Revisiting Fundamentals of the European Gas Market: The Role of Supply Substitution

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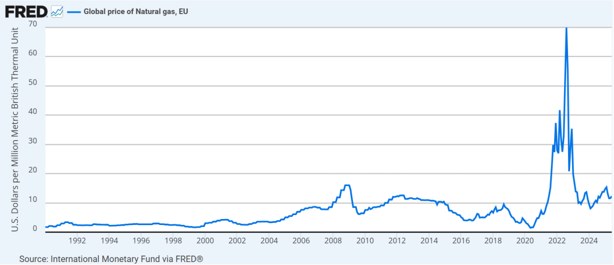
Introduction

- Economic activity relies on **energy consumption**.

- Natural Gas (NG) was the **second most consumed** energy source in 2021.

- **2022 energy crisis** marked the highest NG prices.



Introduction

- Renewed attention to the **structural drivers** of the European gas market
- Apply Structural VAR models developed for crude oil:
  - European NG market: *Adolfsen et al. 2024*, *Güntner et al. 2024* or *Boeck et al. 2025*.
  - American NG market: *Rubaszek et al. 2021* or *Farag 2024*
- But all of them ignore that **supply composition** affects the price formation.

Introduction

- This paper:

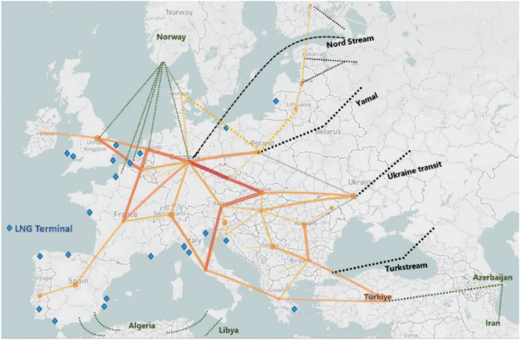
    1. Identifies structural drivers of the European NG market using a Bayesian SVAR with sign restrictions.

    2. Allow the model to capture substitution effects between two types of supply: pipeline gas and liquefied natural gas (LNG).

    3. Examine whether NG shocks affect the valuation of (sectoral) European companies.

- Natural gas, produced primarily outside the EU, must be transported to Europe either by ship (as LNG) or via pipeline.

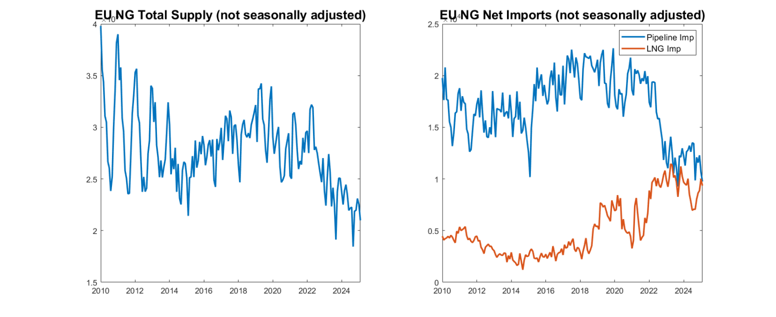
Europe: Cross-Border Transmission Capacities and Import Points



Sources: IMF staff based on ENTSOG (System Development Map, 2021, and Transparency platform)
Notes: Thicker and darker lines represent larger transmission capacities as of December 2021. Direction of flows within EU and individual pipelines not shown. Dotted lines represent import pipelines into Europe. Dashed yellow lines represent pipelines expected to come online in the next twelve months.

Why is supply composition important?

- Ignoring supply composition can lead to an **underestimation of supply-side** dynamics (*Moll et al. 2023; Hamilton 2023*).
- *Why?* because substitution between pipeline gas and LNG obscures the underlying drivers of total supply.



