural gas Pipeline Co. of America Mainline.	4.6
2012-07-24	Pipeline constraints limit supply in the Gulf Coast.	2.1
2012-09-21	Force Majeure at Julesburg compressor station.	3.2
2013-11-01	Transco begins full service on Northeast Supply Link project.	-2.0
2014-02-13	Columbia Gulf transmission pipeline shuts following explosion in Kentucky.	1.7
2014-09-15	Explosion at Chevron gas pipeline.	2.1
2017-05-10	FERC bans new drilling along Rover pipeline.	1.6
2022-06-08	Blast hits Freeport LNG plant, disrupting operations.	-4.5
2023-03-08	Unexpected flows drop at Freeport LNG related to outages.	-3.1
2023-06-30	Restrictions at Oxford and Stony Point compressors amid maintenance.	2.6

Table: Selected gas supply news for EA and US.

Back to examples of news

Appendix D - Assessing the instruments: strength (EA)

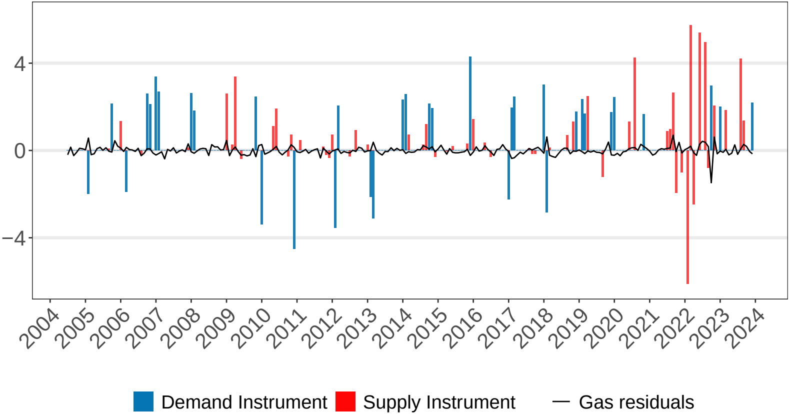


Figure: The figure shows how the gas and demand instruments are related to the reduced-form residuals. The series are rescaled to have unit variance.

Appendix D - Assessing the instruments: strength (US)

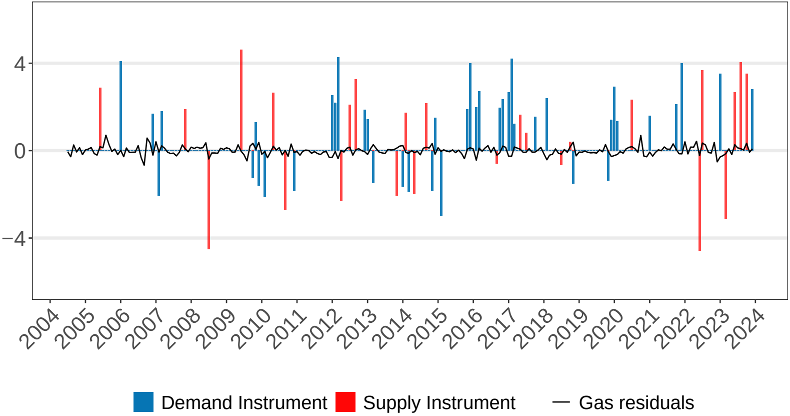
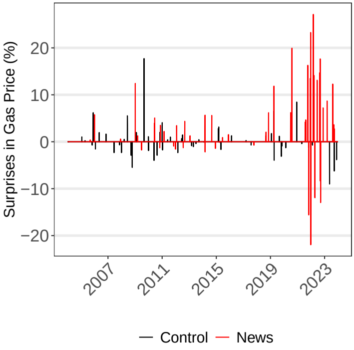
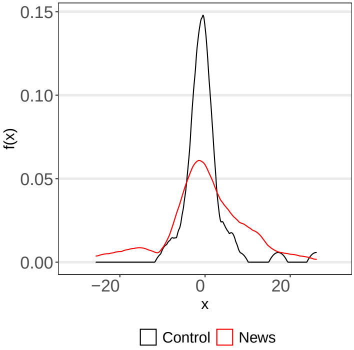


Figure: The figure shows how the gas and demand instruments are related to the reduced-form residuals. The series are rescaled to have unit variance.

