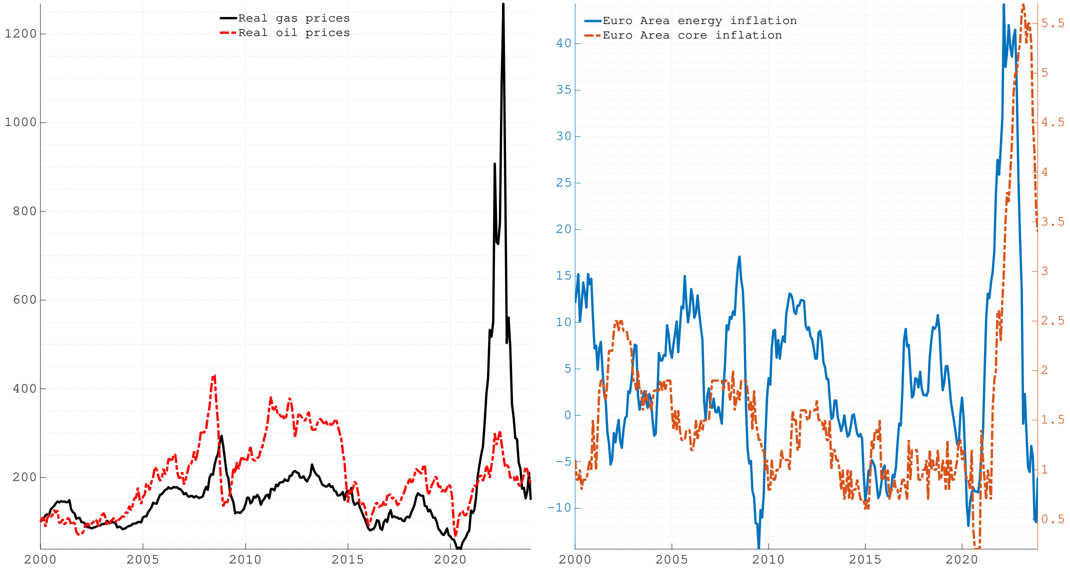
Natural gas and the macroeconomy: not all energy shocks are alike

Piergiorgio Alessandri Andrea Gazzani

Bank of Italy

JPM Research Symposium

Introduction



Introduction

- Europe was hit by **huge shocks to gas supplies** in 2021-22
- **Natural gas unknown** object from a macroeconomic perspective (vs oil)
- What was their impact on **inflation** and **economic activity**?
    - Quantitatively
    - Similar to other energy shocks?
    - Transmission channels

Introduction

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- What was their impact on **inflation** and **economic activity**?
  - Quantitatively
  - Similar to other energy shocks?
  - Transmission channels

- Gas prices reflect both **supply** and **demand** factors Go
- Identification strategies from oil literature (Baumeister & Hamilton, 2019; Kanzig, 2021) not sound/applicable:
  - Seasonality, long-term contracts, wholesale vs retail prices (regulation)
  - Investors do not hedge against aggregate shocks through the gas market Go

This paper

1. **Narrative high-frequency identification**
    - Construct an **instrument/proxy** for **gas supply shocks** analyzing **daily news** on the Title Transfer Facility (TTF) market
    - We focus on days with **large swings** in TTF prices

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   - We focus on days with **large swings** in TTF prices

2. **Bayesian Proxy VAR** $\Longrightarrow$ short samples and breaks in the data

   2.1 Quantify the impact of gas shocks on EU inflation and output

   2.2 Historical narrative

   2.3 Comparison with oil: pass-through

   2.4 Cross-country effects

Key results

1. Gas shocks are stagflationary

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2. **Their propagation is extremely slow**

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2. Their propagation is extremely slow

3. Their pass-through to core prices is larger than oil's

Literature

- Empirical analysis of gas supply shocks
  - Boeck & Zoerner (2023), Casoli et al. (2023), Adolfsen et al. (2024): VAR identified via sign restrictions (impact)
  - Energy shocks (not gas specific)
    - Corsello & Tagliabracci (2023), Neri (2023), Neri et al. (2023) $\Rightarrow$ recursive/mix of sign & 0 restrictions
  - Drivers of gas prices
    - Nick & Thoenes (2014), Rubaszek et al. (2021)

No a priori assumption on effects of gas supply shocks

  - Oil supply (and carbon policy) shocks
    - Hamilton (1983), Kilian (2009), Baumeister and Hamilton (2019), Kanzig (2021), Degasperi (2021), Kanzig (2022).

Outline

Identifying shocks to gas supply

Macro impact of shocks

Gas *versus* oil

Cross-country effects

Conclusions

Narrative identification (A)

Phase A: Consider **major daily price swings** in EU gas market

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- Consider absolute % variation in front month TTF future $> c$
  - Due to structural break in variance split sample Go
  - $c = 5\%$ in 2010-18
  - $c = 10\%$ in 2019-2022

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- 110 dates: 39 in 2010-2018 and 71 in 2019-2022

Narrative Identification (B)

Phase B: Select swings driven by **exogenous supply shocks**

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- Combine quantitative and qualitative analysis:
  1. Count demand (D) and supply(S) news and create sign-weighted index
  2. Select dates with **relevant S shocks** and **no D shocks**
  3. Check consistency between signs of S shocks and ΔTTF

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We conservatively drop all potentially spurious dates to preserve validity in IV

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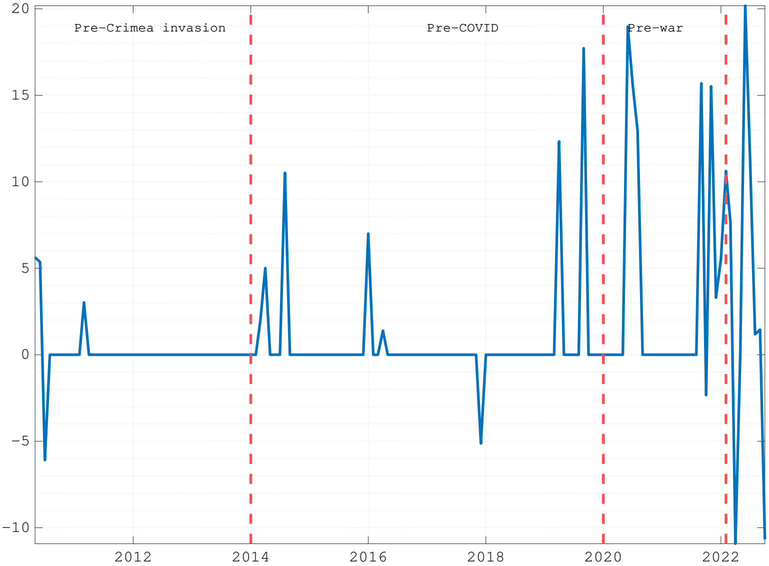
- Finally, we select **50/55 daily gas supply swings** incorporating
  1. **actual supply** shocks
  2. **supply news** shocks
  3. shocks to **supply risk**

Examples of supply swings for the EU gas market

event date	*key headline*	*%ΔTTF*
03-Mar-2014	Tensions piling up between Russia and Ukraine	9.5
29-Aug-2014	Gazprom accuses Ukraine of stealing gas	15.9
28-Apr-2016	Gazprom hopes Nord Stream 2 avoids problems with Brussels faced by predecessor	-9.6
10-Sep-2019	EU court ruling against Gazprom on Opal Pipeline	17.7
29-Jun-2020	US threaten to sanction EU on NS2	15.6
03-Aug-2020	Tensions between Poland and Gazprom	12.9
05-Oct-2021	Putin declaration: "Gazprom will prioritize domestic market"	20.0
28-Oct-2021	Gazprom declares it can pump gas into EU storage	-10.9
29-Oct-2021	Gazprom reaches agreement with ENI and Moldova	-23.3
24-Feb-2022	Russia invades Ukraine	51.1
25-Feb-2022	Reassurances from Gazprom on gas flows	-30.7
02-Mar-2022	Yamal stops; Sanctions on EU-Russian gas joint-ventures	36.1
09-Mar-2022	Gazprom books Yamal transit	-27.3
10-Mar-2022	Regular Gazprom supply to EU	-18.9
23-Mar-2022	Gazprom will require payments in rubles	18.5
14-Jun-2022	Nord Stream 1 limited capacity due to turbine stuck in Canada	16.4
15-Jun-2022	Nord Stream 1 volumes drop further; implications of Freeport LNG Fire Continue to Grow	24.0
04-Jul-2022	Gazprom may ask for rubles payment also for LNG exports; Norway flows drop by 13% due to strike	10.3
25-Jul-2022	Gazprom announced Nord Stream flows cut due to renew dispute on Siemens turbine	10.5
26-Jul-2022	Nord Stream flows drop to 20% of capacity	13.2
22-Aug-2022	Three days stop to Nord Stream announced	13.2
25-Aug-2022	Gazprom states that turbines are not being repaired in Canada	10.0
29-Aug-2022	Flows to Ukraine increase; Yamal flows regularly	-19.6
02-Sep-2022	Data signals Nord Stream 1 flows to resume	-11.7
05-Sep-2022	New halt to Nord Stream1 flows	14.7

