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

Abstract

Natural gas is the second-largest source of energy consumption in Europe, and its role in price formation became particularly salient during the 2022 energy crisis, when disruptions in Russian pipeline flows were accompanied by a sharp expansion in liquefied natural gas (LNG) imports. This episode highlighted the importance of supply substitution in shaping natural gas price dynamics. This paper revisits the fundamentals of the European natural gas market by explicitly distinguishing between pipeline gas and LNG supplies. To this end, it estimates a Bayesian Structural Vector Autoregression (SVAR) identified through sign restrictions, which jointly identifies the contemporaneous elasticities of natural gas prices, imports by supply source, inventories, and euro area industrial production. Allowing for substitution across supply channels reveals substantial heterogeneity in supply elasticities: pipeline gas is markedly more price inelastic than LNG. Moreover, while both supply shocks affect prices, pipeline supply disruptions generate stronger but more transitory inflationary effects. Finally, the identified structural shocks are used in a local projection framework to assess their transmission to European sectoral stock returns, providing new evidence on the macro-financial implications of energy supply disruptions.

1 Introduction

The energy crisis experienced in the European Union (EU) in 2022 reignited the debate about the importance of fossil fuels in the economy. Specifically, natural gas , which represents about 25% of the energy consumed on the EU, is mainly extracted outside of Europe. Consequently, unexpected changes in the production of gas in regions far from Europe can significantly impact the prices in these markets or in the European economies. Although oil markets have been studied in much greater detail in the academic literature, modeling of the natural gas market has become a relevant topic in recent years due to its greater usage for industry. This has made it a recurring topic in academic publications and has increasingly drawn the attention of central banks.

In contrast to crude oil, for which strong regional interconnectedness implies the existence of a largely integrated global market, natural gas (NG) markets have historically been much more fragmented across regions Szafranek and Rubaszek (2024). A key reason for this fragmentation lies in transportation constraints. While crude oil is predominantly shipped by sea, natural gas relies on two distinct supply channels: pipeline gas and liquefied natural gas (LNG). Pipeline gas has historically been the dominant source of supply in Europe, accounting for approximately 85% of total net imports over the period 2010–2018. However, its relative importance has declined markedly since 2019, with its share fluctuating between 55% and 80% during the 2019–2024 period.

Previous studies of natural gas markets have largely relied on SVAR frameworks adapted from the crude oil literature, in which supply is typically modeled as a single aggregate corresponding to total global production. In the context of natural gas, however, this approach is less appropriate, as it abstracts from the composition of supply across different delivery channels. Ignoring this heterogeneity discards valuable information embedded in the relative contributions of pipeline gas and LNG, which is crucial for understanding price formation and substitution dynamics in natural gas markets. Recent publications like Moll et al. (2023) and Hamilton (2023), highlight the central role of substitution effects in natural gas markets, showing that these effects are sufficiently strong to warrant a separate treatment of different supply channels. Ignoring this distinction can lead to a systematic underestimation of the contribution of supply-side shocks. This was particularly evident during the 2022 energy crisis, when Russian sanctions caused a sharp decline in pipeline gas deliveries that was partially offset by a surge in LNG imports. If supply were modeled as a single aggregate, combining pipeline gas and LNG, this adjustment would appear only as a minor fluctuation in total net imports, masking the substantial reallocation across supply sources. This consideration provides a key motivation for explicitly distinguishing between pipeline gas and LNG supply in the empirical analysis.

This paper models the European natural gas market by explicitly distinguishing between pipeline gas and LNG supplies. This approach contributes to the existing literature in two main ways. First, by allowing the model to jointly identify the elasticities of both supply sources, it avoids the implicit assumption—common in previous studies—that pipeline gas and LNG interact with the European economy in an identical manner. This distinction is strongly motivated by a growing literature documenting substantial differences between pipeline gas and LNG in terms of contractual rigidity, cost structures, physical and logistical constraints, and short-run flexibility Molnar (2022); Sharples (2023); Ritz (2019); International Energy Agency (2002). In particular, pipeline gas is typically tied to long-term contracts and fixed transport infrastructure, while LNG operates as a more flexible and globally arbitraged supply margin, with volumes that can be redirected across regions in response to price differentials. As emphasized by Hamilton (2023) and related work, ignoring this heterogeneity risks masking large compositional adjustments in supply—such as those observed during the 2022 European energy crisis—thereby understating the role of supply-side dynamics in price formation.

