Gas Price Shocks and the Inflation Surge

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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*

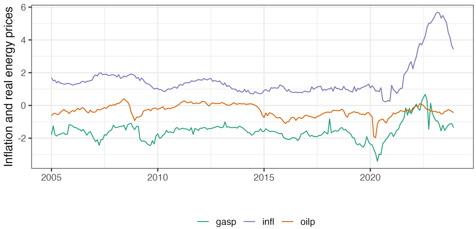
Motivation

- Historically, the dynamics of natural gas and crude oil have been tightly linked
- However, recent developments have highlighted the need to also 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)



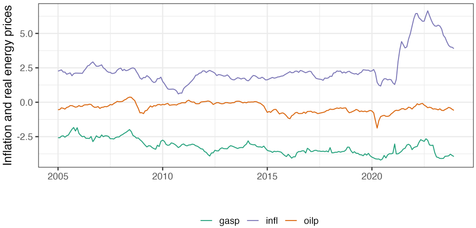


Figure: Top panel: EA. Bottom panel: US.

Related Literature

- **Macroeconomic effects of energy (oil) price shocks.** Hamilton (1983), Kilian (2009), Baumeister and Kilian (2016), Caldara et al. (2019), and Känzig (2021)
- **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)
- **The recent inflation surge.** Celasun et al. (2022) and Mućk and Postek (2023), Stiglitz and Regmi (2023), Gagliardone and Gertler (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 + 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:
   - Demand: *abnormal* temperature deviations from calendar averages
   - Supply: changes in gas futures prices following supply-related news
3. Use these instruments in a VAR setting to identify effects on the macroeconomy of gas shocks
   (a) General responses of macro variables
   (b) Focus on pass-through to inflation
   (c) Compare EA and US
4. Identify SCB, oil price and MP shocks and perform an historical decomposition of inflation for the recent period to assess relative contributions.

Preview of results

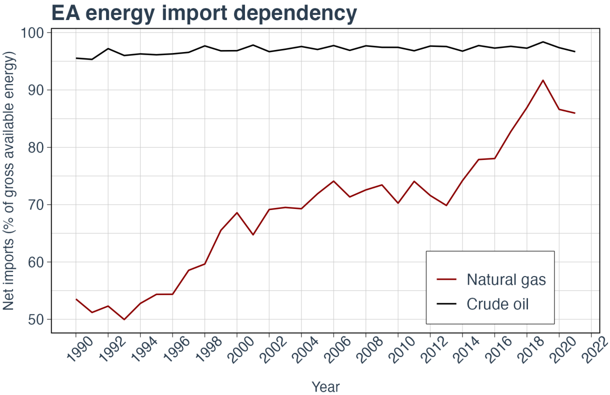
- Gas shocks have significant macroeconomic effects, more so in the EA (net importer of gas) relative to the US (net exporter of gas).
- Estimate gas and oil shocks pass-through to inflation in the EA and the US. Find up to 3% pass-through of both gas and oil shocks to headline in the EA, while in the US gas is not significant and oil shocks are stronger (up to 6%). In both regions oil has stronger effect on energy component.
- Via a historical decompositions exercise find that energy shocks (first oil during lockdown and early reopening right after the pandemic, then gas) and SCB were among the main drivers of the recent inflation surge, while MP has been less effective.

The gas market: Europe vs US gas markets

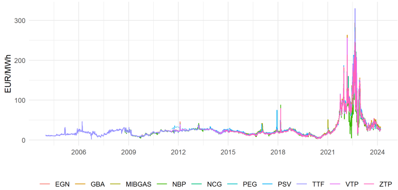
- The global natural gas market is more fragmented than the oil market and prices can vary significantly across regions: *In August 2022 EA gas price surged 14-fold but in the US remained significantly lower IMF Blog (2023)*.
- The EA is a net gas importer. Few countries (e.g. Netherlands) have notable domestic production but the region as a whole heavily relies on imports from Russia, Norway, United States, and Qatar. In 2020, imports from Russia reached 40% of total gas.
- The US are one of the largest natural gas producers, with growth in production driven by shale extraction. The US are a LNG exporter, with a focus on the European and Asian markets. Most natural gas transactions involve pricing mechanisms linked to the Henry Hub (HH).

