Gas Price Shocks and the Inflation Surge

Daniele Colombo[1] and Francesco Toni [2]

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[1]London Business School
[2]Université Côte d'Azur GREDEG; Sant'Anna School of Advanced Studies

Introduction

Motivation

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

Figure: Fire at Russian gas terminal, January 2024.
Source: *Reuters*

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

Motivation

- Historically, the dynamics of natural gas and crude oil prices have been tightly linked
- However, recent developments have highlighted the need to independently examine the dynamics of gas prices, which have increasingly diverged from that of oil prices (Szafranek and Rubaszek, 2023)

Research questions:

1. What are the macroeconomic effects of gas price shocks?
2. What has been the contribution of gas price shocks to the recent inflation surge?

Inflation and energy prices (YoY)

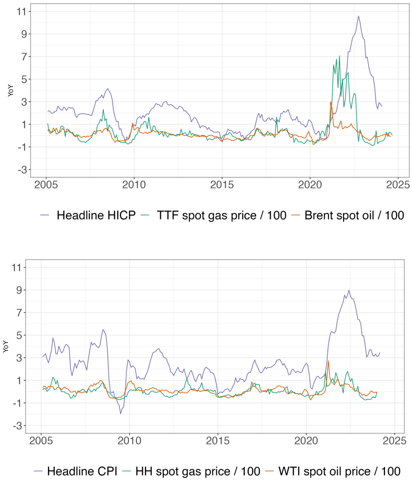


Figure: Top panel: EA. Bottom panel: US.

Related Literature

- **Macroeconomic effects of oil price shocks.** Hamilton (1983), Kilian (2009), Baumeister and Kilian (2016), Caldara et al. (2019), and Känzig (2021)
- **Gas price shocks.** Adolfsen et al. (2024), Baget et al. (2024), Baqaee and Farhi (2024), Di Bella et al. (2024)
- **Energy pass-through to inflation.** Gao et al. (2014), Känzig (2021), Kilian and Zhou (2022), López et al. (2022), Boeck et al. (2023), Adolfsen et al. (2024), Joussier et al. (2023)

Contribution:

1. Identify gas price shocks using external instruments (Lunsford, 2015; Stock and Watson, 2018)
2. Disentangle the effects of gas supply and gas demand shocks
3. Document the differentiated impact of gas and oil price shocks in the EA and in the US and estimate pass-through
4. Assess importance of gas shocks for inflation wrt other shocks

Roadmap

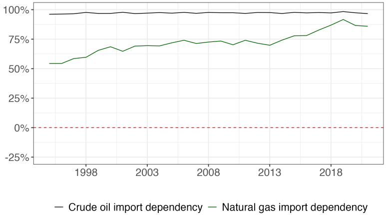
1. Establish some important stylized facts about the gas market
2. Separately identify gas price demand and supply shocks via external instruments:
   - Supply: changes in gas futures prices following supply-related news
   - Demand: *abnormal* temperature deviations from calendar averages
3. Use these instruments in a Bayesian VAR setting to identify macroeconomic effects of gas shocks
   (a) General responses of macro variables
   (b) Compare EA and US
   (c) Sectoral effects on production and consumer prices
4. Identify SCB, oil price and MP shocks and perform an historical decomposition of inflation for the recent inflation surge to assess relative contributions.

Gas markets

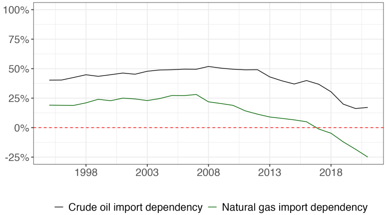
Europe vs US gas markets

1. **Integration** The global natural gas market is more fragmented than the oil market and prices can vary significantly across regions: *In August 2022 EA gas price surged 14-fold but in the US remained significantly lower IMF Blog (2023)*.
2. **Import dependency**
   - The EA is a net gas importer, heavily relying on imports from Russia, Norway, United States, and Qatar. In 2020, imports from Russia reached 40% of total gas.
   - The US is the largest natural gas producers, with growth in production driven by shale extraction. The US exports LNG, primarily to the European and Asian markets.
3. **Market Development** The gas market in the US is more mature, with the HH serving as the benchmark since the 1990s. In Europe, the development of a unified gas market is relatively recent, but the TTF has clearly emerged as the European benchmark Heather (2021). TTF as European benchmark

The EA is a net importer of energy



European Union



United States

- The US has recently become a net exporter of natural gas but remains a net importer of crude oil.
- The EA sources natural gas from a mix of domestic production, pipeline imports, and LNG.
- Gas is mainly used for power generation, residential heating, and industrial activities.