Appendix D - Assessing the instruments: noise



Daily surprises



PDF

Figure: Left panel: daily changes in gas future prices on news and control days (chosen at random among non-news days). Right panel: empirical PDF.

Back to robustness

Appendix D - Assessing the instruments: Granger's tests

Variable	p-value EA	p-value US
Instrument Lags	0.22	0.92
Gas price	0.45	0.71
Oil price	0.38	0.95
Gas demand	0.60	0.89
Gas inventories	0.32	0.83
Headline inflation	0.77	0.81
Industrial production	0.13	0.90
Financial volatility	0.25	0.86
Interest rate	0.69	0.97
Nominal exchange rate	0.66	0.98
Stock market (STOXX50E/SP500)	0.11	0.59
Supply Chain Bottlenecks (GSCPI)	0.22	0.85
Real economic activity	0.51	0.98
Joint Test	0.14	0.99

Table: Granger causality tests.

Back to correlations Back to robustness

Appendix E - Additional results: Drivers of supply responses

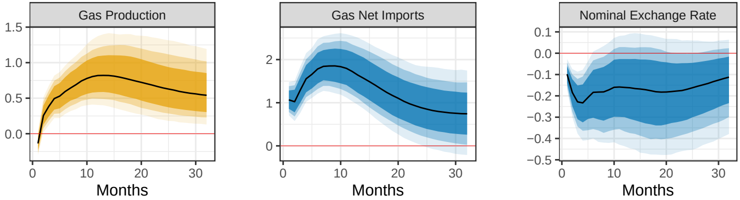


Figure: Drivers of gas supply. Additional responses to a gas demand shock: US in orange, EA in blue

Back to supply and demand responses

Appendix E - Additional results: Drivers of demand responses: interfuel substitution in the power sector

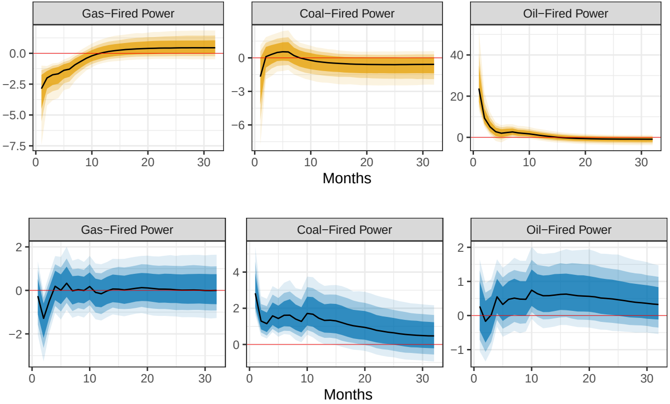


Figure: Drivers of gas demand. Additional responses to a gas supply shock: US in orange, EA in blue. EA sample starts in 2010 due to data availability

Back to supply and demand responses Back to environmental impact

Appendix E - Additional results: Germany

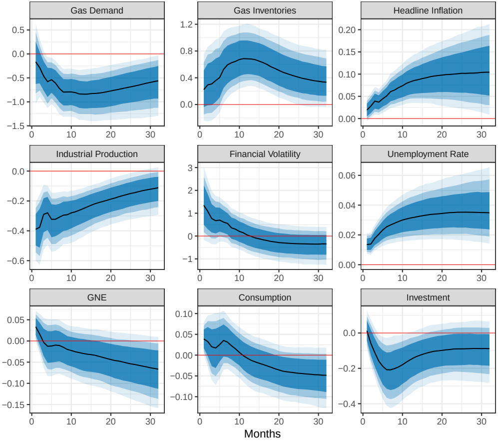


Figure: Impulse responses to a gas supply shock: German economy. GNE, consumption, and investment are interpolated from quarterly

Back to macroeconomic impact

Appendix E - Additional results: PPI Inflation in Europe

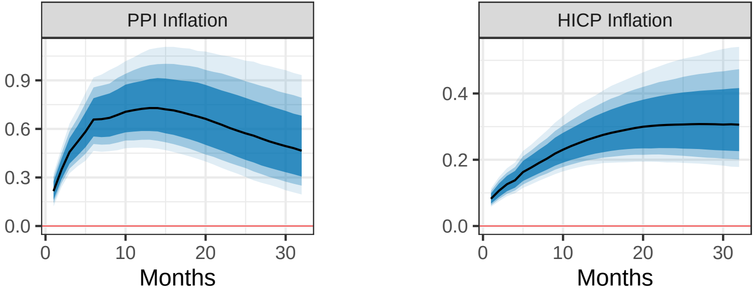


Figure: Responses of producer price and consumer price inflation.