The monthly IV (averaged)



Diagnostics

Several **diagnostics** on the goodness of our natural gas supply IV:

Diagnostics

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1. Cumulative plot Go

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Diagnostics

Several **diagnostics** on the goodness of our natural gas supply IV:

1. Cumulative plot Go
2. Variance ratios Go
3. Correlation with other shocks (IV) Go
4. Overlap with macro surprises & monetary policy events Go
5. Financial effects of the shocks Go

Outline

Econometric framework - VAR

Consider the standard VAR model:

$$\mathbf{y}_t = \mathbf{a} + \mathbf{A}_1\mathbf{y}_{t-1} + \cdots + \mathbf{A}_p\mathbf{y}_{t-p} + \mathbf{u}_t \tag{1}$$

p the lag order, $\mathbf{y}_t$ a $n \times 1$ vector of endogenous variables, $\mathbf{u}_t$ a $n \times 1$ vector of reduced-form innovations with covariance matrix $\text{Var}(\mathbf{u}_t) = \boldsymbol{\Sigma}$, $\mathbf{a}$ is a $n \times 1$ vector of constants, and $\mathbf{A}_1, \ldots, \mathbf{A}_p$ are $n \times n$ matrices.

$\mathbf{u}_t$ is a linear combination of the structural shocks $\boldsymbol{\varepsilon}_t$ under invertibility:

$$\mathbf{u}_t = \mathbf{B}\boldsymbol{\varepsilon}_t$$

$\text{Var}(\varepsilon_t) = \boldsymbol{\Omega}$ is diagonal as the structural shocks are by construction uncorrelated.
$\Sigma = \mathbf{B\Omega B}'$ is not diagonal as the reduced-form residuals are correlated.

Identification via external instruments

We are interested in estimating the causal impact of a unique shock - i.e. the gas supply shock $\varepsilon_{1,t} \Rightarrow$ recover a single column $\mathbf{b}_1$ of the impact matrix $\mathbf{B}$.

Identification via external instruments z_t (Stock and Watson, 2012; Mertens and Ravn, 2013) assumes:

$$\begin{aligned} \mathbb{E}\left[z_t \varepsilon_{1,t}\right] &= \alpha \neq 0 \qquad \textit{(relevance)} \\ \mathbb{E}\left[z_t \varepsilon_{2:n,t}\right] &= 0 \qquad \textit{(exogeneity)} \end{aligned} \tag{2}$$

$\varepsilon_{1,t}$ the gas supply shock; $\varepsilon_{2:n,t}$ the remaining structural shocks. Then $\mathbf{b}_1$ is correctly estimated up to scale and sign as

$$\mathbf{b}_1 \propto \frac{\mathbb{E}\left[z_t \mathbf{u}_t\right]}{\mathbb{E}\left[z_t \mathbf{u}_{1,t}\right]'} \tag{3}$$

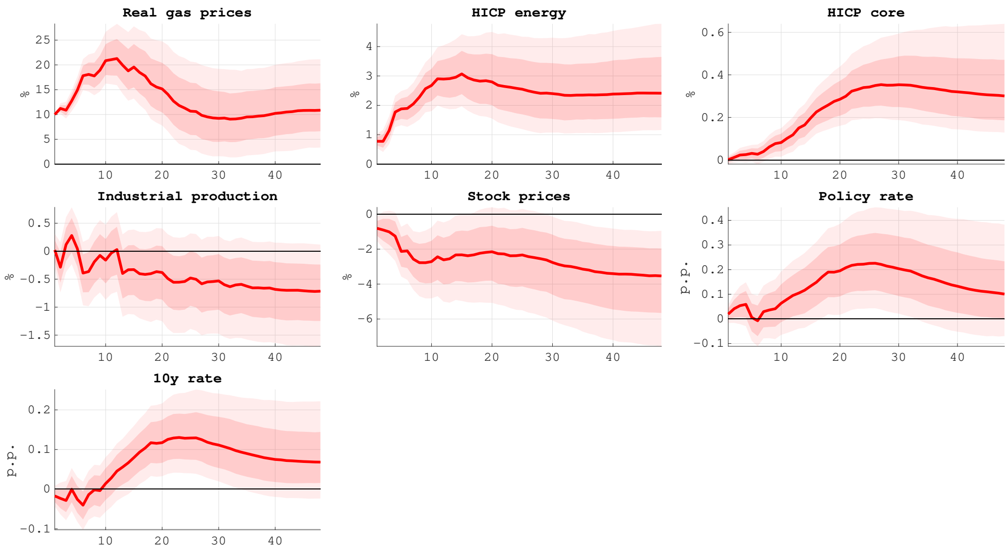
Identification via heteroskedasticity robust to endogeneity of IV Go

Data and model specification

- The estimation sample from Jan-2000 to Dec-2023
- The identification sample from Jan-2010 to Nov-2022 (IV availability; no price cap)
- Baseline VAR for Euro Area 19 includes [*Real gas prices, HICP energy, HICP core, Industrial production, Stock prices, Shadow short-term rate (Krippner 2013, 2018), 10 year Bund rate*]
- Variables in growth rates (except interest rates)
- Bayesian estimation under a Minnesota prior
  - Lenza & Primiceri (2022) Covid rescale of residuals
  - Joint optimization of rescaling factor and prior hyperparameters
- First-stage statistics ⇒ **strong IV**

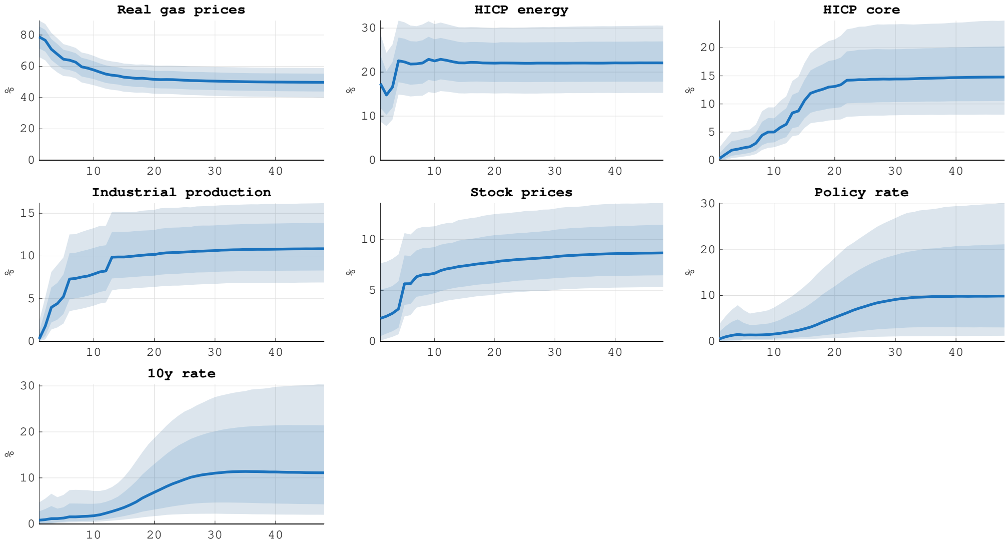
F-stat (rob) $= 40.4\ (17.6)$ Pvalue < 0.0001 $R^2 = 0.20$

Baseline IRFs



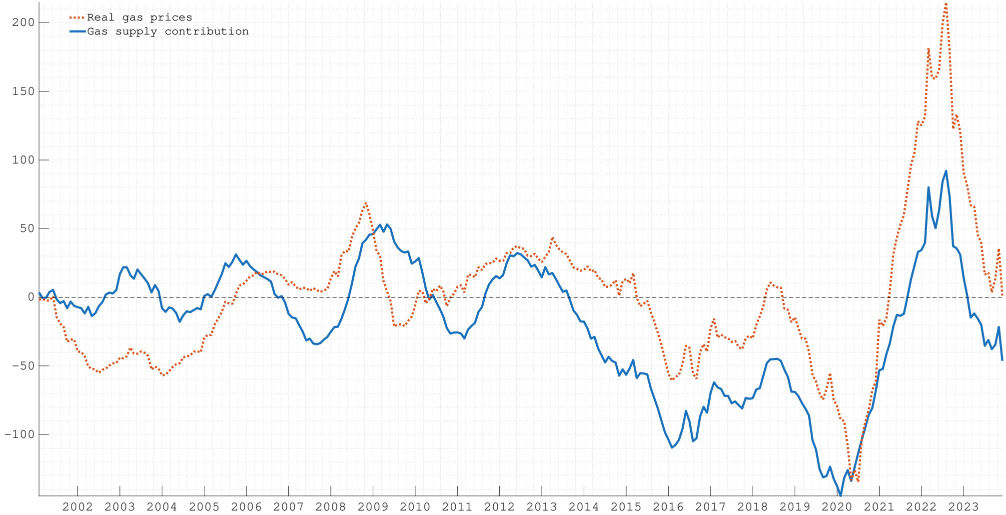
IRFs to a gas supply shock identified via external instrument. Median and 68-90% credible sets.