▸ Details

Data

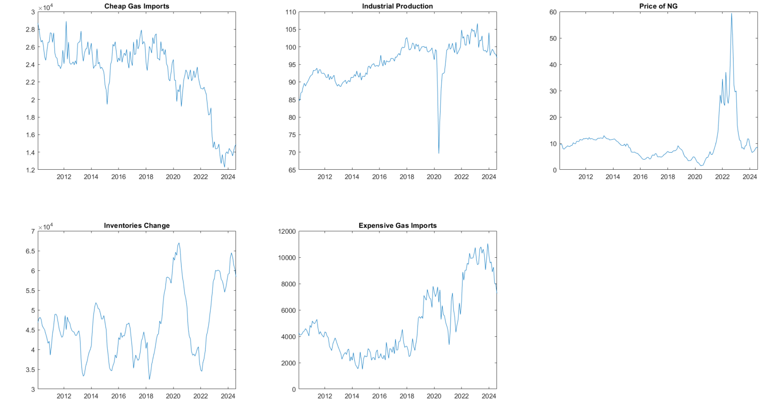
Data is obtained from the following sources:

- Joint Organization Data Initiative (JODI)[1] [2]:
  - **Cheap NG Supply**:
    Pipeline Imports − *Pipeline Exports* + *Domestic Production*
  - **LNG NG Supply**: *LNG Imports* − *LNG Exports*
  - **Change in inventories**: $NG\ Inventories_t - NG\ Inventories_{t-1}$
- Eurostat: manufacturing **industrial production** in the EU19.
- World Bank Commodity Price (WBCP): **Nominal EU NG price** (in $).
- Federal Reserve Economic Data (FRED): **CPI** in the USA.

[1] All of them are seasonally adjusted using ARIMA X13 TRAMO-SEATS.
[2] Selected countries: DE, FR, ES, IT, BE, NL, DK, PT, CH, AT, CZ, HU, GR, LT, FI.

Data

- Data is collected in a vector of endogenous variables: $y_t = [q_{\text{pip}}, ip, p, s, q_{\text{LNG}}]$



- Univariate unit root test strongly reject stationarity. All variables are expressed in log-growths.

Structural relationships

- **Pipeline and LNG supply:**

$$q_t^{pip} = \gamma_{qp} p_t + \mathbf{b}_1' x_{t-1} + \varepsilon_t^{\text{pipeline supply}}$$

$$q_t^{LNG} = \beta_{qp} p_t + \mathbf{b}_5' x_{t-1} + \varepsilon_t^{\text{LNG supply}}$$

- **Industrial activity:**

$$ip_t = \alpha_{yp} p_t + \mathbf{b}_2' x_{t-1} + \varepsilon_t^{\text{aggregate demand}}$$

- **Gas (flow) demand:**

$$Q_t = \alpha_{py} ip_t + \alpha_{pq} p_t + \mathbf{b}_3' x_{t-1} + \varepsilon_t^{\text{flow demand}},$$

- **Inventories (precautionary demand):**

$$s_t = \psi_1 q_t^{pip} + \psi_2 p_t + \psi_3 q_t^{LNG} + \mathbf{b}_4' x_{t-1} + \varepsilon_t^{\text{precautionary demand}}$$

Identification through sign restrictions

- Structural elasticities in **A** matrix follow economic sign assumptions:

Parameter	Interpretation	Restriction
γ_{qp}	Pipeline supply elasticity	> 0
β_{qp}	LNG supply elasticity	> 0
α_{yp}	Price effect on activity	< 0
α_{qy}	Income elasticity of demand	> 0
α_{qp}	Price elasticity of demand	< 0
$\psi_1,\ \psi_2,\ \psi_3$	Inventory elasticities	none

- Restrictions are implemented as truncated priors on **A**.
- Ensures $\mathbf{A}^{-1}$ (impact matrix) yields economically consistent responses.

Structural and impact matrices

Contemporaneous elasticities

$$\mathbf{A} = \begin{pmatrix} 1 & 0 & -\gamma_{qp} & 0 & 0 \\ 0 & 1 & -\alpha_{yp} & 0 & 0 \\ 1 & -\alpha_{py} & -\alpha_{qp} & -1 & 1 \\ -\psi_1 & 0 & -\psi_2 & 1 & -\psi_3 \\ 0 & 0 & -\beta_{qp} & 0 & 1 \end{pmatrix}$$

- Under: $\gamma_{qp} > 0 \quad \beta_{qp} > 0 \quad \alpha_{yp} < 0 \quad \alpha_{qy} > 0 \quad \alpha_{qp} < 0$

Structural and impact matrices

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Impact matrix

$$sign(\mathbf{A}^{-1}) = \begin{pmatrix} + & + & + & ? & ? \\ + & + & - & ? & + \\ - & + & + & + & - \\ ? & ? & - & + & ? \\ ? & + & + & ? & + \end{pmatrix}$$

Each column of $\mathbf{A}^{-1}$ represents the contemporaneous effect of a particular structural shock on the vector of endogenous variables.
Each row of $\mathbf{A}^{-1}$ represents the contemporaneous effect of the vector of structural shocks on a particular variable.