Appendix F - Informationally robust supply instrument

- For the exclusion restriction to hold, gas news must not convey information about confounding factors
- One potential confounder is food prices, also affected by the Ukraine war.
- Construct informationally robust instrument (Romer and Romer, 2004; Miranda-Agrippino and Ricco, 2021)
  1. Compute food surprises around same gas news, using MATIF wheat futures
  2. Build the "informationally-robust" surprises as the residuals of the regression:

$$GasSurprise_t^h = \alpha_0 + \sum_{j=1}^{l} \phi_j GasSurprise_{t-j}^h + \sum_{j=0}^{l} \theta_j FoodSurprise_{t-j}^h + \sum_{j=0}^{l} \mathbf{x}_{t-j}\Gamma_j + IRS_t$$

where $\mathbf{x}_t$ is a vector of monthly macroeconomic shocks sourced from the literature and IRS_t denotes the Informationally Robust Surprises

Appendix F - Informationally robust gas supply shock

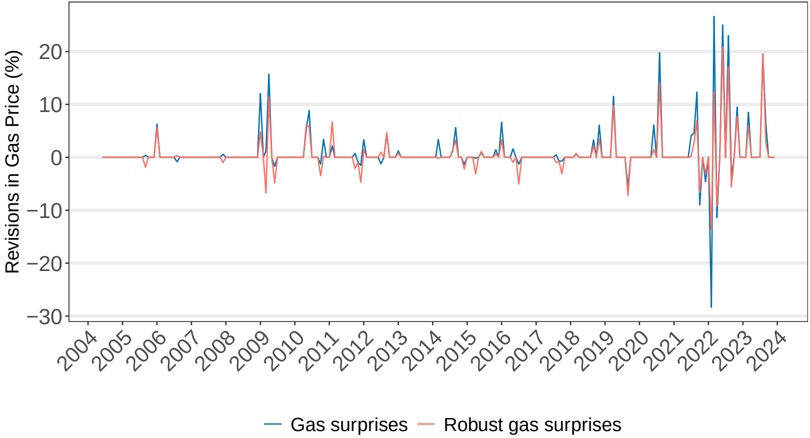


Figure: Gas surprise series (blue) and informationally-robust gas surprises series IRS_t (red).

Back to correlations

Appendix F - Informationally robust gas supply shocks

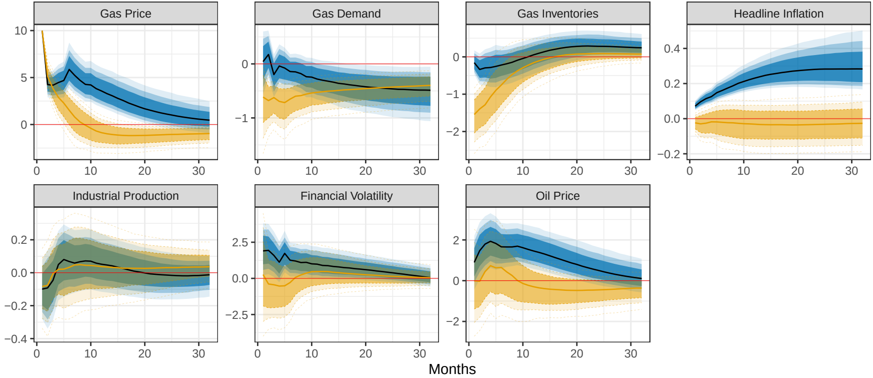
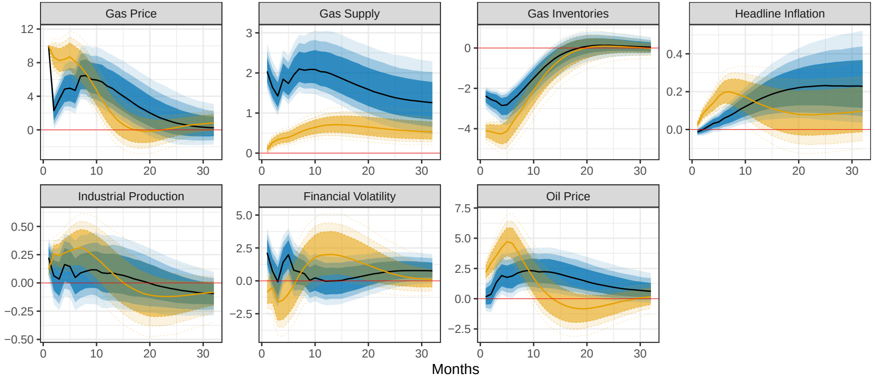


Figure: Responses to an informationally-robust gas shock.