Second, the paper contributes methodologically by modeling the European natural gas market within a Structural Vector Autoregressive (SVAR) framework identified through sign restrictions following Baumeister and Hamilton (2015), Baumeister and Hamilton (2019). To the best of our knowledge, this identification strategy has not previously been applied to the European natural gas market. Beyond its flexibility, this approach is particularly valuable because it allows for the incorporation of economically meaningful priors on structural elasticities, which have been shown to remain asymptotically informative under set identification. The SVAR framework further provides a coherent set of tools to disentangle supply- and demand-driven sources of natural gas price fluctuations. In contrast to existing studies that tend to understate the role of supply-side factors, the results show that supply shocks are almost as important as demand shocks in explaining the short term natural gas price dynamics. Moreover, explicitly distinguishing between supply sources reveals substantial heterogeneity: while both pipeline gas and LNG supply shocks affect prices, pipeline supply shocks are significantly less inflationary than shocks originating from LNG markets.

The usage of this methodology is increasing over time. For example Rubaszek et al. (2021) and Farag (2024) model the American NG market and its spillovers to the rest of the world through natural gas exports.

Subsequently, the study will make use of Local Projections (LP) to measure the effect of these disruptions on the value of European companies sector by sector, using the returns of a representative portfolio of European company stocks as a measure. Doing the sectorial analysis should provide evidence in favor of asymmetries in the contemporaneous responses of the European companies depending on which sector they belong to. A similar idea has been exploited by Adolfsen et al. (2024), identifying the gas market by Rubio-Ramirez and projecting the shocks on inflation.

The remainder of the paper is organized as follows. Section 2 reviews the related literature and situates the paper within existing empirical and theoretical work on natural gas markets and energy price dynamics. Section 3 describes the econometric methodology, which is based on the Bayesian Structural Vector Autoregressive framework with sign restrictions developed by Baumeister and Hamilton (2015). Section 4 introduces the empirical model and the data used in the analysis, detailing the construction of the variables and the underlying identifying assumptions. Section 5 presents and discusses the empirical results, along with several extensions and additional analyses aimed at assessing the robustness and broader implications of the findings. Finally, Section 6 concludes.

2 Literature Review

This chapter relates the present study to three strands of literature. First, it reviews the use of Structural Vector Autoregressive (SVAR) models in the crude oil market, which provides the conceptual and methodological foundation for most empirical work on energy price shocks. Second, it surveys the growing literature applying SVARs to natural gas markets, with primary emphasis on Europe, complemented by evidence from the United States and, to a lesser extent, Asia. Finally, it reviews the literature on contractual and infrastructural differences between pipeline gas and liquefied natural gas (LNG), which motivates the explicit separation of supply sources in the empirical model.

The modern empirical analysis of energy price shocks originates in the crude oil literature. Seminal work by Hamilton1983 documented a strong negative relationship between oil price increases and U.S. macroeconomic activity, giving rise to an extensive literature on the identification and transmission of oil price shocks. A key methodological breakthrough was introduced by Kilian2009, who proposed a Structural VAR framework distinguishing between oil supply shocks, global aggregate demand shocks, and oil-specific demand shocks related to precautionary or speculative motives. This approach emphasized that oil price increases can have markedly different macroeconomic effects depending on their underlying source. Subsequent contributions by KilianMurphy2012 and KilianMurphy2014 highlighted limitations of purely agnostic sign restrictions and argued for incorporating economically meaningful restrictions on short-run elasticities and inventory behavior. Building on these insights, BaumeisterHamilton2015 and BaumeisterHamilton2019 developed a Bayesian SVAR framework under set identification, showing that informative priors on structural elasticities can discipline the identification problem without imposing exact zero restrictions. Applied to the global oil market, this methodology revealed that demand-driven shocks account for the bulk of oil price fluctuations, while supply shocks play a more limited role.

This literature provides three key lessons that are directly relevant for natural gas markets. First, separating supply- and demand-driven shocks is crucial for understanding price dynamics. Second, short-run price elasticities of energy supply and demand are typically very small, implying that even moderate shocks can generate large price movements. Third, careful identification—often requiring priors, sign restrictions, or additional observables such as inventories—is essential to avoid misleading structural interpretations.