The EA is a net importer of energy

- Natural gas used in the EA comes from a mix of domestic production, pipeline imports, and LNG sources.
- Gas is mainly used for power generation, residential heating, and industrial activities.



TTF as the European benchmark for gas



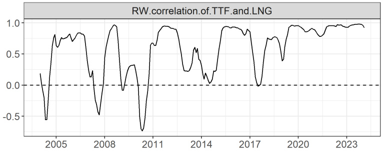


Figure: Left panel: TTF and other European gas hub prices. Right panel: rolling-window correlation between TTF and Global LNG price.

	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.

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, an extreme deviation from the average temperatures is not anticipated by economic agents, and, importantly, not incorporated in trading decisions beforehand.
- 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

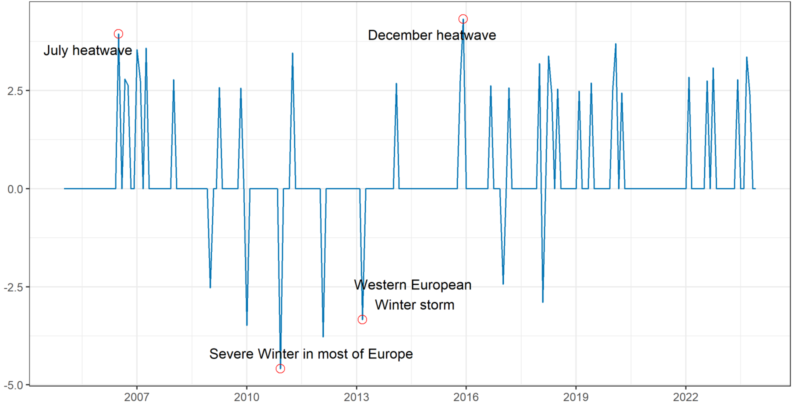
Daily temperature series: grid-level daily temperatures aggregated at the country level, weighting each grid by economic activity. European temperature series obtained by averaging each country weighting by gas consumption

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 extreme temperature deviations from *normal*

Gas demand shock

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



Constructing an instrument for gas supply

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

Data:

- 90 exogenous gas supply news for the period 2004-2023 (Reuters)
- Dutch TTF gas future settlement prices (Datastream)

Constructing the gas supply surprises:

1. Compute gas supply surprises:

$$Gas\_surprise_d^h = F_d^h - F_{d-1}^h$$

   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^{th} February 2022

Surprise related to Putin's announcement

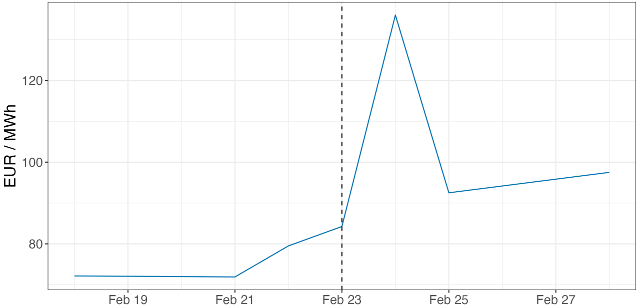


Figure: Daily TTF spot price, selected sample

Gas supply shock

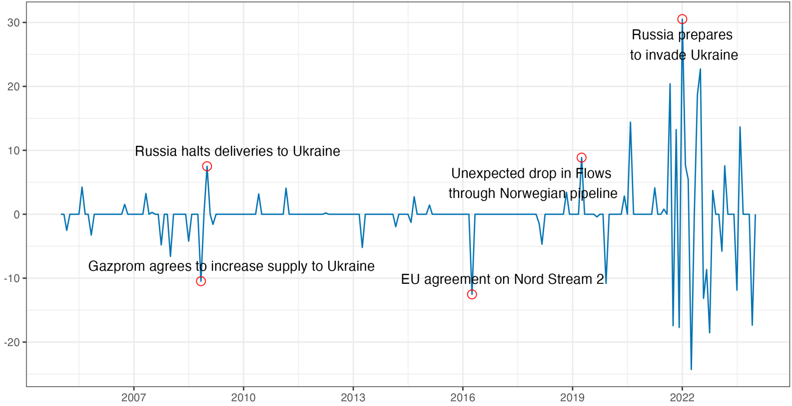


Figure: Gas price surprises series constructed from changes in gas futures prices around announcements (principal component spanning first year of TTF gas futures term structure).

Gas shocks contribution to gas price

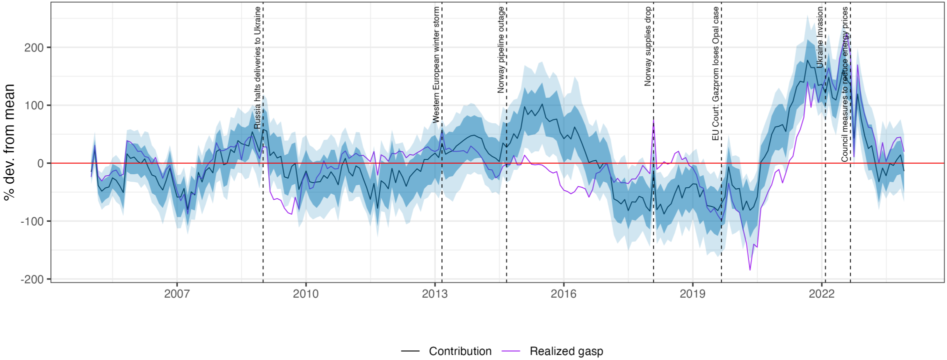


Figure: EA: Historical decomposition of the real price of gas. **2009M1** Russian halt of all gas deliveries to Ukraine for 13 days. **2013M3** Western European storm. **2014M9** Norwegian Langeled pipeline halt. **2018M2** an Earthquake in Norway and decrease in exports. **2019M9** EU court decision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

The impulse response of the gas price

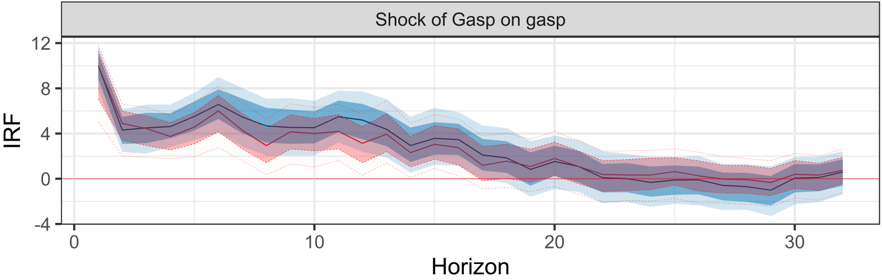


Figure: Demand shock in blue (Fstat: 18.20), Supply shock in red (Fstat: 25.16). Demand shocks are more frequent but on average smaller (sd of 1.24) than supply shocks (sd of 5.14).

Macroeconomic Effects of gas shocks in the EA

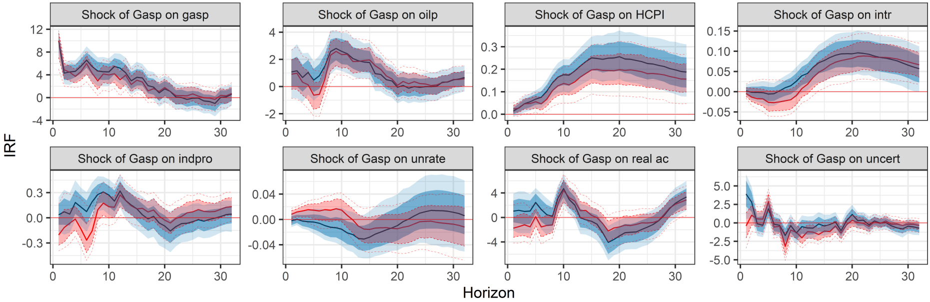


Figure: Impulse responses to a 10% increase in the real price of oil. Demand shocks in blue and supply shocks in red.