Baseline FEVD



FEV contribution of gas supply shocks identified via external instrument. Median and 68-90% credible sets.

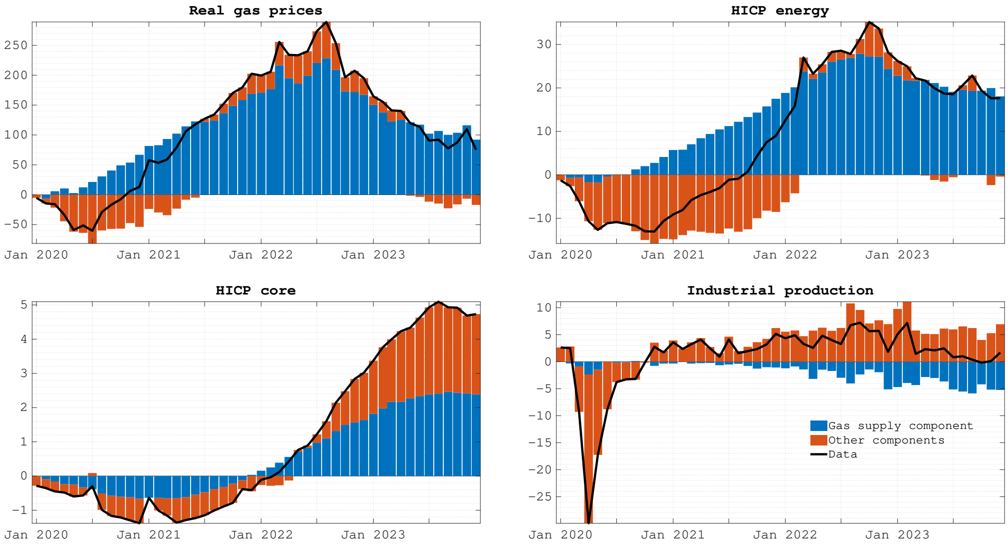
Historical narrative



Historical contribution of gas supply shocks identified via external instrument. Deviation from sample average.

HD in growth rates Shocks

The gas crisis



Historical contribution of gas supply shocks identified via external instrument since 2020.

Robustness & additional results

- Soften IV exogeneity assumption ⇒ Identification via heteroskedasticity
- Alternative specification
  - economic activity Urate , inflation (YoY) YoY inflation , oil prices Brent , geopolitical risk GPR , bottlenecks GSCPI , gas quantities GasQ , nominal gas prices Nominal Pgas
- Alternative Covid modelling
  - do not model it
  - drop Covid (Mar-2020 to Mar-2021)
  - include health variables (Ng, 2021)
- Stop sample in 2021 2021
- Inference under a flat prior Flat
- Local projection
  - LP with extracted shocks LP
  - employing LP-IV estimation (restricted sample) LP-IV

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Macro impact of shocks

Gas *versus* oil

Cross-country effects

Conclusions

Are all energy shocks alike? (A)

- Rich literature and debate on the impact of **oil price shocks** on non-energy inflation and inflation expectations

- Oil and gas markets **diverge** across **multiple dimensions** steaming from technical and historical roots
  - Contracts (spot vs long-term)
    - Gas imports based in part on long-term contracts: price is a lagged MA of day ahead TTF (or Brent); nominations
    - Arbitrage opportunity if prices are volatile
  - Relationship with electricity mkt in EU
    - Gas prices typically drive electricity prices $\Rightarrow$ marginal fuel of production (merit order)
    - Proposal to redesign EU electricty mkt after gas crisis (Fabra, 2023)
  - Role and timing for consumers and firms
    - Regulation in gas and electricity prices

- No reasons to expect the **transmission** of those shocks to be homogeneous

Are all energy shocks alike? (B)

To compare effects of oil and gas supply shocks

- Enrich VAR with real electricity prices (EEX), PPI energy, and HICP liquid fuels (gasoline)
- Repeat VAR exercise for gas and oil prices (10% increase driven by supply)
- Use **2SLS Proxy-SVAR** identification of oil supply shocks combining **oil supply shocks** from Baumeister & Hamilton (2019) and **oil supply news shocks** from Kanzig (2021)
- Keeping fixed estimation and identification samples

Compare **pass-through** of **oil** and **gas** supply shocks to **core inflation**

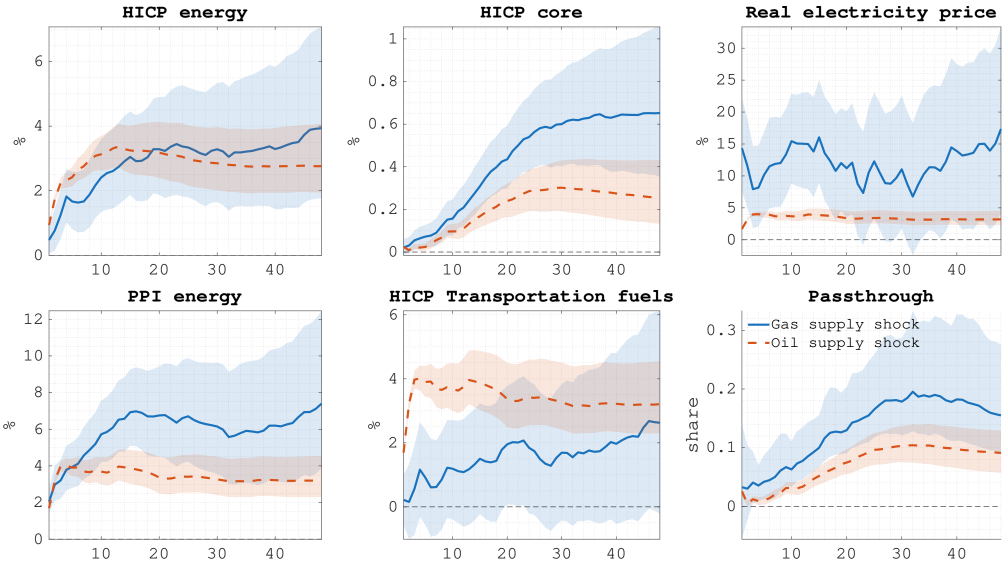
Pass-Through comparison

IRFs-based measure of **pass-through** (PT) from energy to core prices:

$$PT_h^s = \frac{\sum_{1:h} IRF_h^s(HICP\ core)}{\sum_{1:h} IRF_h^s(HICP\ energy)} \tag{4}$$

- h is the horizon in months and s denotes either oil or gas supply shocks
- PT_h^s is nothing but the (cumulative) *HICP core* response scaled by the *HICP energy* response observed in the same months.
- represents the response of the core prices that one would expect to see in period h after a one unit increase in energy prices stemming from a contraction in oil or gas supplies.