In contrast to crude oil, natural gas markets have historically been regionally fragmented due to transportation constraints and infrastructure specificity. In Europe, gas supply has long relied on pipeline imports under rigid long-term contracts, with LNG playing a limited role until recently, and early empirical work focused on the linkage between gas and oil prices under oil-indexed contracts. As shown by SzafranekRubaszek2024, this relationship weakened markedly from the mid-2000s onward, reflecting market liberalization and the transition to hub-based pricing. More recent studies adopt SVAR frameworks to analyze European gas price dynamics, typically identifying supply shocks, demand shocks related to economic activity or weather, and storage-driven precautionary demand. While these studies document relatively inelastic short-run demand and historically constrained supply responses, the 2022 energy crisis has underscored the importance of supply-side disruptions and substitution mechanisms. In particular, Güntner$_Wolters_2024showthatthecollapseinRussianpipelinedeliveriesrepresentedado$
$sideshocks, motivatingmodelsthatexplicitlydistinguishbetweensupplysources.$

Recent European SVAR studies therefore stress the importance of explicitly distinguishing between supply sources to correctly characterize price formation, elasticities, and transmission to inflation and real activity. [Citar a Moll y Hamilton]

The U.S. natural gas market differs fundamentally from the European market. It is largely self-sufficient, price formation is domestic, and supply is dominated by market-based production rather than imports. SVAR analyses of the U.S. gas market have focused on disentangling domestic supply shocks—such as technological innovations associated with the shale gas revolution—from demand shocks driven by weather, economic activity, and storage behavior. Rubaszek et al. (2021) provide a comprehensive Bayesian SVAR analysis of the U.S. gas market, estimating short-run demand elasticities that are larger in absolute value than those typically found for oil. Their results suggest that fuel-switching in electricity generation and industrial use renders U.S. gas demand more price-responsive than in Europe. They also document a non-negligible role for storage-related demand shocks, analogous to precautionary demand in the oil market. More recent work highlights the growing international dimension of the U.S. gas market following the expansion of LNG export capacity [Citar a Farag]. As the United States has become a major LNG exporter, domestic gas prices have become increasingly exposed to global demand conditions. Empirical evidence suggests that shocks originating in Europe or Asia can now transmit to U.S. gas prices through LNG arbitrage, although the magnitude of this channel remains smaller than in more import-dependent regions.

2.0.1 Asia and the Global LNG Market

Asia represents the largest importing region for LNG and exhibits distinctive demand characteristics. Historically, Asian LNG prices were often indexed to crude oil, limiting the relevance of gas-specific supply and demand dynamics. However, the expansion of spot LNG trading and the emergence of benchmarks such as the Japan–Korea Marker have increased the role of market-based pricing.

Empirical SVAR evidence for Asian gas markets remains limited, but institutional and descriptive studies consistently emphasize the high price sensitivity of demand in emerging Asian economies. During the 2022–2023 period, elevated LNG prices led to substantial demand destruction in South and Southeast Asia, freeing cargoes that were redirected to Europe. This episode illustrates how LNG functions as a global arbitrage margin linking regional gas markets.

Overall, the emerging literature suggests that while regional gas markets retain important idiosyncrasies, LNG increasingly transmits shocks across regions. As a result, supply disruptions or demand surges in one region can have global price effects, reinforcing the need for empirical models that explicitly account for LNG flows and substitution.

2.1 Contractual and Infrastructural Differences Between Pipeline Gas and LNG

A substantial body of literature documents that pipeline gas and LNG constitute fundamentally different supply margins. Pipeline gas has traditionally been governed by long-term contracts featuring take-or-pay clauses, destination restrictions, and route-specific infrastructure. As emphasized by the International Energy Agency and by Molnar2022, these features generate low short-run price elasticity and limited flexibility in response to demand or price shocks.

In contrast, LNG supply has become progressively more flexible. Sharples2023 documents a shift toward shorter contract durations, weaker destination clauses, and greater reliance on spot markets. This evolution allows LNG cargoes to be redirected across regions in response to price differentials, making LNG a highly responsive and globally integrated supply margin.

From a strategic perspective, Ritz2019 shows that the availability of LNG constrains the market power of pipeline exporters by introducing a credible outside option for buyers. Even when LNG volumes are small, their potential redeployment can discipline pipeline pricing. Empirical evidence from the 2022 European energy crisis strongly supports this view: the surge in LNG imports partially compensated for the collapse in Russian pipeline gas, albeit at the cost of extremely high spot prices.