Identification

Constructing an instrument for gas supply

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

Data:

- 89 exogenous gas supply news (41 in the US case) for the period 2004-2023 from Reuters
- 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. Aggregate to monthly by summing daily surprises
3. Take the first principal component of the gas surprises spanning the first year of the gas futures term structure

Gas market-relevant news example

Example of News: Putin's announcement

> *"We have been left no other option to protect Russia and our people, but for the one that we will be forced to use today. The situation requires us to take decisive and immediate action. The People's Republics of Donbas turned to Russia with a request for help. [. . .]*
> *In this regard, in accordance with Article 51 of Part 7 of the UN Charter, with the approval of the Federation Council of Russia and in pursuance of the treaties of friendship and mutual assistance ratified by the Duma on February 22 with the Donetsk People's Republic and the Luhansk People's Republic, I have decided to conduct a special military operation."*

BBC News, 24$^{\text{th}}$ February 2022

Surprise related to Putin's announcement

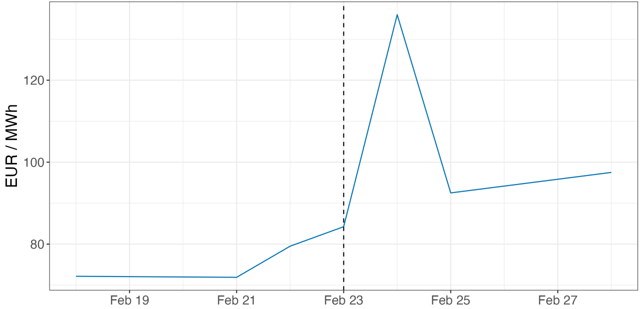


Figure: Daily TTF spot price, selected sample

Gas supply shock

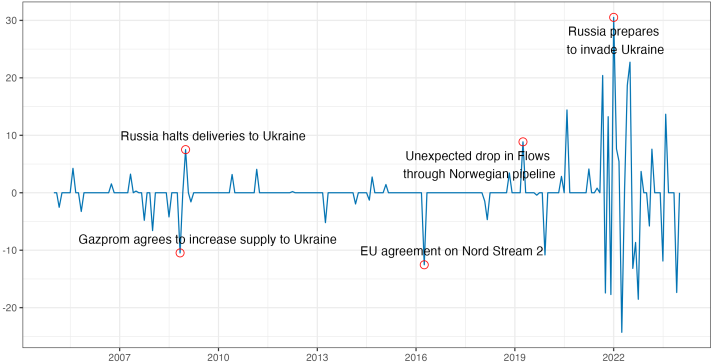


Figure: Gas price surprises series constructed from changes in gas futures prices around announcements (principal component spanning first year of TTF gas futures term structure).

- Similarly, we construct a surprises series for US US surprises series
- Results robust to info-robust version of the shock Info-robust

Gas demand shock

- Private households consume $\approx 1/4$ of total natural gas in the EA (a key difference wrt oil).
- **Exogenous variation:** unexpected demand of gas for heating due to anomalous temperatures.
- Unlike average seasonal temperature fluctuations, a large deviation from the average temperatures 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.

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

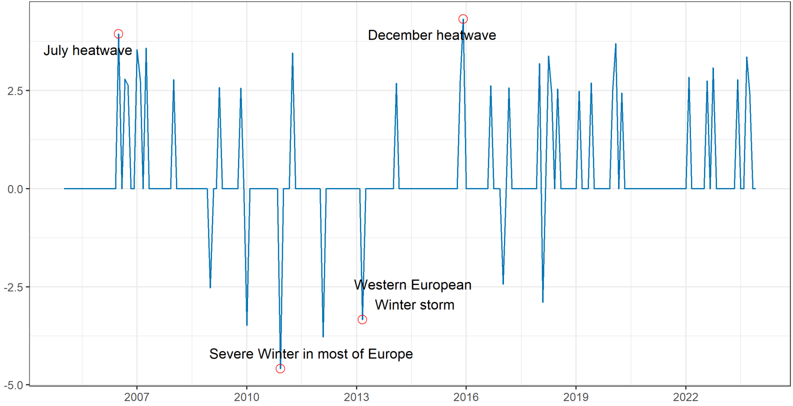
Daily temperature series: grid-level daily temperatures aggregated at the country level, weighting each grid by economic activity. European temperature series obtained by averaging each country weighting by gas consumption

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. Standardise using month-specific μ and σ
4. Threshold the series to isolate only months with large temperature deviations from *normal*

Gas demand shock

Large deviations from *normal* temperatures affect the demand for heating, which, in turn, influences gas prices.



Estimation

Econometric Framework

- Structural VAR

$$B_0 y_t = B_1 y_{t-1} + \cdots + B_p y_{t-p} + w_t$$

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

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

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

Bayesian Estimation

- Bayesian VAR implementing Minnesota and sum-of-coefficients priors following Banbura et al. (2007), expanded with dummy-initial-observations priors Sims (1993).
- The prior distributions are implemented using Normal-inverse-Wishart distributions, which are conjugate priors: $vec(\beta)|\Psi \sim N(vec(\beta_0), \Psi \otimes \Omega_0)$ and $\Psi \sim iW(\Sigma_0, v_0)$.
- The choice of the informativeness of the prior is based on Giannone et al. (2015): prior distribution $\pi_\gamma(\varphi)$ with $\varphi = \{\beta, \Psi\}$ vector of model parameters and γ vector of hyperparameters (coefficients that parameterize the prior distribution, but do not directly affect the likelihood).