Pass-Through comparison: IRFs



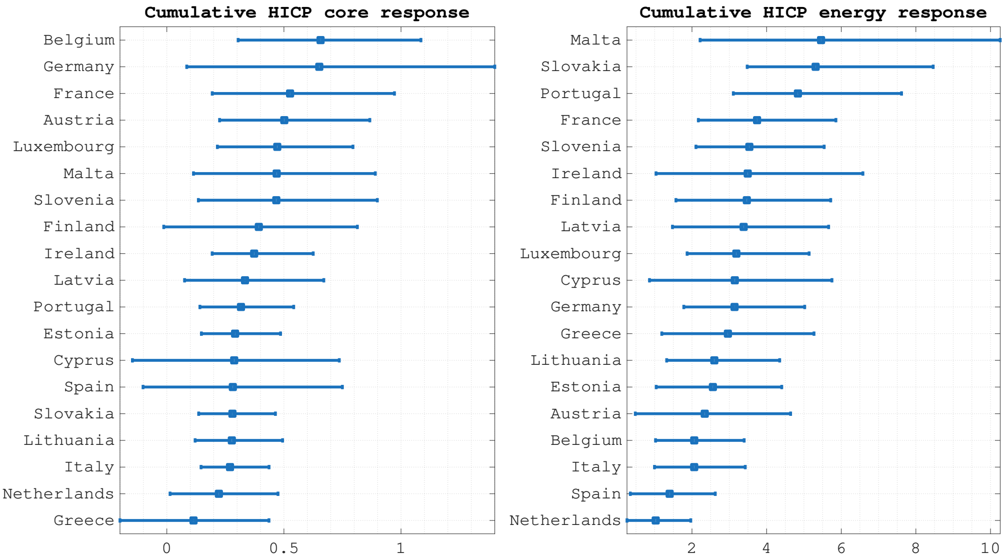
delta

Outline

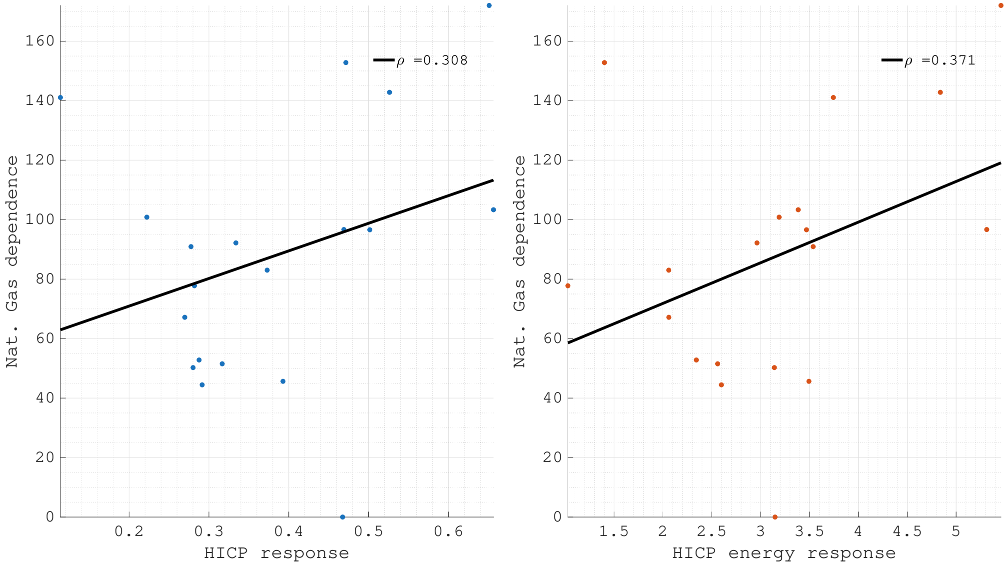
Cross-country analysis

- Repeat VAR exercise for each of the Euro Area (19) country
- Including domestic HICP energy, HICP core and IP
- Correlate responses with the gas intensity of each economy

Cross-country effects



Gas supply effects and gas intensity



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- How do **gas supply shocks** affect the **macroeconomy**?
- A **key issue** for Europe, but one that we **know/knew little** about
- We provide qualitative and quantitative answers combining **narrative high-frequency identification** and **Bayesian econometrics**

Conclusions

- How do **gas supply shocks** affect the **macroeconomy**?
- A **key issue** for Europe, but one that we **know/knew little** about
- We provide qualitative and quantitative answers combining **narrative high-frequency identification** and **Bayesian econometrics**
    - Gas supply shocks play a key role since 2021
    - **Sizable impact** on **output** and **inflation**
    - Their propagation is very much **delayed**
    - **Natural gas pass-through** is **larger** then **oil**
    - Heterogeneity driven by the crucial role played by gas in the the **electricity market**

Lesson for the future

Green transition ⇒ consider the specific features of each commodity market

Background

Daily LP-IV models

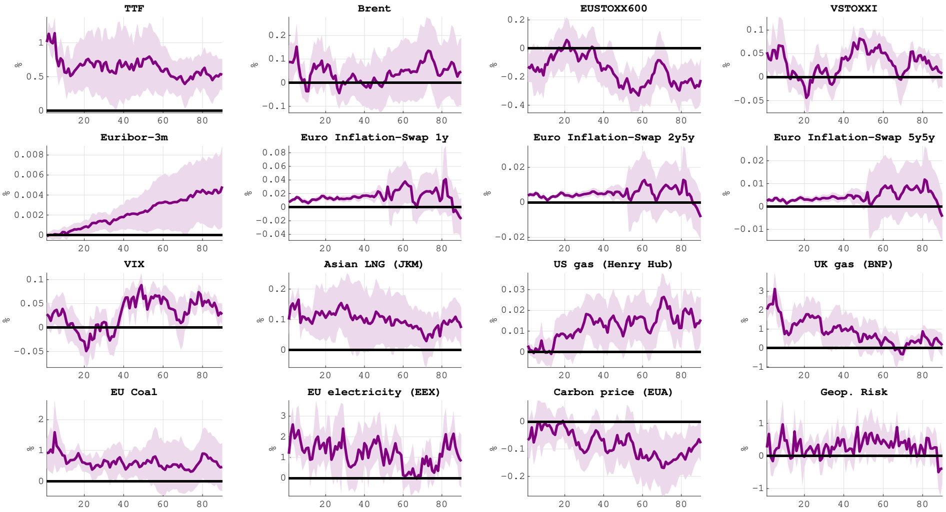
- How do **gas supply shocks** affect **asset** and **commodity/energy prices**?
- We estimate IV **Local Projection** models using daily data
  - Instrument z_t takes values ΔTTF_t on our selected dates, 0 otherwise
  - LP usually preferred to estimate IRFs over very long horizons
  - Daily data abundant and not subject to same breaks as macro aggregates

$$y_{t+h} - y_{t-1} = \alpha_h + \beta_h TTF_t + A^h(L)X_{t-1} + \epsilon_t \quad h = 0, .., 100 \tag{5}$$

- where TTF_t is instrumented with the supply swing series z_t and X contains up to 10 lags of y and TTF
- First stage:

$$\text{Robust F-stat} = 624.5 \qquad \text{Pvalue} < 0.0001 \qquad R^2 = 0.46$$

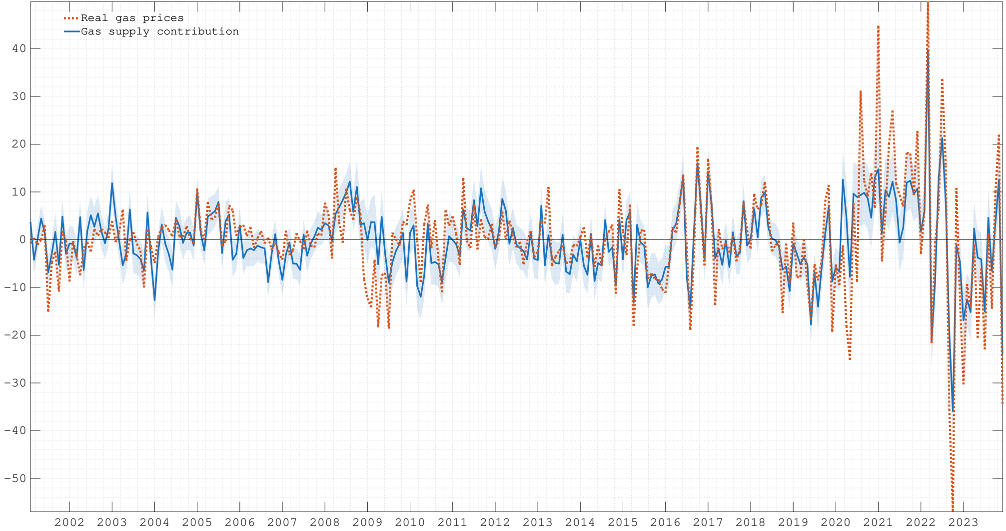
IRFs from daily LP-IV



IRFs to a gas supply shock with LP-IV.