Taken together, this literature implies that pipeline gas and LNG differ markedly in contractual rigidity, cost structures, elasticity, and adjustment speed. Ignoring these differences risks mischaracterizing both the sources of natural gas price fluctuations and their macroeconomic consequences. This insight provides a central motivation for the empirical strategy adopted in this chapter, which explicitly distinguishes between pipeline and LNG supplies within a Bayesian SVAR framework.

3 Methodology

The model can be rewritten in matrix form as a typical structural VAR (SVAR).

$$\mathbf{A}y_t = \mathbf{B}x_{t-1} + u_t \tag{1}$$

$$u_t \sim N(0_{5x1}, \mathbf{D}) \tag{2}$$

where $y_t = (y_{1t}, y_{2t}..., y_{nt})'$ is the $n \times 1$ vector of endogenous variables, $\mathbf{A}$ is the $n \times n$ matrix that contains all the contemporaneous elasticities across the endogenous variables, $x_{t-1} = (y_{t-1}, ...y_{t-m})'$ is the $k \times 1$ vector of lagged regressor, $\mathbf{B}$ is the $n \times k$ autoregressive matrix of coefficients and $\mathbf{D} = diag(d_{11}, ..., d_{nn})$ is the variance of the structural innovations.

But it also has a reduced form, which can be interpreted as a conventional VAR:

$$y_t = \Phi x_{t-1} + \varepsilon_t \tag{3}$$

$$\varepsilon_t \sim N(0_{5x1}, \Omega) \tag{4}$$

$$\Phi = A^{-1}B \tag{5}$$

$$\Omega = A^{-1}D(A^{-1})' \tag{6}$$

The model is estimated using Bayesian methods and sign-restrictions. Under set-identified models, the prior of these elasticities does not disappear asymptotically as Baumeister and Hamilton (2015) (henceforth BH) demonstrated. Later on this methodology was enhanced and applied for the global crude oil market in Baumeister and Hamilton (2019) and for the American natural gas market in Rubaszek et al. (2021) and Farag (2024). The use of BH methodology brings the flexibility to center all the priors of the elements in $\mathbf{A}$ at reasonable values given by the literature. Hence, centering the location and scale of the prior for the structural elasticities in reasonable values already acknowledged makes the model to incorporate valuable information that is not available in the data. In this section I provide a brief description of the methodology.

3.1 Prior

The starting point for setting the prior is decomposing $p(A, B, D)$ as:

$$p(\mathbf{A}, \mathbf{B}, \mathbf{D}) = p(\mathbf{A}) \times P(\mathbf{D}|\mathbf{A}) \times p(\mathbf{B}|\mathbf{A}, \mathbf{B}) \tag{7}$$

The prior for the diagonal variance-covariance matrix $\mathbf{D}$ consists in setting that the inverse of its elements d_{ii}^{-1} are jointly independent and follow a Gamma distribution with $\kappa_i, \tau_i(\mathbf{A})$ as parameters.

$$p(\mathbf{D} \mid \mathbf{A}) = \prod_{i=1}^{n} p(d_{ii} \mid \mathbf{A}) \tag{8}$$

$$d_{ii}^{-1} \mid \mathbf{A} \sim \Gamma(\kappa_i, \tau_i(\mathbf{A})), \tag{9}$$

Similarly, rows of matrix $\mathbf{B}$ are assumed to be jointly independent and to follow a multivariate normal distribution with parameters m_i, M_i.

$$p(\mathbf{B} \mid \mathbf{A}, \mathbf{D}) = \prod_{i=1}^{n} p(b_i \mid \mathbf{D}, \mathbf{A}) \tag{10}$$

$$b_i \mid \mathbf{A}, \mathbf{D} \sim N(m_i,\, d_{ii} M_i), \tag{11}$$

The prior for $\mathbf{A}$ can be freely chosen to reflect any knowledge about the structural relations between the endogenous variables. In the case of this study it will be the joint distribution of several truncated Student-t.