Results

Gas shocks contribution to gas price

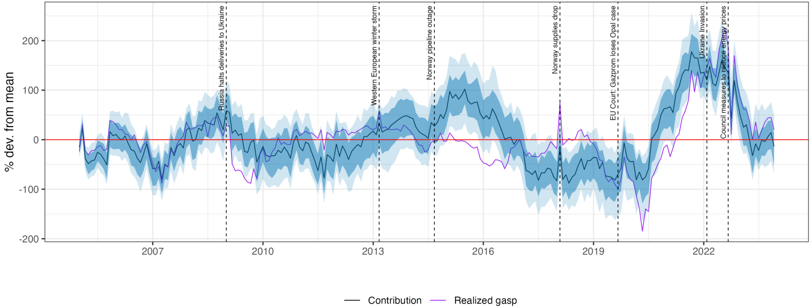
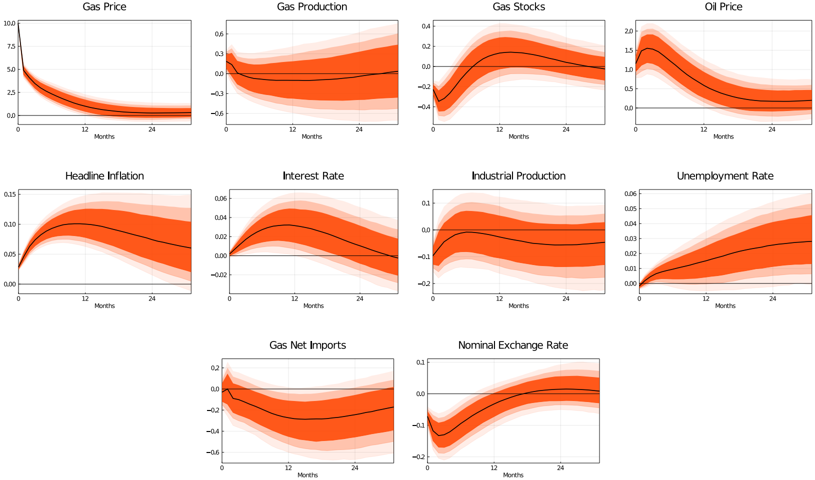


Figure: EA: Historical decomposition of the real price of gas. **2009M1** Russian halt of all gas deliveries to Ukraine for 13 days. **2013M3** Western European storm. **2014M9** Norwegian Langeled pipeline halt. **2018M2** an Earthquake in Norway and decrease in exports. **2019M9** EU court decision to limit Gazprom's market dominance. **2022M2** Invasion of Ukraine.

Gas supply shock in Europe



F-stat: 30.63, Robust F-stat: 9.33

Effects on Industrial Production (EA)

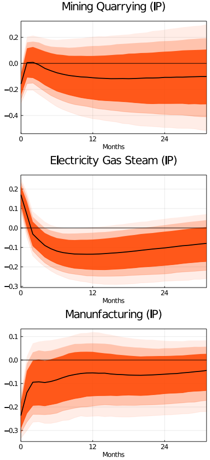


Figure: Level 1 Nace sectors

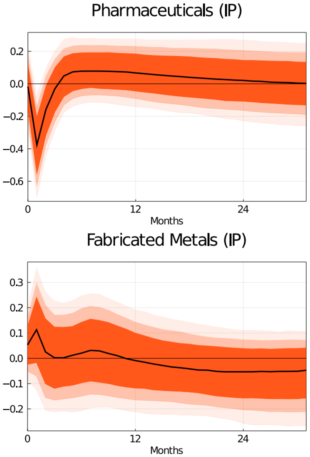


Figure: Selected level 2 Nace sectors

Gas pass-through to consumer prices (EA)