Median and 90% confidence bands. Back

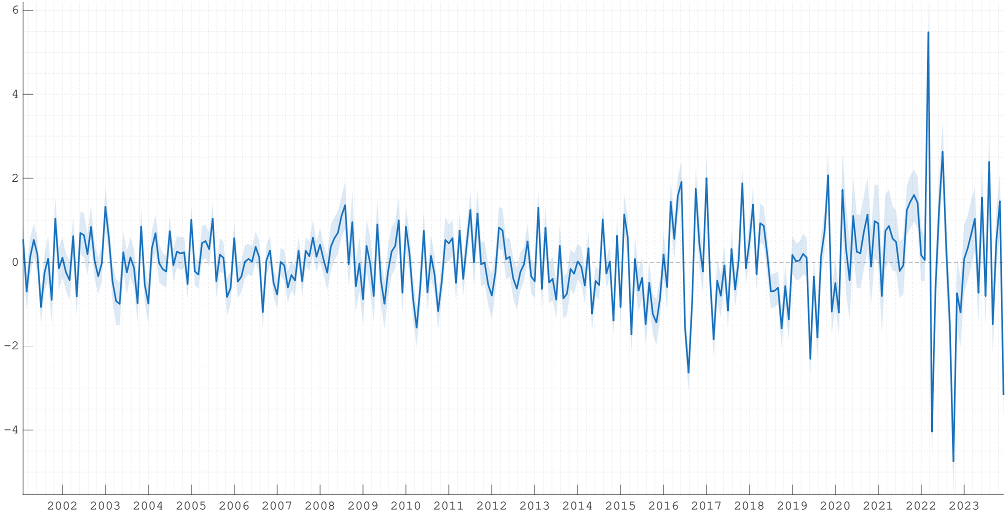
Historical narrative



Historical contribution of gas supply shocks identified via external instrument. Median and 68% credible sets.

Back

Gas supply shocks



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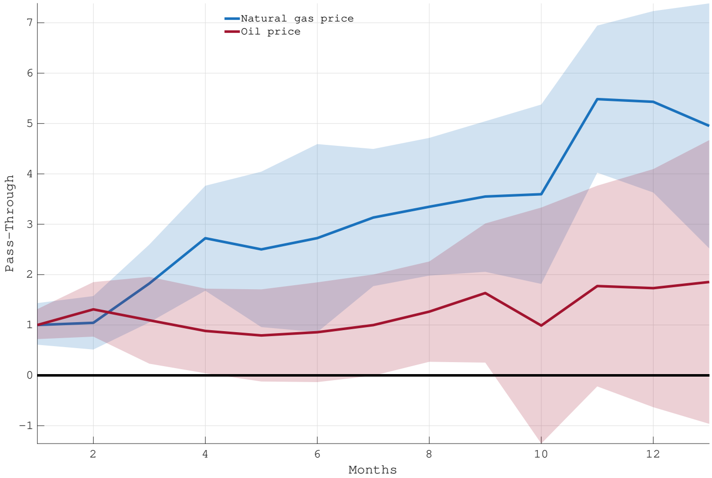
Back

Oil vs Gas transmission (naive)

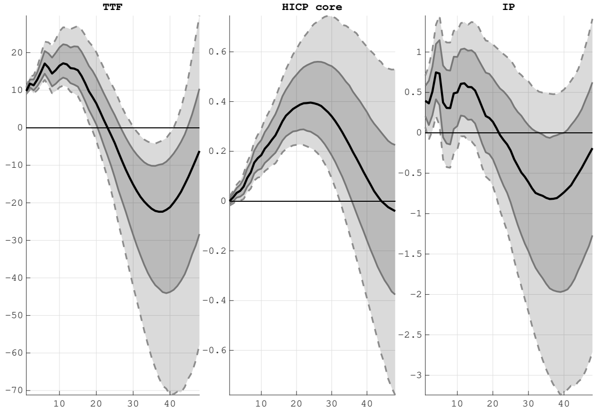


PASS-THROUGH FROM GAS AND OIL PRICES TO CONSUMER ENERGY PRICES.

The figure shows the estimated β^h coefficients from a local projection of the form $Y_{t+h} = \alpha^h + \beta^h p_t + \theta^h X_t + \epsilon_{t+h}$, where Y is the energy component of the Euro Area consumer price index, p is the wholesale gas or oil price and X includes four lags of Y and p (all in logarithms). The sample runs from January 2012 to November 2022. Back

Supply vs Demand in gas prices

- Gas prices are driven by both demand and supply factors
- A Cholesky "gas shock" causes an **increase in IP** ...



IMPACT OF GAS SUPPLY SHOCKS UNDER A NAIVE CHOLESKY IDENTIFICATION

Small monthly BVAR for European economy (EA17), 2010-2022. Logs of Real gas prices (SA), HICP core (SA), IP. BVAR under a Minnesota prior and Covid fix as in Lenza and Primiceri (2022). Median and 68-90% confidence sets. Back

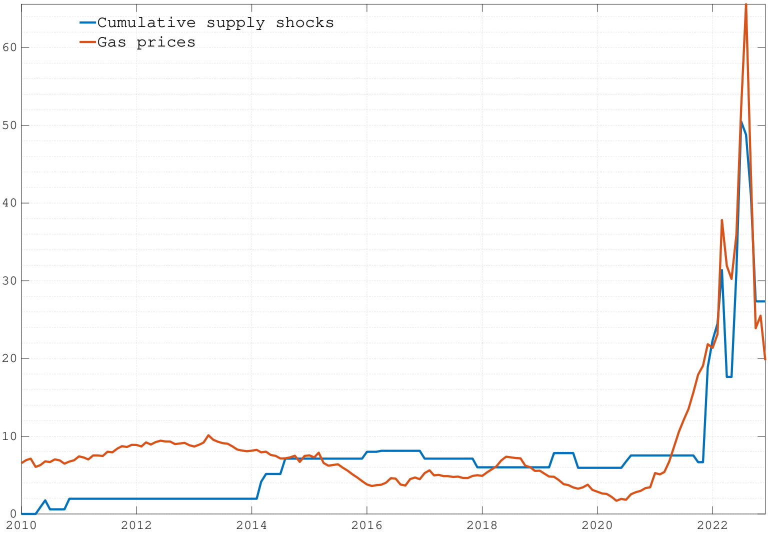
Variance test

Sample	Observations	Mean	Std
2019-2022	874	0.175	5.783
2010-2018	939	0.007	1.996
Pooled	1813	0.088	4.264
Levene's statistic (absolute)	227.4		
Degrees of freedom	11811		
p-value	0		

Test of equality of variances (Levene test).
The test compares the volatility in the TTF growth rate across the samples 2010-18 and 2019-2022.

Back

Data *vs* cumulated ΔTTF on supply shock dates



Back

A simple identification diagnostic: variance ratios

- Do our dates systematically pick up shocks of other types?
- Simple check: look at how **variances** change on **gas supply swing dates**
  ⇒ the shocks should affect TTF more than any other series

Sample	TTF	Brent	Coal	Wheat	EuroStoxx	VStoxx	Euribor-3m	Geopol. Risk
2010-2022	25.4*	1.5	23.5*	2.7*	2.4*	1.8*	3.3*	0.72
2010-2019	14.3*	2.6	1.6	1.2	1.4	1.8	0.4	0.78
2020-2022	12.6*	0.6	11.3*	2.7*	2.2*	1.5	1.5	0.60

VOLATILITIES ON SHOCK AND NO-SHOCK DATES.

For each indicator the table reports the ratio between the volatility observed gas supply swing days versus the remaining dates in the sample. The ratios are computed over the full sample as well as the 2010-2019 and 2020-2022 subsamples. * denote a ratio statistically different from 1 at the 1% level (Levene test).

- TTF displays the largest increase in variance
- In 2020-2022, **oil prices** are actually ***less* volatile** on gas supply swing dates (!)