3.2 Likelihood

Innovation of the structural model is assumed to be normal.

$$p(Y_T \mid \mathbf{A}, \mathbf{D}, \mathbf{B}) = (2\pi)^{-Tn/2} \,|\det(\mathbf{A})|^{T} \, \det(\mathbf{D})^{-T/2} \tag{12}$$

$$\times \exp\left\{ -\tfrac{1}{2} \sum_{t=1}^{T} (\mathbf{A} y_t - \mathbf{B} x_{t-1})' \mathbf{D}^{-1} (\mathbf{A} y_t - \mathbf{B} x_{t-1}) \right\}, \tag{13}$$

3.3 Posterior

To proceed with the posterior distribution, we need a similar decomposition as before:

$$p(\mathbf{A}, \mathbf{B}, \mathbf{D} \mid Y_t) = p(\mathbf{A} \mid Y_t) \times P(\mathbf{D} | \mathbf{A} \mid Y_t) \times p(\mathbf{B} | \mathbf{A}, \mathbf{B} \mid Y_t) \tag{14}$$

Where the conditional posterior of the elements of the diagonal variance covariance $P(\mathbf{D}|\mathbf{A} \mid Y_t)$ is expressed as the joint distribution of all the elements in the diagonal:

$$p(\mathbf{D} \mid \mathbf{A} Y_t) = \prod_{i=1}^{n} p(d_{ii} \mid \mathbf{A} Y_t) \tag{15}$$

$$d_{ii}^{-1} \mid \mathbf{A} \sim \Gamma(\kappa_i^*, \tau_i^*(\mathbf{A})), \tag{16}$$

These parameters $\kappa_i^*, \tau_i^*(\mathbf{A})$ that fully characterize this posterior are a function of the data and of $mathbf{A}$ as it follows.

$$\kappa_i^* = \kappa_i + T/2 \tag{17}$$

$$\tau_i^*(\mathbf{A}) = \tau_i(\mathbf{A}) + \xi_i^*(\mathbf{A}) \tag{18}$$

And the term ξ_i^* refers to the sum of squared residuals from regressing $\widetilde{Y}_i(\mathbf{A})$ on $\widetilde{X}_i$ defined as:

$$\xi_i^*(\mathbf{A}) = \left(\widetilde{Y}_i(\mathbf{A})' \widetilde{Y}_i(\mathbf{A})\right) - \left(\widetilde{Y}_i(\mathbf{A})' \widetilde{X}_i\right) \left(\widetilde{X}_i' \widetilde{X}_i\right)^{-1} \left(\widetilde{X}_i' \widetilde{Y}_i(\mathbf{A})\right) \tag{19}$$

$$\widetilde{Y}_i = \begin{bmatrix} y_1' a_i & \cdots & y_T' a_i & m_i' P_i \end{bmatrix}'_{(T+k)\times 1} \tag{20}$$

$$\widetilde{X}_i = \begin{bmatrix} x_0' & \cdots & x_{T-1}' & P_i \end{bmatrix}'_{(T+k)\times k} \tag{21}$$

where $M_i = P_i' P_i$ and a_i are the rows of the matrix $\mathbf{A}$.

Now the conditional posterior of the autoregressive matrix $p(\mathbf{B}|\mathbf{A}, \mathbf{B})$ can be defined as the joint posterior of its rows:

$$p(\mathbf{B} \mid \mathbf{A}, \mathbf{D}, Y_t) = \prod_{i=1}^{n} p(b_i \mid \mathbf{D}, \mathbf{A}) \tag{22}$$

$$b_i \mid \mathbf{A}, \mathbf{D} Y_t \sim N(m_i^*,\, d_{ii} M_i^*) \tag{23}$$

where

$$m_i^* = \left(\widetilde{X}_i' \widetilde{X}_i\right)^{-1} \left(\widetilde{X}_i' \widetilde{Y}_i\right), \tag{24}$$

$$M_i^* = \left(\widetilde{X}_i' \widetilde{X}_i\right)^{-1}. \tag{25}$$

Finally, the posterior of A is:

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

where $\hat{\Omega}_T = T^{-1} \sum_{t=1}^{T} \hat{\varepsilon}_t \hat{\varepsilon}_t'$ is the sample variance covariance matrix estimated by maximum likelihood.