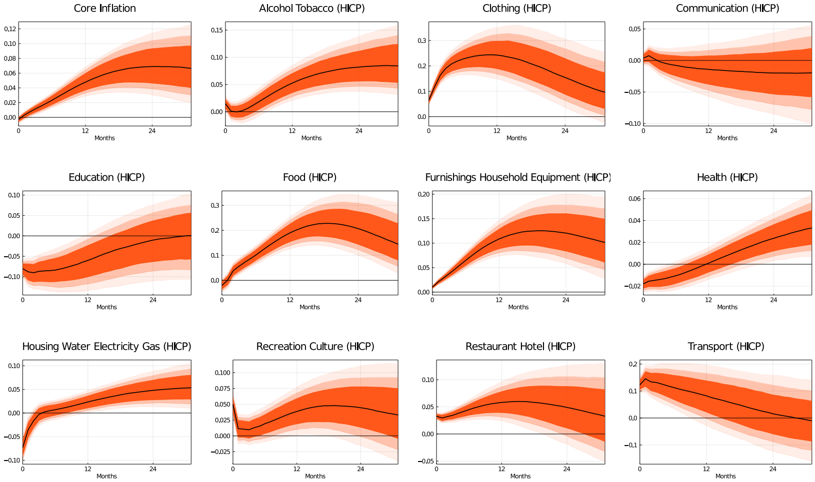
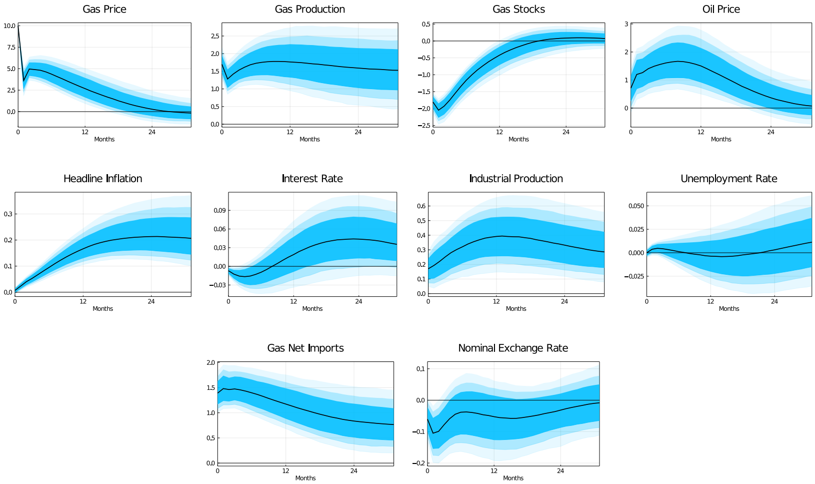