Gas and oil markets interrelation in EA and US

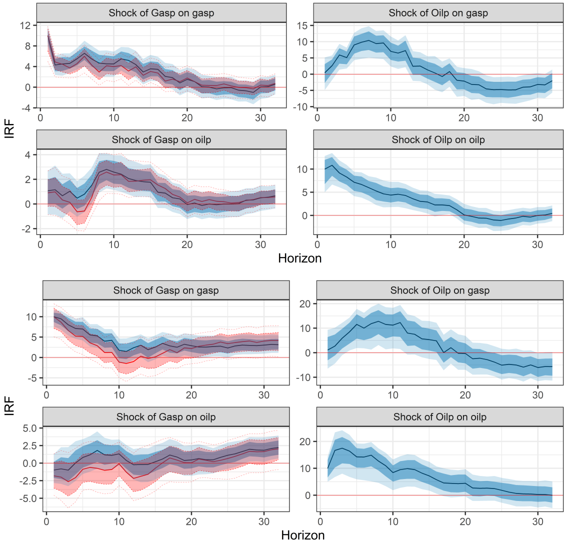


Figure: Top panel: EA. Bottom panel: US.

Gas and oil pass-through to inflation

Extensive literature on energy shocks pass-through:

- **Oil in the US**:
  - Gao et al., 2014 (recursive VAR) 7% on headline, 40% on energy component. Känzig, 2021 (proxy VAR) 4.5% on headline, not significant on core, 35% on energy component
- **Gas in the US**:
  - Kilian and Zhou, 2022 (recursive VAR) 1% and not persistent on headline
- **Gas in the EA**:
  - Boeck et al., 2023 (sign restricted VAR) 1% and not persistent on headline. López et al., 2022 (reduced-form VAR) 1.9% on headline. Joussier et al., 2023 (shift-share on French firms) total pass-through of all energy shocks of 7.3% on headline. Adolfsen et al., 2024 (sign restricted VAR) up to 8.5% on headline and 4.5% on core

First study that provides comparable estimates of pass-through across both commodities and regions:

Gas in EA: up to 3% on headline, 1% on core, 10% on energy component (gas demand stronger pass-through than supply).
Oil in EA: up to 3% on headline, 0.8% on core, 15% on energy component.
Gas in US: only significant on energy component, 10% only after 10 months.
Oil in US: 6% on headline, non significant on core, 50% on energy (same as Känzig, 2021 with different sample and specification).

Gas and oil pass-through to inflation in the EA

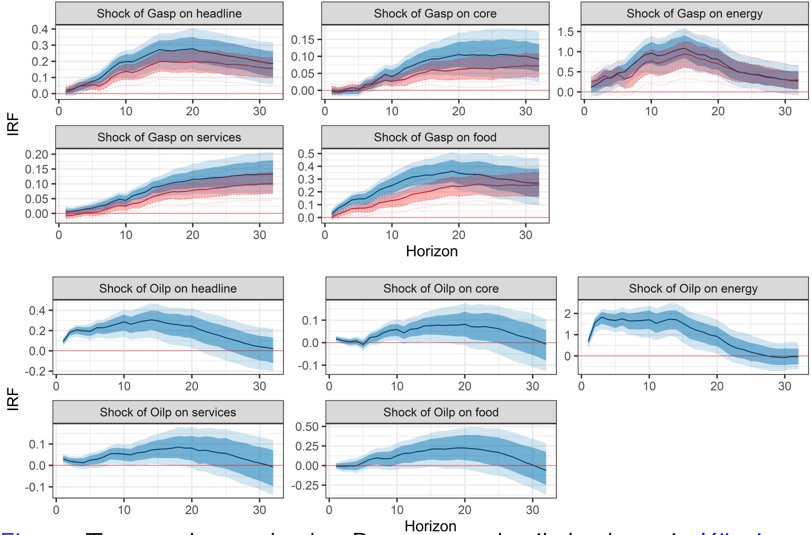


Figure: Top panel: gas shocks. Bottom panel: oil shocks as in Känzig (2021) (Fstat: 19.01)