4 Empirical model and data

4.1 Data

For the construction of the baseline model, the dataset comprises five variables. The first variable, q_{pip}, measures the net imports of natural gas through pipelines into the EU on a monthly basis, obtained from the IEA's *Gas Trade Flows* database. The second variable, ip, corresponds to the industrial production index of the manufacturing sector in the EU-19, sourced from Eurostat. The third variable, p, captures the real price of natural gas traded at the Dutch TTF, which serves as the benchmark price for the European market, available from the World Bank Commodity Price Database. The fourth variable, s, represents total natural gas inventories, included given their key role in consumption smoothing as well as precautionary and speculative behavior, also sourced from the IEA's *Gas Trade Flows* database. Finally, the fifth variable, q_{LNG}, denotes net imports of liquefied natural gas (LNG) into the EU, likewise obtained from the IEA's *Gas Trade Flows* database.

$$y_t = [q_{\text{pip}}, ip, p, s, q_{\text{LNG}}] \tag{26}$$

All series are available at monthly frequency, and are expressed in logarithmic growth rates to remove unit roots in prices, industrial production, and gas imports.

4.2 Specification and assumptions

This section describes the structural model used in the paper to make the identification for the European natural gas market. The main characteristics of the contemporaneous elasticities among endogenous variables is equivalent to the one used in Baumeister (2019), Rubaszek et al (2021) or Farag (2024).

We begin with the structural equations of the two supply components. Both pipeline and LNG imports are assumed to respond contemporaneously only to innovations in the gas price. Consistent with previous studies, both supply types are considered to be mildly elastic; that is, the corresponding supply price elasticities γ_{qp} and β_{qp} are assumed to differ from zero. Because the production and delivery of natural gas involve adjustment costs, imports are expected to react to real activity shocks only with a delay of at least one month. Moreover, since the output of these two technologies is extracted simultaneously, they cannot be adjusted relative to one another within the same period.

$$q_t^{pip} = \gamma_{qp} p_t + \mathbf{b}_1' x_{t-1} + \varepsilon_t^{\text{pipeline supply}} \tag{27}$$

$$q_t^{LNG} = \beta_{qp} p_t + \mathbf{b}_5' x_{t-1} + \varepsilon_t^{\text{LNG supply}} \tag{28}$$

Real activity is broadly proxied by industrial production, which is assumed to respond contemporaneously only to the gas price. This assumption is motivated by the fact that a supply disruption affects industrial activity primarily through its impact on prices. In the short run, however, a shortfall in gas supply can be partially offset by substituting other components of the energy mix, such as biogas or alternative electricity sources. Nevertheless, any increase in the gas price is expected to exert a negative effect on industrial production.

$$ip_t = \alpha_{yp} p_t + \mathbf{b}_2' x_{t-1} + \varepsilon_t^{\text{aggregate demand}} \tag{29}$$

Demand for natural gas is separated into *flow demand* and *precautionary demand*. Flow demand captures shifts in the portion of gas that is effectively consumed, and can be mostly associated with changes in market conditions that make gas more desirable to consumers. The structural equation for gas demand allows industrial production to affect the gas price contemporaneously, with the elasticity of industrial demand denoted by $\alpha_{py} > 0$. The remaining parameter of the demand's structural equation, $\alpha_{py} < 0$, reflects the price elasticity of the demand. Since consumers are indifferent to the source of natural gas supply, any unit of pipeline gas, LNG, or stored gas is treated as identical, so aggregate demand is defined as $Q_t = q_t^{pip} + q_t^{LNG} - s_t$. In this case, the structural demand equation is given by:

$$Q_t = \alpha_{py} ip_t + \alpha_{pq} p_t + \mathbf{b}_3' x_{t-1} + \varepsilon_t^{\text{flow demand}}, \tag{30}$$

or equivalently, in inverse demand form:

$$\alpha_{qp} p_t = q_t^{pip} + q_t^{LNG} - s_t + \alpha_{py} ip_t + \mathbf{b}_3' x_{t-1} + \varepsilon_t^{\text{flow demand}}. \tag{31}$$

Precautionary demand captures changes in market participants' expectations that lead to adjustments in natural gas inventories. Such behavior may arise either because agents anticipate a potential supply disruption or because a rise in prices triggers speculative motives