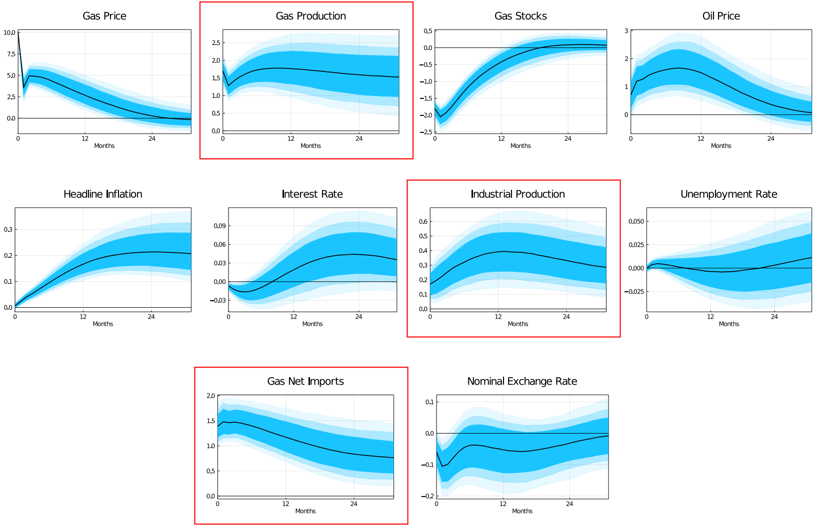
Figure: Gas supply shock

Gas demand shock in Europe



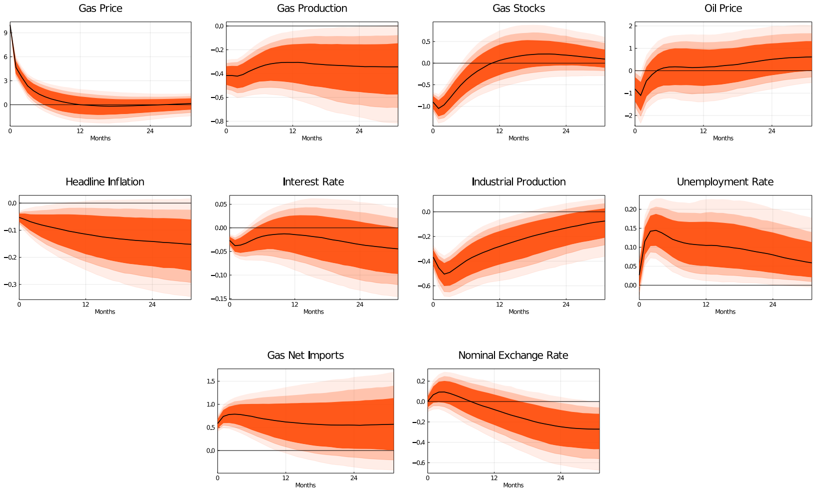
F-stat: 20.24, Robust F-stat: 12.66

Gas demand shock in Europe



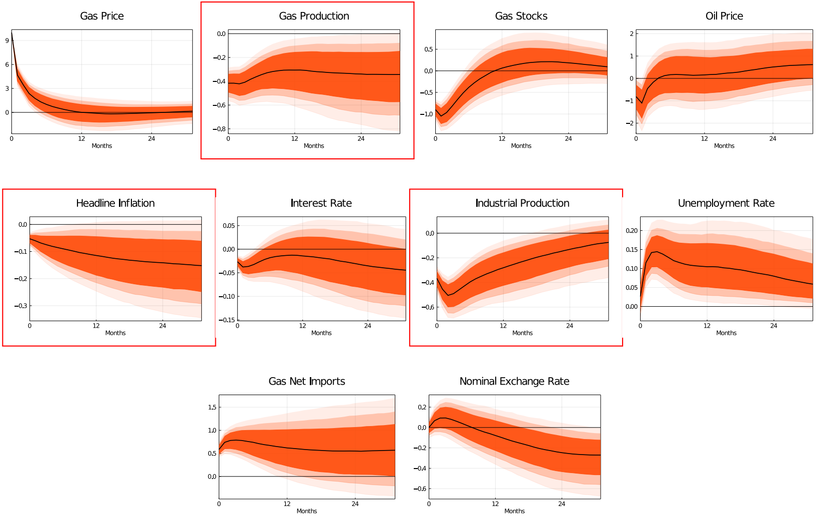
F-stat: 20.24, Robust F-stat: 12.66

Gas supply shock in US



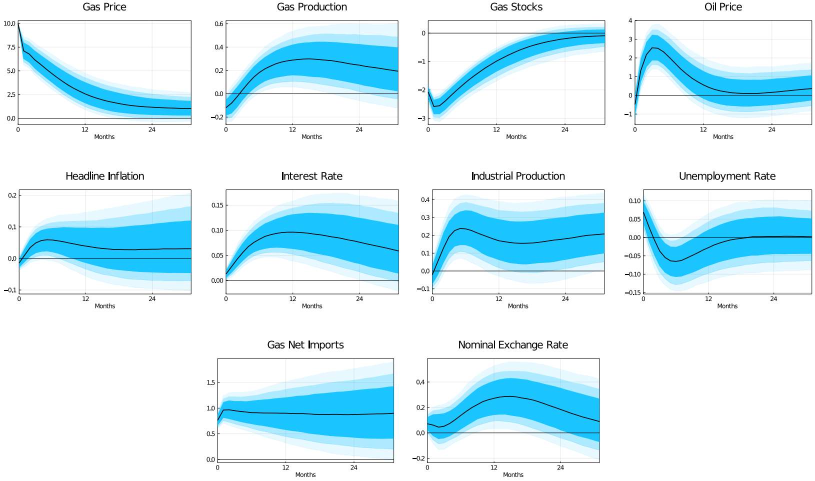
F-stat: 14.37, Robust F-stat: 2.67

Gas supply shock in US



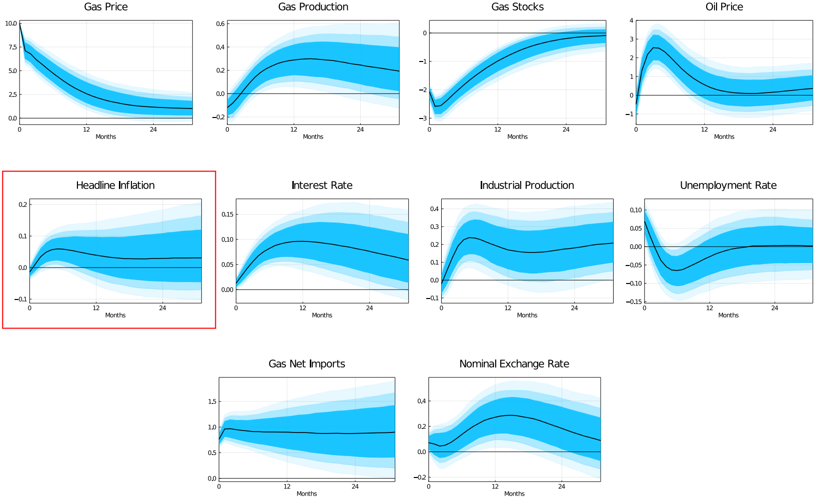
F-stat: 14.37, Robust F-stat: 2.67

Gas demand shock in US



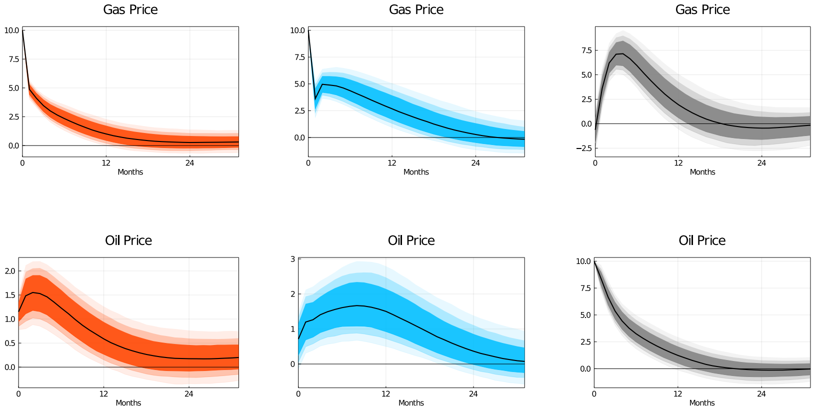
F-stat: 40.14, Robust F-stat: 30.91

Gas demand shock in US



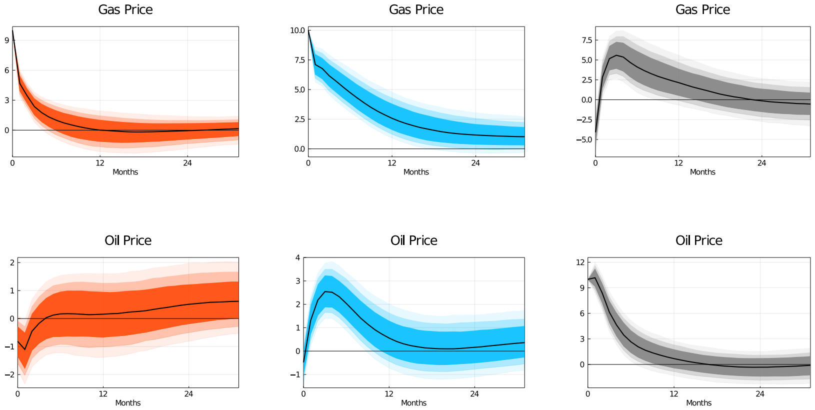
F-stat: 40.14, Robust F-stat: 30.91

Gas and Oil markets interrelation in EA



Gas Supply Shock | Gas Demand Shock | Oil Supply Shock

Gas and Oil markets interrelation in US



Gas Supply Shock | Gas Demand Shock | Oil Supply shock

Robustness

Perform several robustness checks

- **Identification**:
  - Informationally Robust Instrument (Details on info robust)
  - Background noise and Placebo (Details on noise and placebo)
  - Futures contract
- **Model specification**:
  - Frequentist VAR-OLS estimation (Frequentist VAR)
  - Variable selection

$\Longrightarrow$ Results are robust

Conclusions

Conclusions

- Proposed a novel identification strategy to separately identify demand and supply shocks to the price of gas.
- Found that gas shocks have significant macroeconomic effects, both in the EA and the US.