Methodology: SVAR framework

- The model is formulated as a Structural VAR (SVAR):

$$\mathbf{A}y_t = \mathbf{B}x_{t-1} + u_t, \quad u_t \sim N(0, \mathbf{D})$$

- The parameters of the model are:
  - **A** contains contemporaneous elasticities among endogenous variables.
  - **B** captures autoregressive coefficients.
  - **D** is the variance covariance matrix of structural shocks.
- The reduced form can be recovered:

$$y_t = \Phi x_{t-1} + \varepsilon_t, \quad \Phi = \mathbf{A}^{-1}\mathbf{B}, \quad \Omega = \mathbf{A}^{-1}\mathbf{D}(\mathbf{A}^{-1})'$$

- Estimated using **Bayesian methods** with **sign restrictions** Baumeister et al. 2015 & Baumeister et al. 2019.

Methodology: Priors and identification

- Joint prior decomposed as:

$$p(\mathbf{A}, \mathbf{B}, \mathbf{D}) = p(\mathbf{A})\, p(\mathbf{D} \mid \mathbf{A})\, p(\mathbf{B} \mid \mathbf{A}, \mathbf{D})$$

- Elements of **D** follow inverse-Gamma priors; rows of **B** follow multivariate normal priors.
- Priors on **A** reflect economic knowledge via truncated Student-t distributions.
- Following BH (2015, 2019), priors on elasticities remain informative under set identification.
- Remark: Priors incorporate information not given by the likelihood. They can incorporate information from the literature to ensure plausible structural elasticities.

Methodology: Posterior and estimation

- Likelihood assumes normal structural innovations:

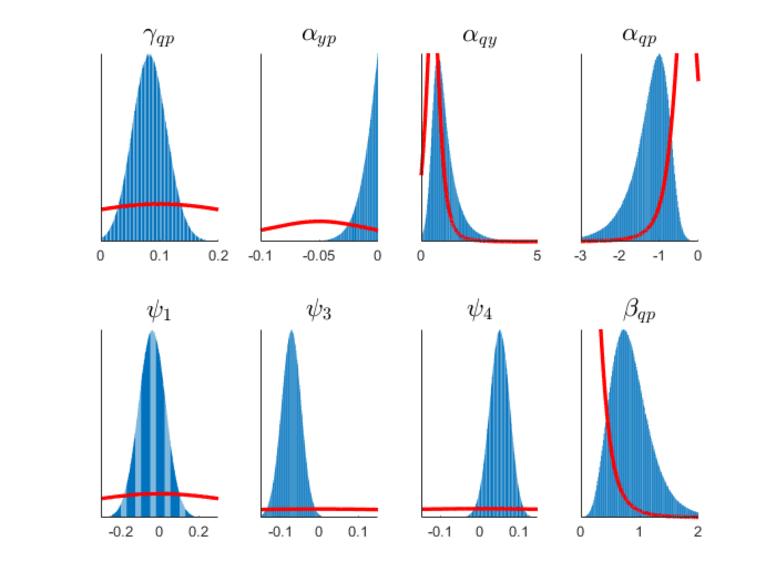
$$p(Y_T \mid \mathbf{A}, \mathbf{D}, \mathbf{B}) = (2\pi)^{-\frac{Tn}{2}} |\det(\mathbf{A})|^T \det(\mathbf{D})^{-\frac{T}{2}}$$

$$\times \exp\left\{ -\tfrac{1}{2} \sum_{t=1}^{T} (\mathbf{A}y_t - \mathbf{B}x_{t-1})' \mathbf{D}^{-1} (\mathbf{A}y_t - \mathbf{B}x_{t-1}) \right\}$$

- The MCMC used for drawing from the posterior:
  - *Gibbs-Sampler step*: Posteriors for **B** and **D** are conditionally conjugate (Normal–Gamma).
  - *Metropolis hasting step*: **A** is sampled numerically under sign restrictions. ▸ Convergence