Gas and oil pass-through to inflation in the US

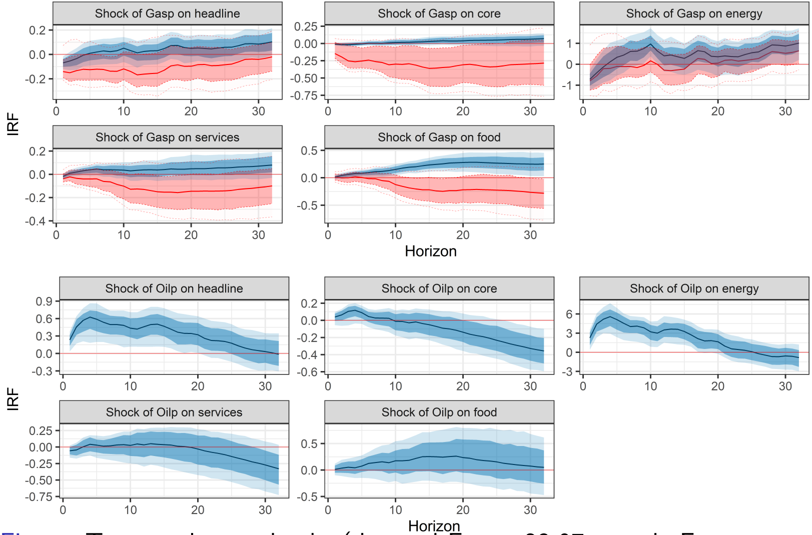


Figure: Top panel: gas shocks (demand Fstat: 23.07, supply Fstat: 3.91). Bottom panel: oil shocks as in Känzig (2021) (Fstat: 4.92)

A small-scale inflation VAR

Mixed *Proxy/Recursive-VAR* of 5 variables, where identify 4 structural shocks and leave a residual variable unidentified:

- **Supply chain disruptions shock**, identified recursively via short run restrictions
- **Gas price shock**, identified using exogenous variation in TTF Dutch gas price from
    1. Large deviations from calendar averages in temperatures
    2. High-frequency instrument based on gas-related news
- **Oil price shock**, extension of Känzig (2021), using Brent
- **MP shock**, extension of Altavilla et al. (2019) and informationally robust refinement by Miranda-Agrippino and Nenova (2022)

Look at IRFs and historical decompositions to assess the relevance of each series of shocks in the recent high-inflation period.

Supply chain bottlenecks

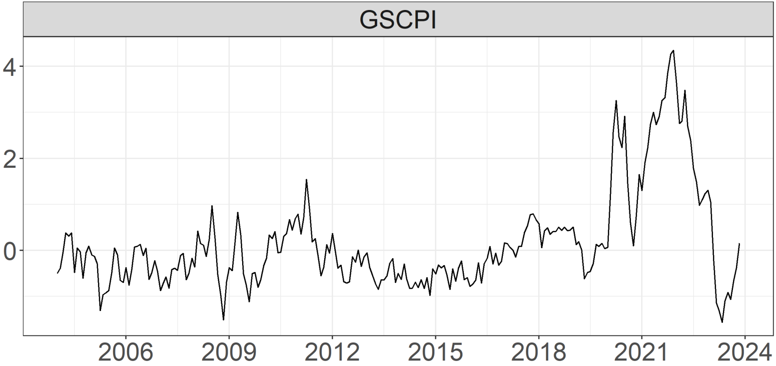


Figure: Global Supply Chain Pressure Index, Benigno et al. (2022).