- Evidence shows strong inflationary effects mainly in Europe (net importer of gas) compared to the US (net exporter of gas), as Europe is more vulnerable to constraints from both demand and supply shocks.
- This framework can provide comparable estimates of both gas and oil shocks pass-through to (components of) inflation. We estimate a pass-through up to 0.8% for core and 1% for headline inflation.

Appendix A - US gas supply surprises

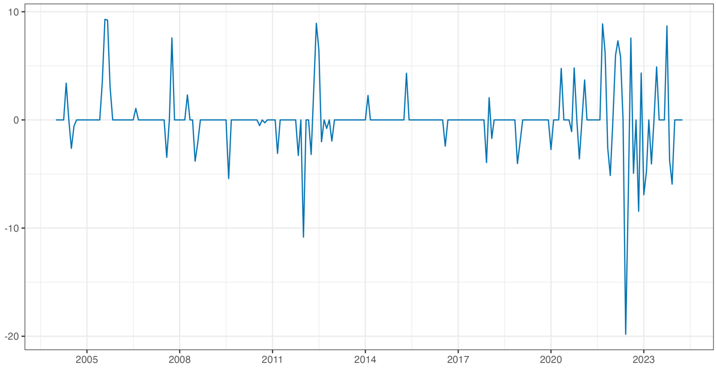


Figure: Gas price surprises series constructed from changes in gas futures prices around announcements (principal component spanning first year of HH gas futures term structure).

Back to Gas supply shock

Appendix B - Robustness checks: informationally robust supply instrument

- To guarantee exogeneity, it is crucial that gas news do not contain new information about confounding factors
- Obvious potential confounders are food and oil prices (also disrupted with the Ukraine war)
- Construct informationally robust instrument (Miranda-Agrippino and Ricco, 2021; Romer and Romer, 2004)
  1. Compute food and oil surprises around same gas news, using MATIF wheat and Brent crude oil futures
  2. Build the "informationally-robust" surprises as the residuals of the regression:

$$GasSurprise_t^h = \alpha_0 + \sum_{j=1}^{2} \phi_j GasSurprise_{t-j}^h + \sum_{j=0}^{2} \theta_j FoodSurprise_{t-j}^h +$$

$$+ \sum_{j=0}^{2} \psi_j OilSurprise_{t-j}^h + \sum_{j=0}^{2} \mathbf{x}_{t-j} \Gamma_j + IRS_t$$