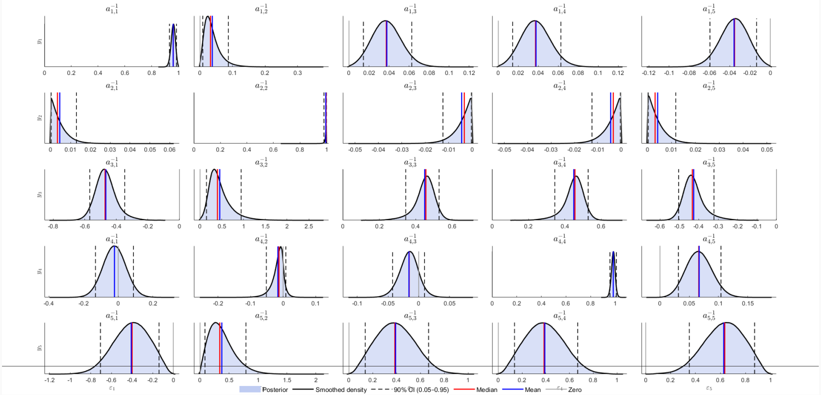
Results: Posterior of A

▸ Posterior formula



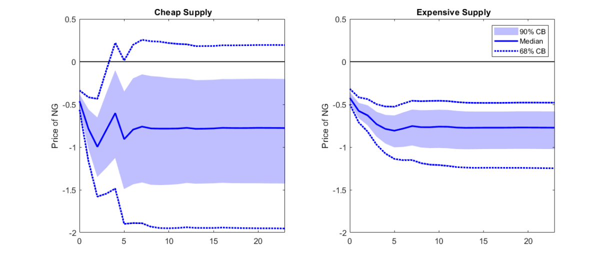
Results: Identification

$$\underbrace{\begin{pmatrix} \varepsilon_{q^{pip},t} \\ \varepsilon_{ip,t} \\ \varepsilon_{p,t} \\ \varepsilon_{s,t} \\ \varepsilon_{q^{LNG},t} \end{pmatrix}}_{\text{Reduced form shocks}} = \underbrace{\begin{pmatrix} + & + & + & + & - \\ + & + & - & - & + \\ - & + & + & + & - \\ ? & ? & ? & + & + \\ - & + & + & + & + \end{pmatrix}}_{\mathbf{A}^{-1}} \underbrace{\begin{pmatrix} u_t^{\text{pipeline supply}} \\ u_t^{\text{aggregate demand}} \\ u_t^{\text{flow demand}} \\ u_t^{\text{precautionary shock}} \\ u_t^{\text{LNG supply}} \end{pmatrix}}_{\text{Structural shocks}}$$

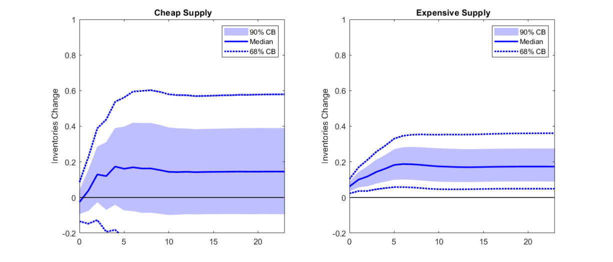


Results: (cumulative) IRF of two supplies

- Cheap supply disruptions have positive transitory effects on the price.

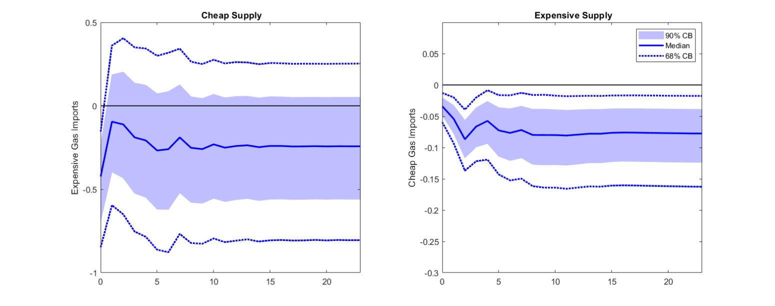


- Expensive supply disruptions have permanent effects on inventories.