IRFs of Inflation

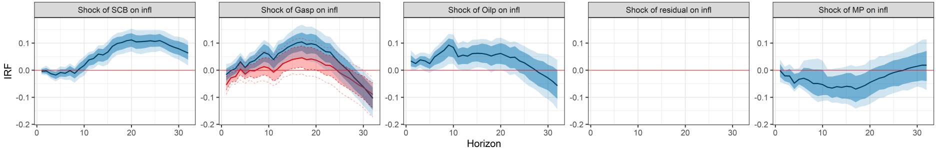


Figure: Responses of inflation to macroeconomic shocks (1sd impulses)

Findings:

- The recent inflation surge in the EA has mainly been driven by gas shocks and supply chain bottlenecks shocks, both of which have persistent effects. SCB operate with a significant lag.
- While oil prices have traditionally played a pivotal role, gas prices have been more significant. MP has been less effective.

Contribution to Inflation Surge in EA

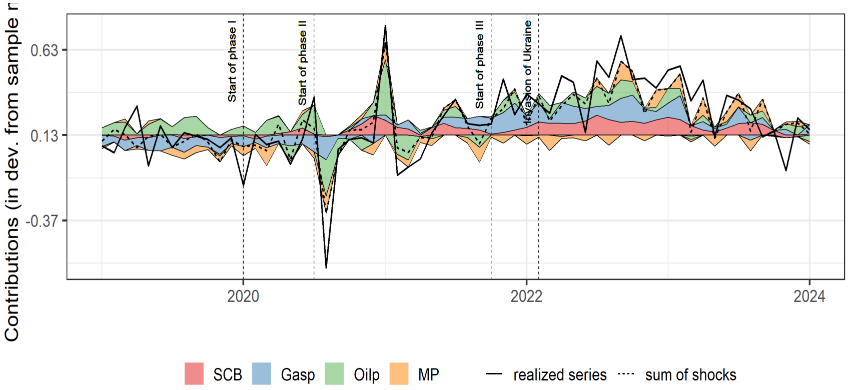


Figure: Historical decompositions of MoM inflation, selected sample, phases categorization by Ascari et al. (2023).

Implied contributions to price level

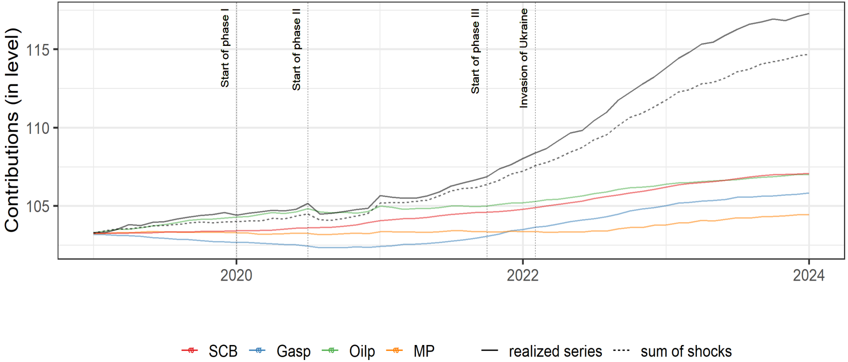


Figure: Historical decompositions of price level, selected sample, phases categorization by Ascari et al. (2023).

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, more so in the EA (net importer of gas) relative to the US (net exporter of gas).
- Provided comparable estimates of gas and oil shocks pass-through to inflation in the EA and the US. Estimated up to 3% pass-through of both gas and oil shocks to headline in the EA, while in the US gas is not significant and oil shocks are stronger (up to 6%). In both regions oil has stronger effect on energy component.
- Via a historical decompositions exercise found that energy shocks (first oil during lockdown and early reopening right after the pandemic, then gas) and SCB were among the main drivers of the recent inflation surge, while MP has been less effective.