Back to robustness

Appendix G - Robustness checks: Demand instrument including summer months



First stage regressions: EA F: 13.4 , Robust F: 6.3 ; US F: 10 , Robust F: 12

Figure: Responses to a gas demand shock, including summer months.

Back to robustness

Appendix G - Robustness checks: US demand with extended sample (1997-2023)

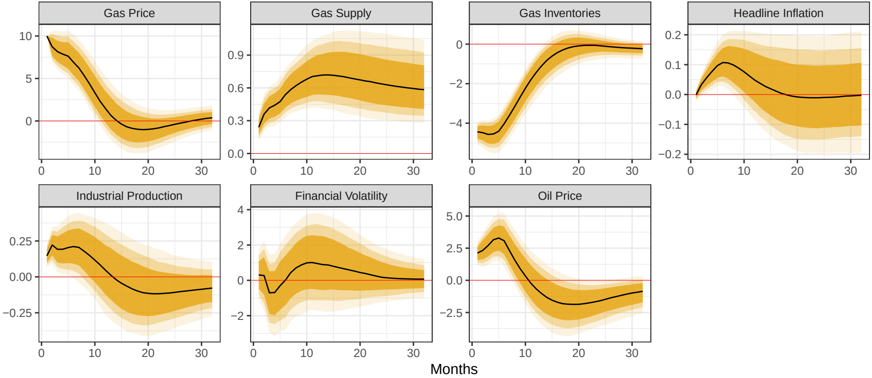


Figure: Full responses to a gas demand shock in the US, extended sample.

Appendix G - Robustness checks: US supply with extended sample (1997-2023)

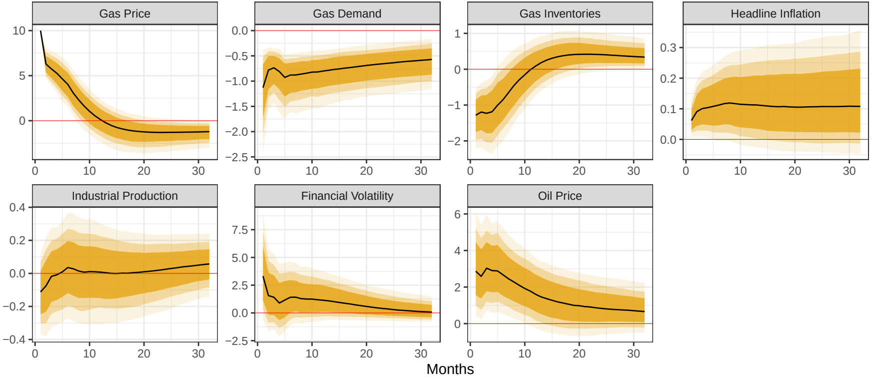


Figure: Full responses to a gas supply shock in the US, extended sample.

Back to robustness

Appendix G - Robustness checks: VAR-OLS

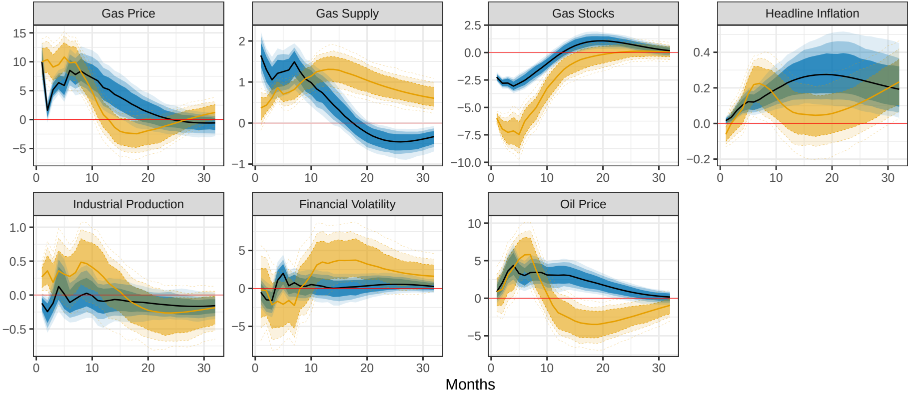


Figure: Responses to a gas demand shock, estimated by VAR-OLS.