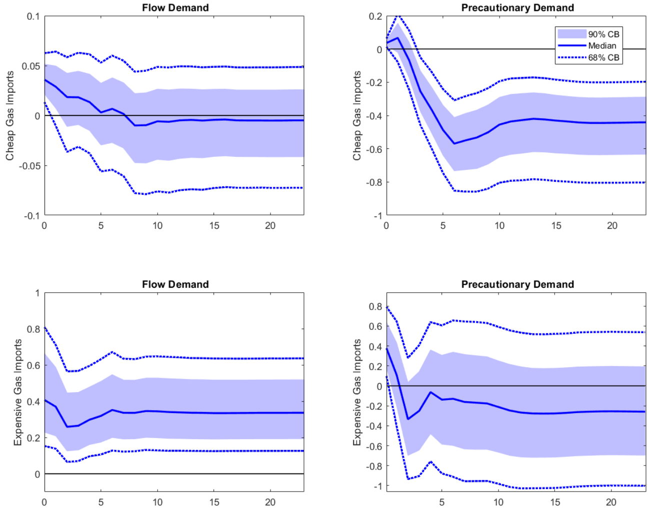
Results: Substitution between two supplies

- Expensive supply shock substitutes cheap NG imports.

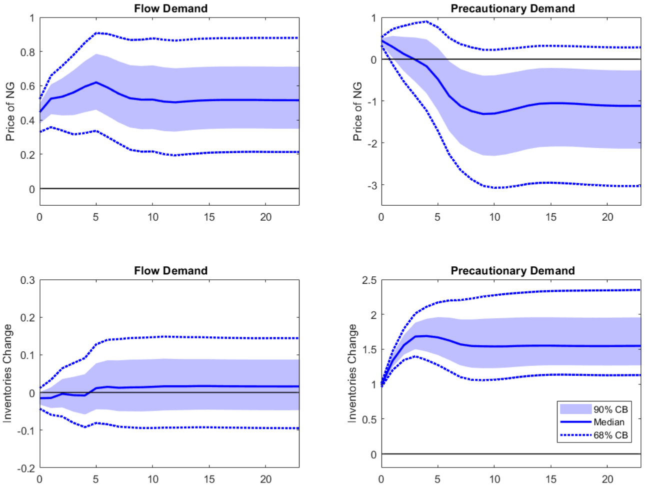


Results: (cumulative) IRF of two demands

- Precautionary demand anticipates disruptions on the cheap imports.



Results: (cumulative) IRF of two demands



Results: Forecast Error Variance Decomposition

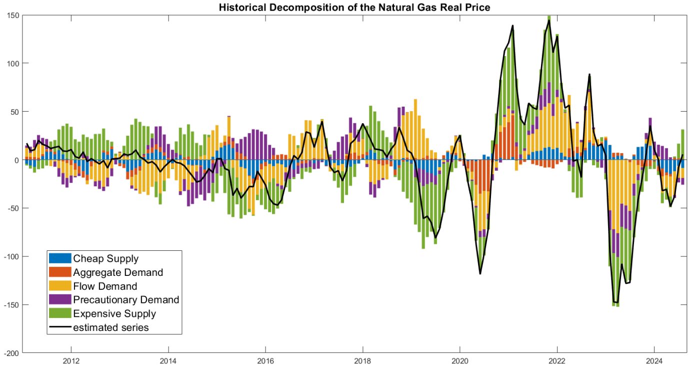
Table: Median FEVD of the Price (contribution of every shock in %)

	Cheap. Sup.	Aggr. Dem.	Flow Dem.	Prec. Dem.	Exp. Sup.
1 month	22.7	15.0	21.1	21.1	19.1
2 months	18.4	42.9	11.0	13.9	10.9
3 months	19.3	43.1	9.4	15.1	9.5
6 months	16.9	55.8	5.2	14.6	5.5
1 year	15.7	53.7	4.4	19.5	4.7
2 years	15.6	53.7	4.3	19.8	4.7

- Supply factors shape more than 40% of the price variance in the short-run.
- Aggregate demand explains alone most of the long run variance.