Appendix A - 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

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

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

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
- An obvious potential confounder are food prices (also disrupted with the Ukraine war)
- To address this, construct informationally robust instrument (Romer and Romer, 2004)
  1. Construct food surprises around same gas news, using MATIF wheat futures (Datastream)
  2. Build the "informationally-robust" surprises as the residuals of the regression:

$$gas\_surprise_t^h = \alpha_0 + \sum_{j=1}^{2} \theta_j gas\_surprise_{t-j}^h + \sum_{j=0}^{2} \phi_j food\_surprise_{t-j}^h + IRS_t$$

where IRS_t denotes the Informationally Robust Surprises

Robustness checks: informationally robust supply instrument

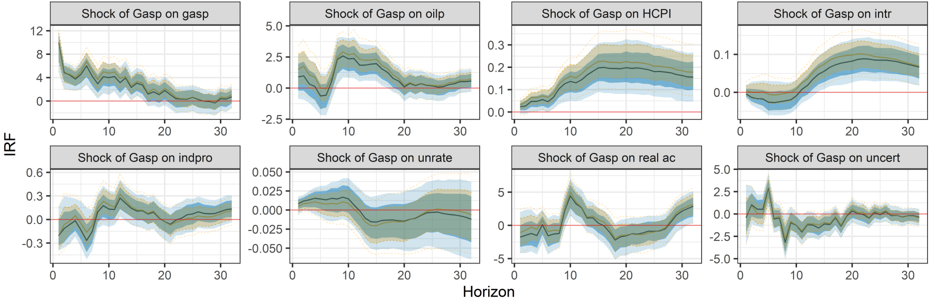


Figure: Standard (blue) and informationally robust (yellow) gas supply impulse responses.

Robustness checks: LPS

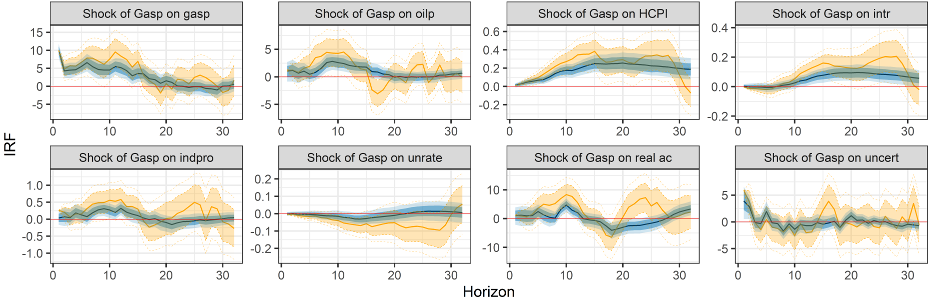


Figure: VAR (blue) and LP (yellow) gas demand impulse responses.

Robustness checks: LPS

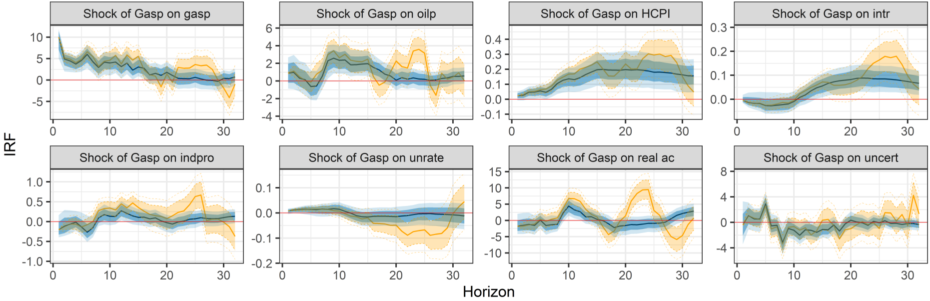


Figure: VAR (blue) and LP (yellow) gas supply impulse responses.