Appendix G - Robustness checks: VAR-OLS - II

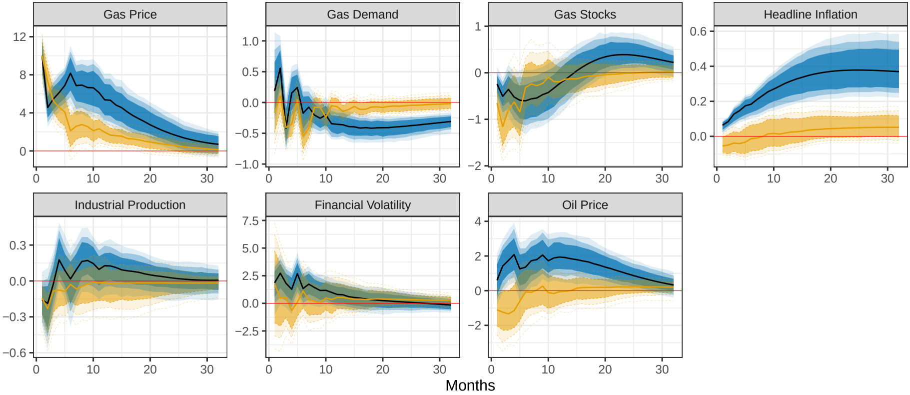


Figure: Responses to a gas supply shock, estimated by VAR-OLS.

Back to robustness

Orthogonalising the structural shocks

- Our baseline includes 7 variables: gas price, quantity, and other gas-market and macro variables.

Orthogonalising the structural shocks

- Our baseline includes 7 variables: gas price, quantity, and other gas-market and macro variables.
- We use gas demand (supply) as the quantity variable when identifying a supply (demand) shock, since the two differ due to the role of imports and exports.

Orthogonalising the structural shocks

- Our baseline includes 7 variables: gas price, quantity, and other gas-market and macro variables.
- We use gas demand (supply) as the quantity variable when identifying a supply (demand) shock, since the two differ due to the role of imports and exports.
- As we estimate one shock at a time, we instrument gas price separately in each case. This avoids endogeneity concerns, such as price responding contemporaneously before quantities adjust (*e.g. anticipation or speculation*).

Orthogonalising the structural shocks

- Our baseline includes 7 variables: gas price, quantity, and other gas-market and macro variables.
- We use gas demand (supply) as the quantity variable when identifying a supply (demand) shock, since the two differ due to the role of imports and exports.
- As we estimate one shock at a time, we instrument gas price separately in each case. This avoids endogeneity concerns, such as price responding contemporaneously before quantities adjust (*e.g. anticipation or speculation*).
- A limitation of this approach is that it does not ensure orthogonality between structural shocks, which is required for computing elasticities using formulas such as in Baumeister and Hamilton (2024).

Orthogonalising the structural shocks - II

- Mertens and Ravn (2013) propose imposing a recursive structure when multiple shocks are instrumented, which requires identifying different shocks through different endogenous variables.

Orthogonalising the structural shocks - II

- Mertens and Ravn (2013) propose imposing a recursive structure when multiple shocks are instrumented, which requires identifying different shocks through different endogenous variables.
- To implement this, we expand the model to 8 variables by including both gas demand and supply. We identify both shocks jointly, instrumenting gas price with the supply shock and gas quantity with the demand shock.

Orthogonalising the structural shocks - II

- Mertens and Ravn (2013) propose imposing a recursive structure when multiple shocks are instrumented, which requires identifying different shocks through different endogenous variables.
- To implement this, we expand the model to 8 variables by including both gas demand and supply. We identify both shocks jointly, instrumenting gas price with the supply shock and gas quantity with the demand shock.
- In a proxy-SVAR, instrumenting one variable or another has no impact on point estimates of IRFs-only on confidence bands, which depend on instrument strength. Therefore, differences with the 7-variable setup stem only from small changes in residuals.