Results: Historical Decomposition of the Price

Historical Decomposition of the log-growth of the price



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Results: Historical Decomposition of the Price

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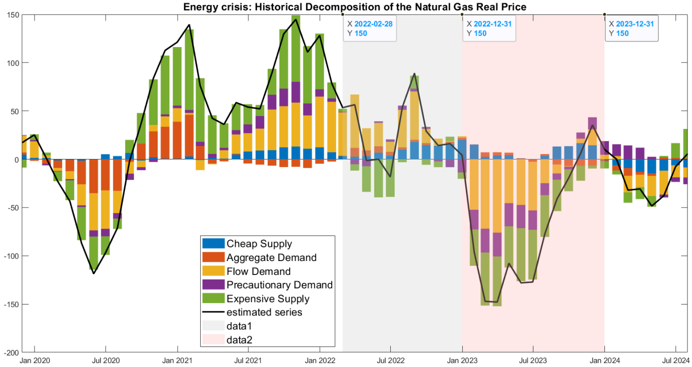
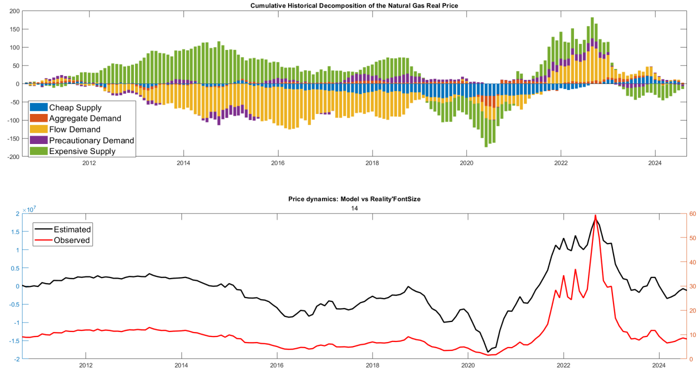


Results: Historical Decomposition of the Price

Cumulative Historical Decomposition of the log-growth of the price



Local Projections Specification (preliminar)

$$y_{t+h} = \alpha_h + \beta_h\, s_t + \tilde{\boldsymbol{\gamma}}_h^{\top} \tilde{\mathbf{x}}_t + \varepsilon_{t+h}, \quad h = 0, 1, \ldots, H$$

Explanation:

- The equation is estimated separately for each horizon h (*Local Projection*, Jordà 2005).
- y_{t+h}: response variable (e.g. a sectoral price index) at horizon h.
- s_t: structural shock at time t.
- $\tilde{\mathbf{x}}_t$: control vector including contemporaneous and lagged controls, lagged y, and lagged s.
- β_h: captures the impulse response of y_{t+h} to a unit innovation in s_t.

Conclusion

- The role of natural gas **supply-side drivers** has been largely underestimated in previous studies.
- While **demand factors** remain crucial for the long run price formation, **supply** is nearly as influential in the short run.
- Greater LNG supply and reduced flow demand (driven by the EU's energy-saving measures) contributed to stabilizing prices by the end of 2022.
- Future research: complete the Local Projections step.

Thank you!

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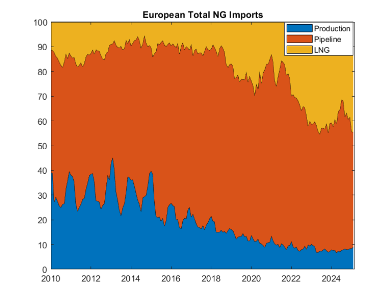
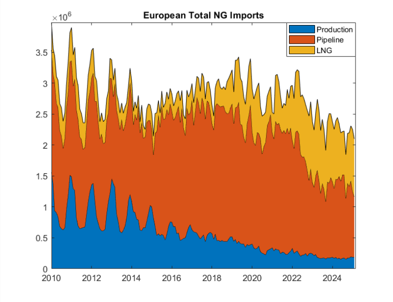
European NG Supply by source





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Convergence of the MCMC

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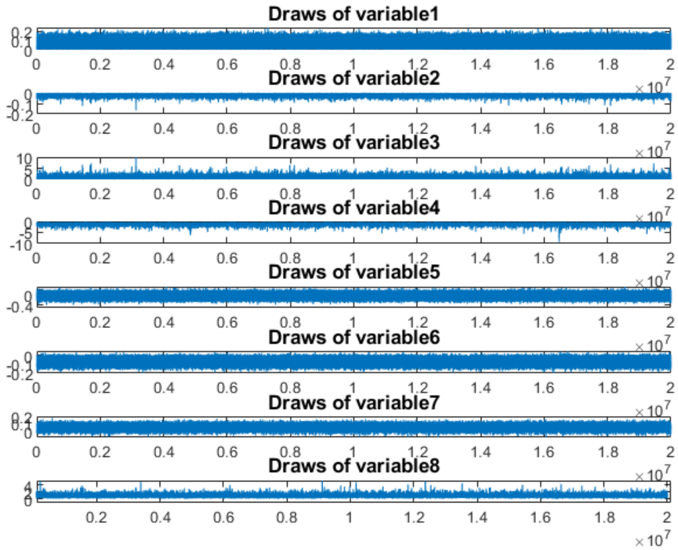