Back

Macro news diagnostics

- Check correlation with macro suprises (CESI)

	Fstat	Pvalue	R2	Adj. R2	Obs.
Supply swing days	0.08	0.99	0.01	-0.11	55
Whole sample	0.37	0.89	0.001	-0.001	3631

Ortogonality test: CESI and gas supply IV

- Check overlap with monetary policy meetings (FOMC & ECB Governing Council)
  - No overlap with FOMC meetings
  - 4 days overlap with ECB Governing Councils: 6 May 2010, 21 Apr 2016, 28 Oct 2021, 10 Mar 2022
    - Monetary policy surprises (Jarocinski and Karadi, 2020) are very small: 0.20, 0.04, 0.01, 0.36 standard deviations of the daily surprises
    - If we regress at monthly (daily) the gas supply IV on the monetary policy surprises we find no explanatory power F-stat = 1.73(0.0464), Pvalue = 0.19(0.83)
    - Within our daily LP and monthly VAR, interest rates respond with marked delay to a gas supply shock $\Rightarrow$ contamination risk appear negligible
    - If we exclude the overlapping dates we obtain similar results but for a more noisy response of IP

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Correlation with other shocks

	Corr.	P-value	Obs.
Kanzig (2021) oil supply shocks	0.001	0.98	156
Kanzig (2022) carbon policy shocks	0.12	0.21	120
Baumeister and Hamilton (2019) oil supply shocks	-0.14	0.13	156
Baumeister and Hamilton (2019) demand shocks	-0.03	0.74	156
Caldara and Iacoviello (2022) GPR global - AR(1) residual	0.07	0.37	156
Caldara and Iacoviello (2022) GPR Russia - AR(1) residual	0.09	0.22	156

Back

Identification via heteroskedasticity - setup

Even if the **exogeneity assumption** is **violated**, we can still achieve identification by mixing the external instrument approach with identification via heteroskedasticity.

$$z_t = \varepsilon_{1,t} + \sum_{j>1} \varepsilon_{j,t} + \nu_t \tag{6}$$

Control group (C): those TTF swings dates that we had excluded from our supply-driven/treatment set of events (T) because related to demand factors or a mixture of supply and demand. The crucial assumption is:

$$\begin{aligned} \frac{\sigma^2_{\varepsilon_1,T}}{\sigma^2_{\varepsilon_j,T}} &\neq \frac{\sigma^2_{\varepsilon_1,C}}{\sigma^2_{\varepsilon_j,C}} \quad \text{for } j = 2, \ldots, n \\ \sigma^2_{v,C} &= \sigma^2_{v,T} \end{aligned} \tag{7}$$

Identification via heteroskedasticity - estimation

The impact of gas supply shocks can be recovered as

$$\mathbf{b}_1 = \frac{\mathbb{E}_T\left[z_t \mathbf{u}_t\right] - \mathbb{E}_C\left[z_t \mathbf{u}_t\right]}{\mathbb{E}_T\left[z_t^2\right] - \mathbb{E}_C\left[z_t^2\right]} \quad (8)$$

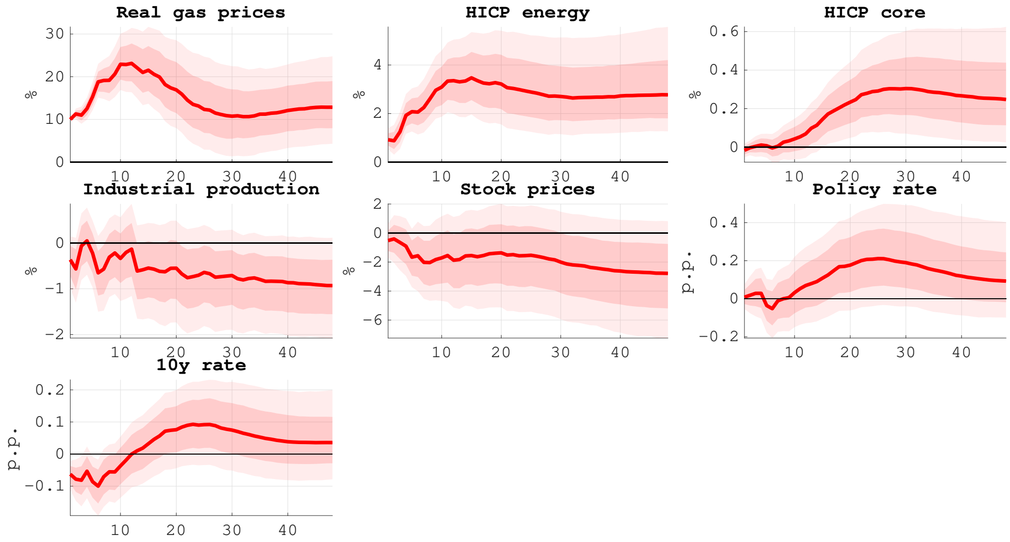
Equivalently Rigobon and Sack (2004) show that the estimation can be performed through an IV approach

$$\mathbf{b}_1 = \left(\tilde{\mathbf{z}}'\mathbf{z}\right)^{-1}\left(\tilde{\mathbf{z}}'\mathbf{u}\right) \quad (9)$$

where $\tilde{\mathbf{z}} = \left(z'_T, -z'_C\right)'$ and $\mathbf{z} = \left(z'_T, z'_C\right)'$.

Back

Identification based on heteroskedasticity



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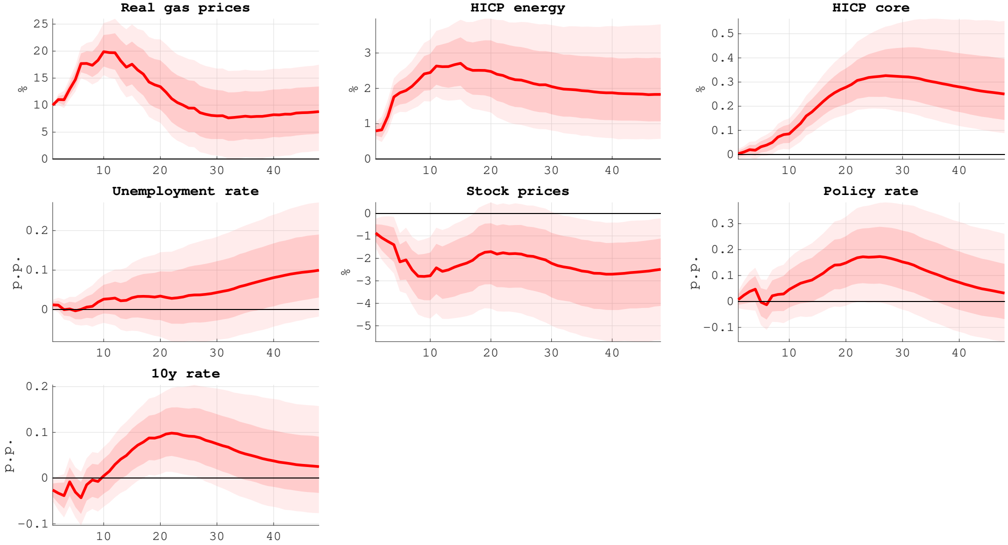
Unemployment



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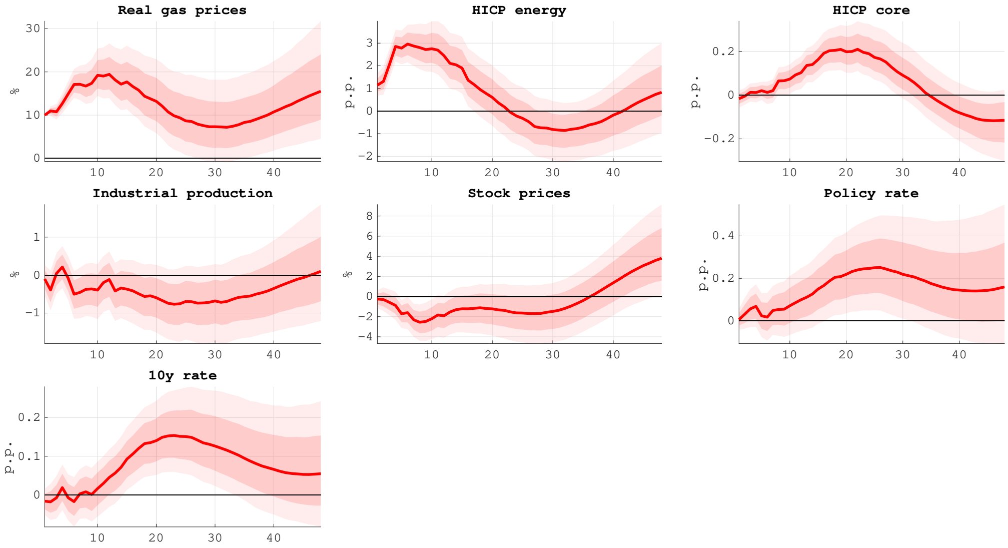
YoY inflation