where IRS_t denotes the Informationally Robust Surprises

Informationally robust gas supply shock

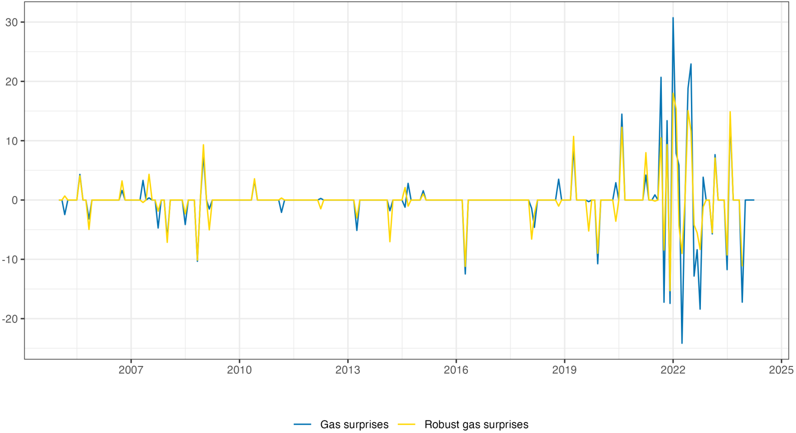


Figure: Gas surprise series (blue) and informationally-robust gas surprises series IRS_t (yellow).

Back to Gas supply shock Back to Robustness

Robustness checks: VAR-OLS

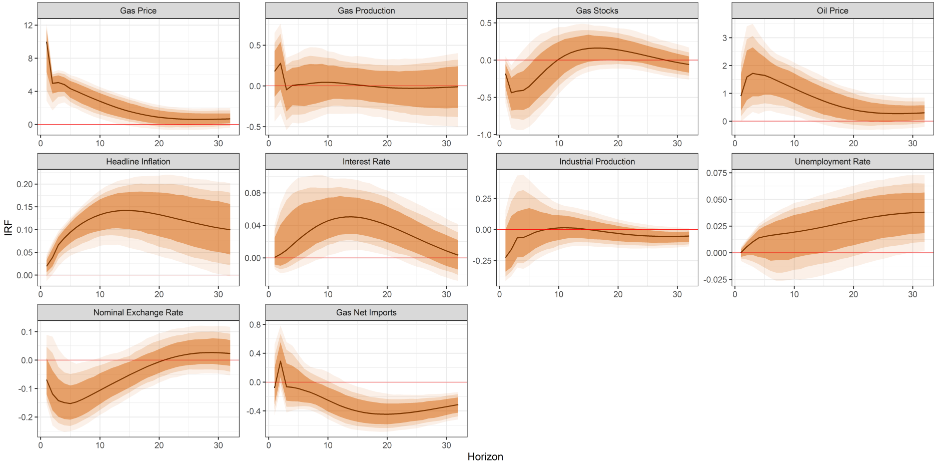


Figure: Responses from a gas supply shock.

Robustness checks: VAR-OLS

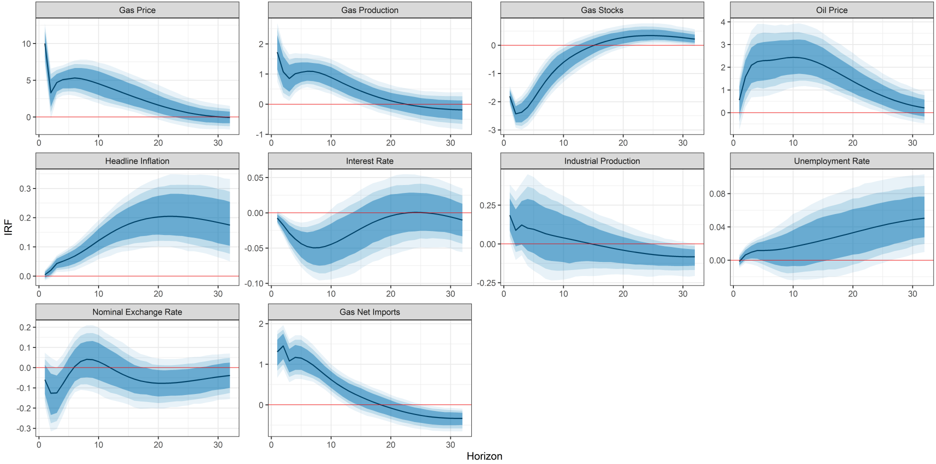


Figure: Responses from a gas demand shock.