Posterior formula (Theorem 1 BH15)

- **Joint posterior decomposition:**

$$p(\mathbf{A}, \mathbf{B}, \mathbf{D} \mid Y_T) = p(\mathbf{A} \mid Y_T)\, p(\mathbf{D} \mid \mathbf{A}, Y_T)\, p(\mathbf{B} \mid \mathbf{A}, \mathbf{D}, Y_T)$$

- **Posterior of D** (diagonal covariance):

$$d_{ii}^{-1} \mid \mathbf{A}, Y_T \sim \Gamma(\kappa_i^*, \tau_i^*(\mathbf{A})), \qquad \kappa_i^* = \kappa_i + \tfrac{T}{2}, \quad \tau_i^*(\mathbf{A}) = \tau_i + \xi_i^*(\mathbf{A})$$

- **Posterior of B** (VAR coefficients):

$$b_i \mid \mathbf{A}, \mathbf{D}, Y_T \sim \mathcal{N}\big(m_i^*, d_{ii} M_i^*\big), \qquad m_i^* = (\tilde{X}_i' \tilde{X}_i)^{-1} (\tilde{X}_i' \tilde{Y}_i), \quad M_i^* = (\tilde{X}_i' \tilde{X}_i)^{-1}$$

- **Posterior of A** (structural matrix):

$$p(\mathbf{A} \mid \mathbf{Y}_T) = \frac{k_T\, p(\mathbf{A}) \left[\det(\mathbf{A} \hat{\Omega}_T \mathbf{A}')\right]^{T/2}}{\prod_{i=1}^n \left[(2\tau_i^*/T)^{\kappa_i^*}\right]} \prod_{i=1}^n \left\{ \frac{|\mathbf{M}_i^*|^{1/2}}{|\mathbf{M}_i|^{1/2}} \frac{\tau_i^{\kappa_i}}{\Gamma(\kappa_i)} \Gamma(\kappa_i^*) \right\}.$$

Table 1: Priors and posteriors distributions for parameters in **A**

	γ_{qp}	β_{qp}	α_{yp}	α_{qy}	α_{qp}	ψ_1	ψ_2	ψ_3
Priors affecting contemporaneous coefficients **A**								
Location	0.1	0.1	-0.05	0.7	~~-0.1~~ -0.3	0	0	0
Scale	0.2	0.2	0.1	0.2	0.2	0.5	0.5	0.5
Degrees of freedom	3	3	3	3	3	3	3	3
Sign restriction	t^+	t^+	t^-	t^+	t^-	t	t	t
Posterior affecting contemporaneous coefficients **A**								
5%	0.033	0.339	-0.027	0.351	-2.566	-0.148	-0.112	0.010
50%	0.081	0.776	-0.007	0.881	-1.210	-0.036	-0.070	0.053
95%	0.131	1.474	-0.001	2.011	-0.654	0.075	-0.029	0.094
Mean	0.081	0.827	-0.010	0.993	-1.332	-0.036	-0.070	0.053

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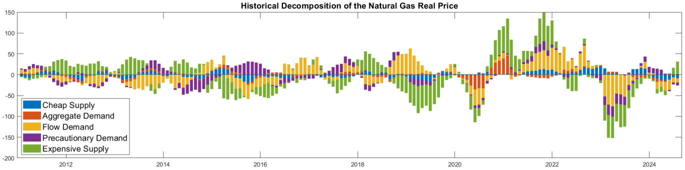
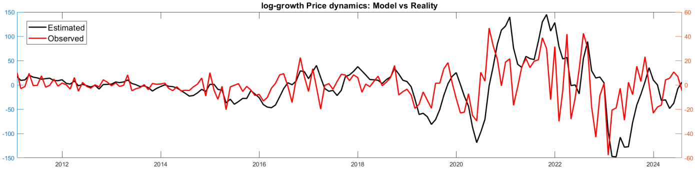
European NG Supply by source





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