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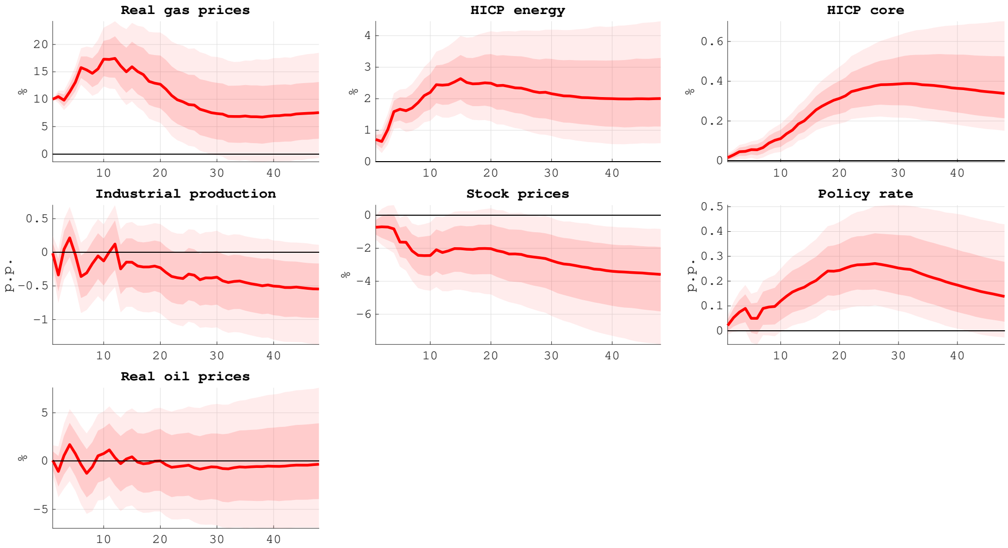
Brent



Real gas prices
%
HICP energy
HICP core
Industrial production
p.p.
Stock prices
Policy rate
Real oil prices

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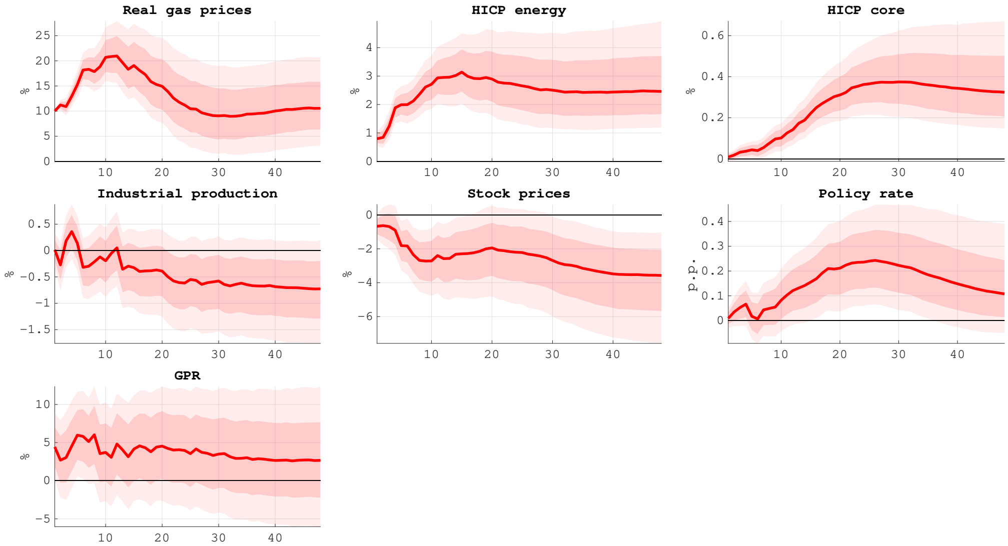
Geopolitical risk



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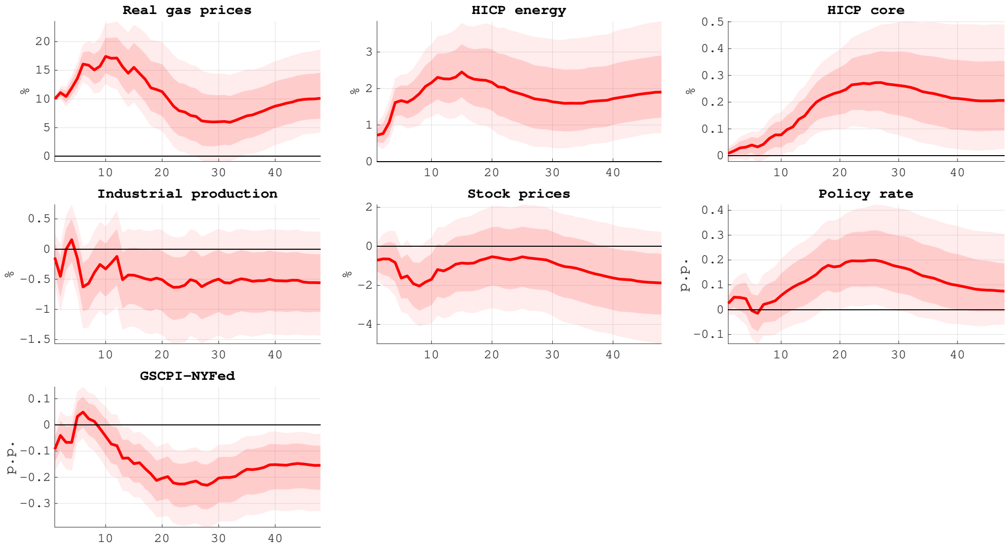
Bottlenecks NY index



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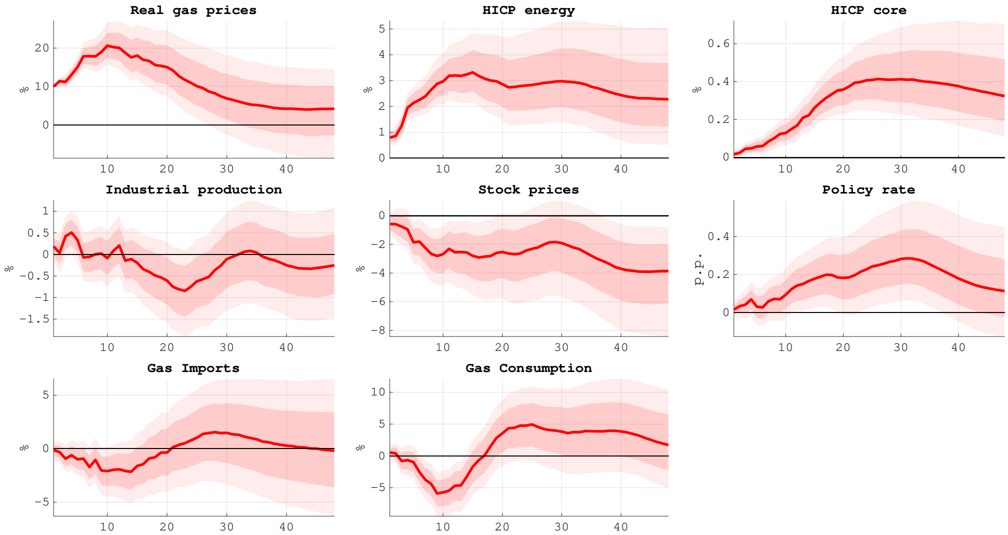
Gas quantities



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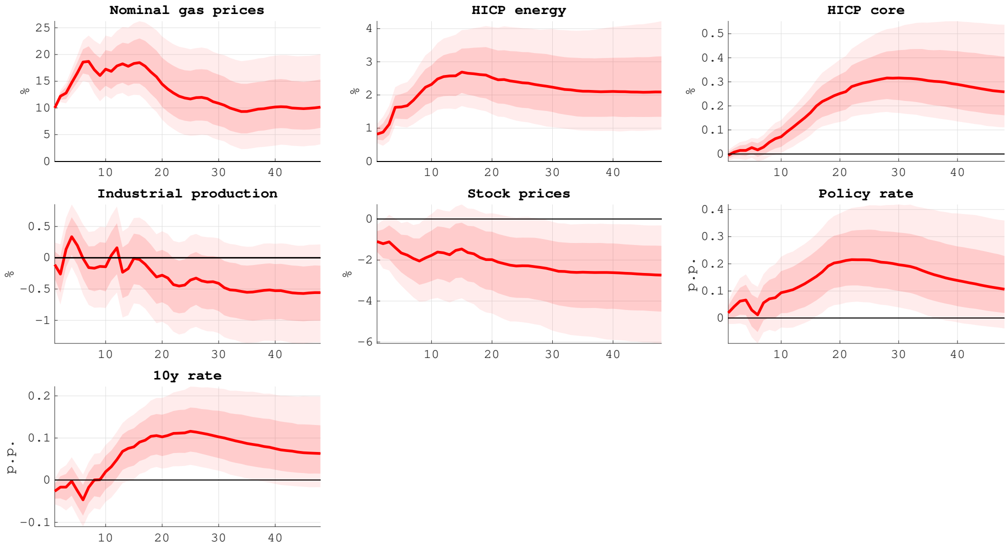
Nominal gas prices