Orthogonalising the structural shocks - II

- Mertens and Ravn (2013) propose imposing a recursive structure when multiple shocks are instrumented, which requires identifying different shocks through different endogenous variables.
- To implement this, we expand the model to 8 variables by including both gas demand and supply. We identify both shocks jointly, instrumenting gas price with the supply shock and gas quantity with the demand shock.
- In a proxy-SVAR, instrumenting one variable or another has no impact on point estimates of IRFs-only on confidence bands, which depend on instrument strength. Therefore, differences with the 7-variable setup stem only from small changes in residuals.
- While this expanded model may reintroduce endogeneity concerns, it ensures orthogonality between shocks.

Orthogonalising the structural shocks - II

- Mertens and Ravn (2013) propose imposing a recursive structure when multiple shocks are instrumented, which requires identifying different shocks through different endogenous variables.
- To implement this, we expand the model to 8 variables by including both gas demand and supply. We identify both shocks jointly, instrumenting gas price with the supply shock and gas quantity with the demand shock.
- In a proxy-SVAR, instrumenting one variable or another has no impact on point estimates of IRFs-only on confidence bands, which depend on instrument strength. Therefore, differences with the 7-variable setup stem only from small changes in residuals.
- While this expanded model may reintroduce endogeneity concerns, it ensures orthogonality between shocks.

$\Longrightarrow$ In any case our results are robust to including both quantities in the specification and to imposing recursive ordering!

Appendix G - Robustness checks: specification with 8 vars

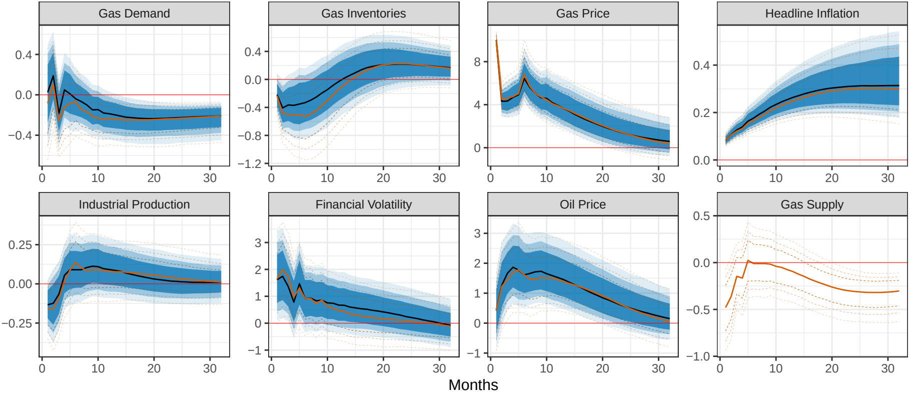


Figure: Responses to a gas supply shock, baseline in blue and expanded specification in red.

Appendix G - Robustness checks: orthogonalising the shocks

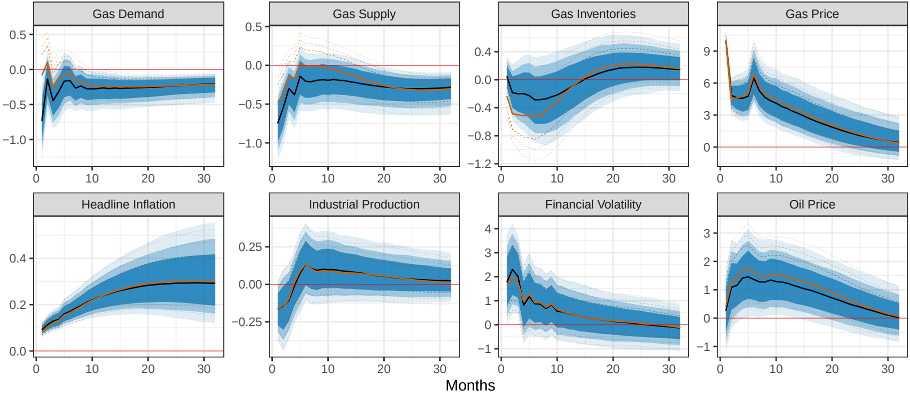


Figure: Responses to a gas supply shock, ordered first (red IRFs) and ordered second (blue IRFs). See Mertens and Ravn (2013).