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Appendix C - Assessing the instruments: instruments strength

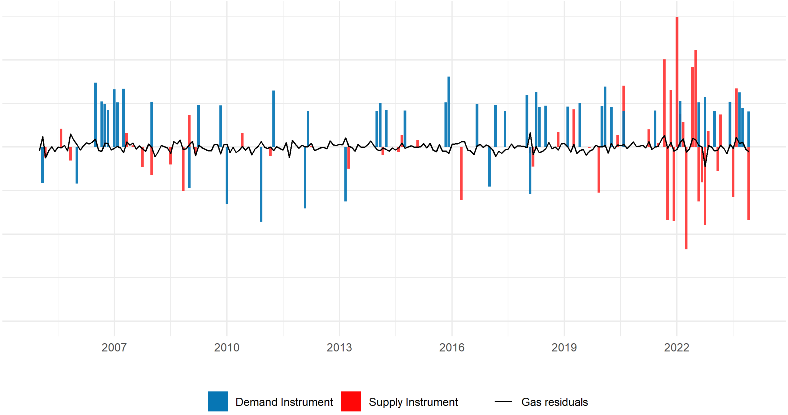
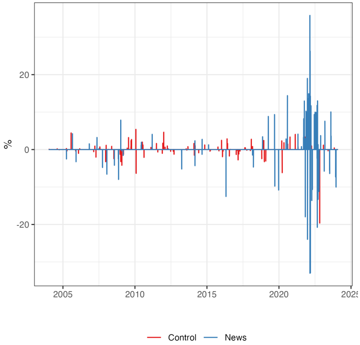
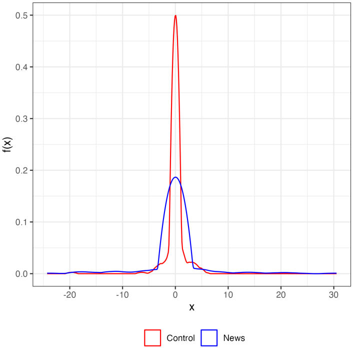


Figure: The figure shows how the gas and demand instruments are related to the reduced-form residuals. The series are rescaled.

Assessing the instrument: noise in the daily surprises



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

Assessing the instrument: correlation with other shocks

Source	Shock	ρ_{supply}	p-value supply	ρ_{demand}	p-value demand	n
Kilian (2009)**	Oil supply	-0.00	0.96	-0.05	0.29	241
Kilian (2009)**	Aggregate demand	-0.05	0.44	-0.02	0.57	241
Kilian (2009)**	Oil-specific demand	0.08	0.21	-0.02	0.61	241
Caldara et al. (2019)	Oil supply	0.05	0.52	0.02	0.65	144
Baumeister and Hamilton (2019)*	Oil supply	-0.07	0.25	0.08	0.08	240
Baumeister and Hamilton (2019)*	Oil demand	0.07	0.30	-0.01	0.80	240
Känzig (2021)**	Oil supply expectations	-0.10	0.12	-0.01	0.86	244
Gertler and Karadi (2015)	FF4 monetary policy (US)	0.07	0.50	0.14	0.02	102
Altavilla et al. (2019)*	Target monetary policy (EA)	0.02	0.77	0.06	0.29	234
Jarociński and Karadi (2020)	"Poor man" monetary policy	-0.03	0.68	0.01	0.91	234
Miranda-Agrippino and Nenova (2022)	Target monetary policy (EA)	-0.19	0.01	0.03	0.58	207
Bloom (2009)**	VXO-VIX	0.01	0.90	-0.03	0.48	243
Gilchrist and Zakrajšek (2012)*	Corporate credit spread index	-0.04	0.49	0.05	0.21	243
Baker et al. (2016)*	Global Economic Policy Uncertainty Index	0.03	0.63	0.08	0.17	240
Caldara and Iacoviello (2022)*	Geopolitical risk index	-0.01	0.83	0.04	0.41	243

Table: Correlation with other shocks

[2] *Extended by the original authors with respect to the original paper sample.

[2] **Extended by us.

Appendix D - Additional results: historical decomposition of US gas price

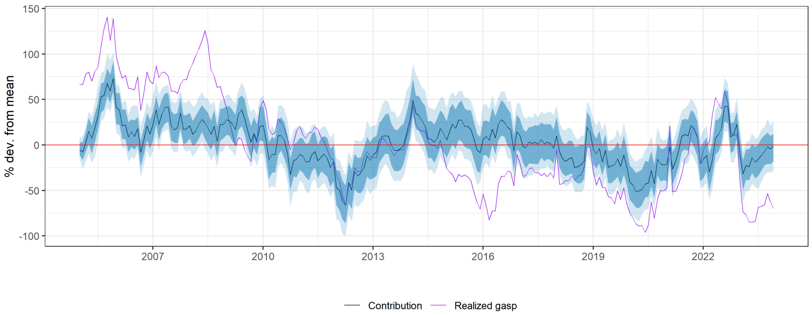
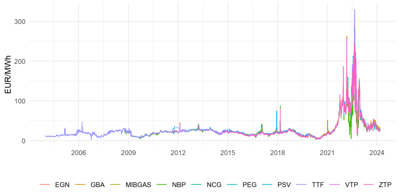


Figure: US: Historical decomposition of the real price of gas

Appendix E - TTF as the European benchmark for gas



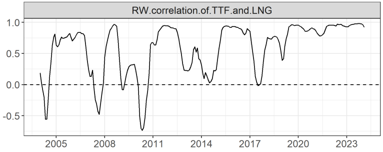


Figure: Left panel: TTF and other European gas hub prices. Right panel: rolling-window correlation between TTF and Global LNG price.

	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.

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