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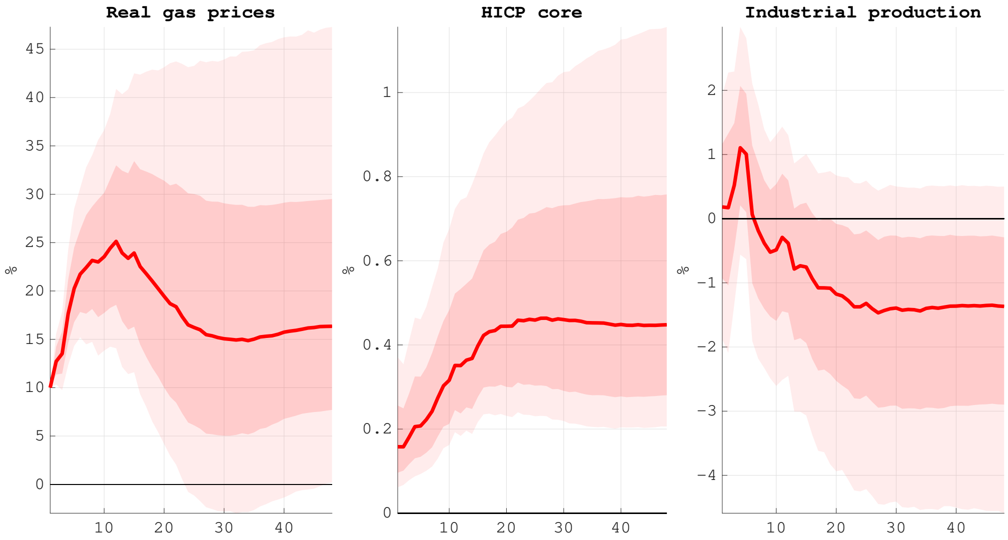
Stop sample in 2021



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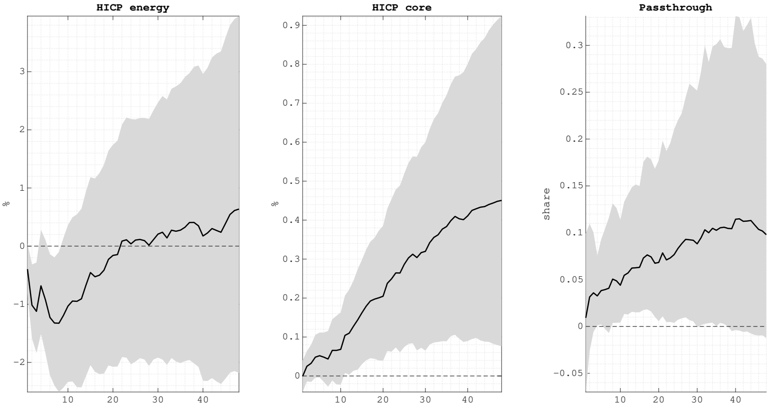
Gas and oil explicit delta

- Assess explicitly statistical difference in inflation and PT responses to a oil/gas supply shocks
- Include gas and oil prices in the VAR and identify IRFs via external IV method
- For each posterior draw, compute delta in responses to gas and oil:



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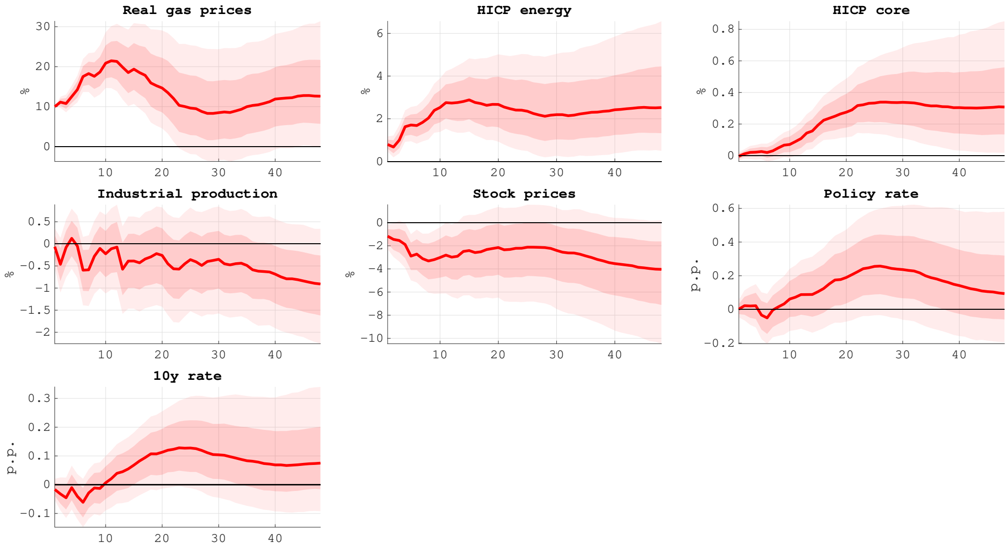
Flat prior



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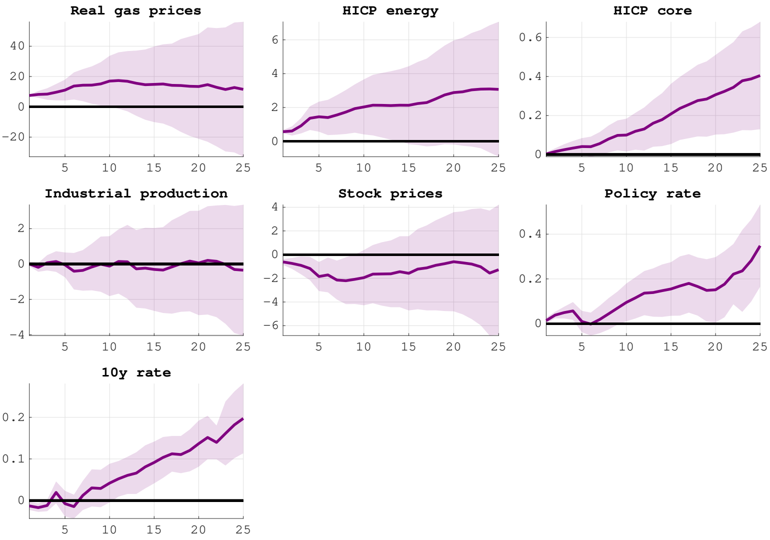
Local projects IRFs



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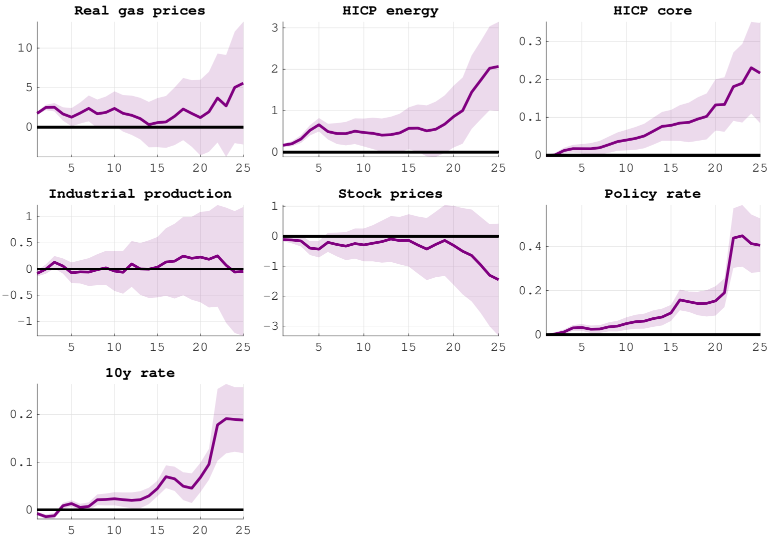
LP-IV IRFs



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