Appendix C - Assessing the instruments: instruments strength

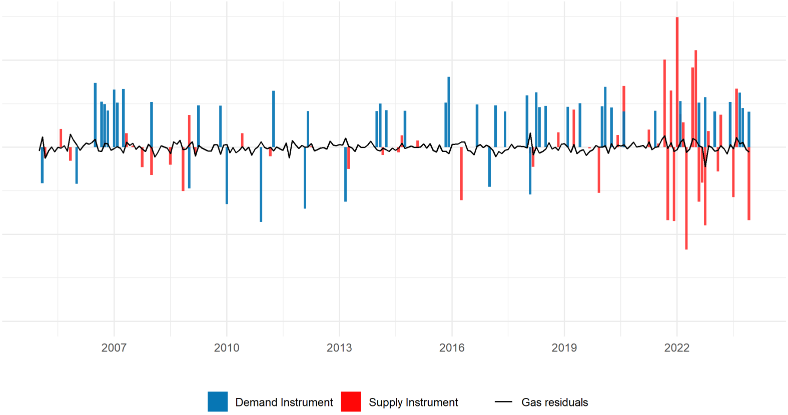
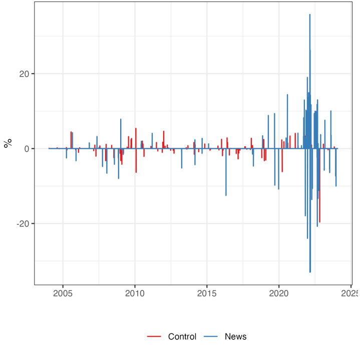
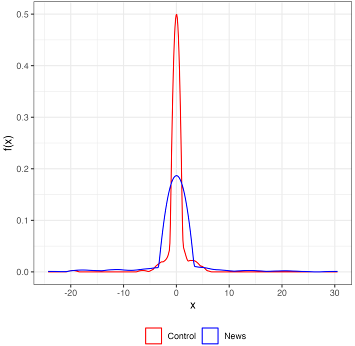


Figure: The figure shows how the gas and demand instruments are related to the reduced-form residuals. The series are rescaled.

Assessing the instrument: noise in the daily surprises



(a) Daily surprises



(b) 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.

Assessing the instrument: correlation with other shocks

Shock	ρ_{gas}	p-value gas	ρ_{temp}	p-value temp	n
Proxies_PC_oil	-0.08	0.20	0.03	0.58	242
Altavilla2019_Target	0.02	0.77	0.06	0.29	234
Jarocinski2020_Poorman	-0.03	0.68	0.01	0.91	234
MirandaAgrippino2022_TargetEA	-0.19	0.01	0.03	0.58	207
Caldara2019_CCI	0.05	0.52	0.02	0.65	144
Baker2016_GEPU	0.03	0.63	0.08	0.17	240
Hamilton2003_Oilp	0.00	0.95	0.02	0.66	168
Baumeister2019_Oilsupply	-0.14	0.08	0.07	0.16	168
Kilian2009_Oilsupply	-0.14	0.34	0.03	0.56	48
Kilian2009_Oildemand	-0.05	0.74	0.01	0.84	48
Kilian2009_Oilspecific	0.04	0.80	0.02	0.67	48
Gertler2015_FF4	0.15	0.07	0.06	0.27	156
Bloom2009_Uncert	-0.04	0.60	0.02	0.64	168
Baker2016_Uncert	0.04	0.57	-0.02	0.75	168
Gilchrist2012_EBP	-0.09	0.28	0.06	0.23	144

Table: Correlation with other macroeconomic shocks

Appendix D - historical decomposition of US gas price

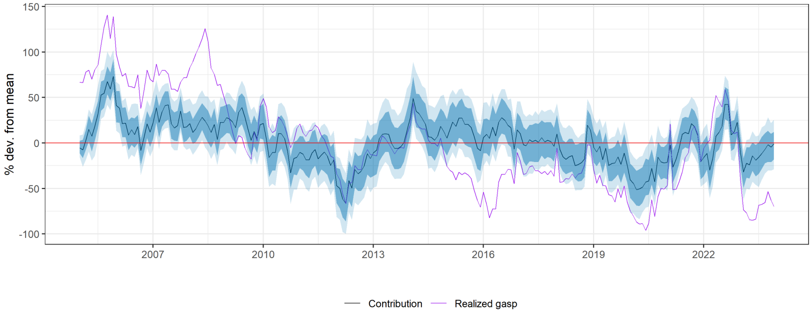


Figure: US: Historical decomposition of the real price of gas