Appendix G - Robustness checks: specification with 8 vars

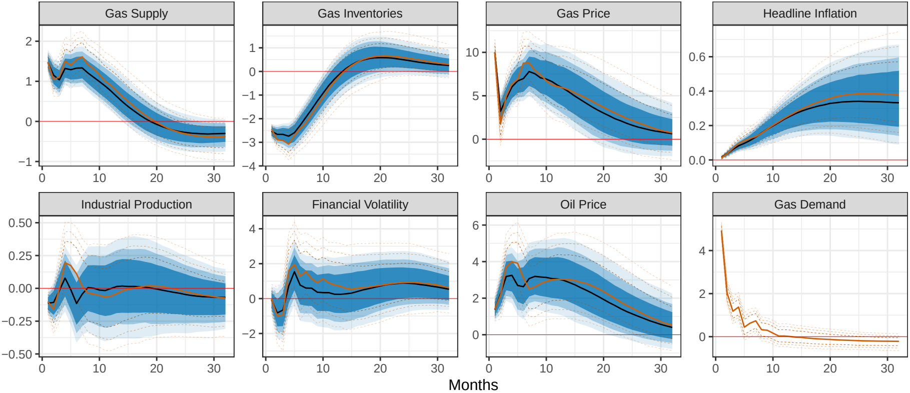


Figure: Responses to a gas demand shock, baseline in blue and expanded specification in red.

Appendix G - Robustness checks: orthogonalising the shocks

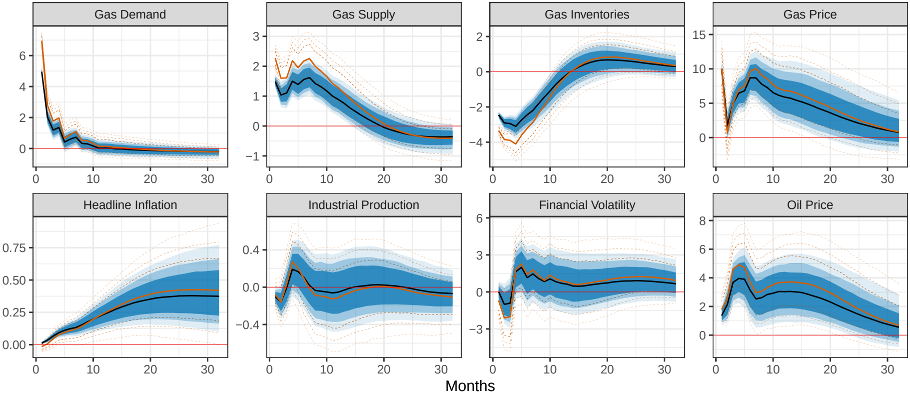


Figure: Responses to a gas demand shock, ordered first (red IRFs) and ordered second (blue IRFs).

Back to estimation Back to robustness

Appendix H - Comparison with alternative gas supply instrument for Europe

- **Technical:** ENDEX *vs* TRPC, 2010M1-2022M11 identification and 2000M1-2022M11 estimation *vs* 2004M1- 2023M12 for both.
- **Substantive:** Only surprises in 1M futures *vs* also longer maturities $\implies$ cleans from noise and captures effects also via future expectations (shown to be very relevant)
- **Obtain different proxies:** modest correlation (0.30)
- **Different results:** Positive effect on gas demand

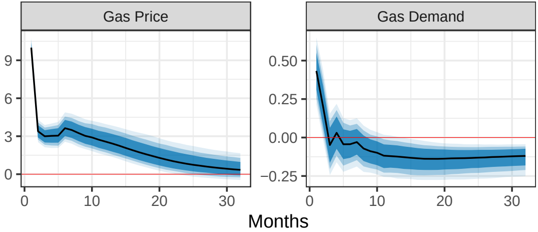


Figure: Selected impulse responses obtained by using the Alessandri and Gazzani (2025) gas supply instrument in our baseline specification.

Appendix H - Comparison with alternative gas supply instrument for Europe (II)

Source	Shock	ρ	n
This study	Temperature demand shock	-0.10	155
Baumeister and Hamilton (2019)*	Oil demand	0.13	155
Caldara et al. (2019)*	CCI oil supply	-0.23	72
Jarociński and Karadi (2020)	Information median monetary policy (EA)	0.19	155

Table: Correlation of Alessandri and Gazzani (2025) instrument with other shocks.

- Instrument is correlated with demand-side indicators and may capture some demand-side component
- Inclusion of news potentially confounded by demand.
  Example: approval of Italy's LNG terminal on October 21, 2022 coincided with an unseasonal heatwave in Europe