Table 1: Contemporaneous elasticities in $\mathbf{A}$

Parameter	Meaning	Sign restriction
γ_{qp}	Pipeline supply elasticity	$\gamma_{qp} > 0$
β_{qp}	LNG supply elasticity	$\beta_{qp} > 0$
α_{yp}	Effect of p on economic activity	$\alpha_{yp} < 0$
α_{qy}	Income elasticity of gas demand	$\alpha_{qy} > 0$
α_{qp}	Gas demand elasticity	$\alpha_{qp} < 0$
ψ_1	Effect of q^{pip} on oil inventories	none
ψ_2	Effect of p on oil inventories	none
ψ_3	Effect of q^{LNG} on oil inventories	none

among inventory holders. Stocks of gas are adjusted to the current imports gas, which makes inventories to be a potential substitute for them. But inventories also react to the price innovations within the same month, because any trigger that ends in a rise of the gas price will have two effects in the stocks: On one hand, the rise in the price brings the opportunity of inventory holders to make a profit by selling their gas at a higher price than the one they faced when they bought the commodity, which implies that stocks decline given a increase of the price $\psi_2 < 0$. But on the other hand, if inventory holders foresee that the current rise of the price is preluding additional future price increments, then it is likely that they prefer to increase current inventories for selling more gas in the future, $\psi_2 > 0$. These two conflicting forces make the sign of the price elasticity ψ_2 theoretically ambiguous, and thus, like the other two supply elasticities, it is left without a sign restriction.

$$s_t = \psi_1 q_t^{pip} + \psi_2 p_t + \psi_3 q_t^{LNG} + \mathbf{b}_4' x_{t-1} + \varepsilon_t^{\text{precautionary demand}} \tag{32}$$

4.3 Matrix form

Following the specification of a SVAR the model is rewritten in matrix form as it follows:

$$\begin{pmatrix} 1 & 0 & -\gamma_{qp} & 0 & 0 \\ 0 & 1 & -\alpha_{yp} & 0 & 0 \\ 1 & -\alpha_{py} & -\alpha_{qp} & -1 & 1 \\ -\psi_1 & 0 & -\psi_2 & 1 & -\psi_3 \\ 0 & 0 & -\beta_{qp} & 0 & 1 \end{pmatrix} \begin{pmatrix} q_t^{pip} \\ ip_t \\ p_t \\ s_t \\ q_t^{pip} \end{pmatrix} = \mathbf{B}x_{t-1} + \begin{pmatrix} u_t^{\text{pipeline supply}} \\ u_t^{\text{aggregate demand}} \\ u_t^{\text{flow demand}} \\ u_t^{\text{precautionary shock}} \\ u_t^{\text{LNG supply}} \end{pmatrix}$$

Where the structural shocks are assumed to be normally distributed $u_t \sim N(0_{5x1}, \mathbf{D})$ and the contemporaneous elasticities in $\mathbf{A}$ satisfy the following 5 sign restrictions:

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

The way to implement these restrictions is to incorporate them in the prior of the contemporaneous matrix, $p(\mathbf{A})$, assigning truncated distributions in each case. The purpose of this is twofold, first it makes easier to incorporate prior knowledge of the elements in $\mathbf{A}$ that is not directly provided by the likelihood of the data. On top of that it helps to ensure that the posterior of the elasticities $p(\mathbf{A} \mid Y_t)$ gives most of the probability to values of $\mathbf{A}$ that

Table 2: Priors and posteriors distributions for parameters in $\mathbf{A}$

	γ_{qp}	β_{qp}	α_{yp}	α_{qy}	α_{qp}	ψ_1	ψ_2	ψ_3
Priors affecting contemporaneous coefficients $\mathbf{A}$								
Location	0.1	0.1	-0.05	0.7	-0.1	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 $\mathbf{A}$								
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

make the impact matrix $\mathbf{A}^{-1}$ to satisfy the following signs.

$$\begin{pmatrix} \varepsilon_{q^{pip},t} \\ \varepsilon_{ip,t} \\ \varepsilon_{p,t} \\ \varepsilon_{s,t} \\ \varepsilon_{q^{LNG},t} \end{pmatrix} = \begin{pmatrix} + & + & + & ? & ? \\ + & + & - & ? & + \\ - & + & + & + & - \\ ? & ? & + & ? & ? \\ ? & + & + & ? & + \end{pmatrix} \begin{pmatrix} u_t^{\text{pipeline supply}} \\ u_t^{\text{aggregate demand}} \\ u_t^{\text{flow demand}} \\ u_t^{\text{precautionary shock}} \\ u_t^{\text{LNG supply}} \end{pmatrix}$$

4.4 Prior knowledge about these elasticities

Under set-identified models, the prior of these elasticities does not disappear asymptotically as Baumeister and Hamilton (2015) demonstrated. That is why it is important to account for reasonable priors for the reduced-form variance-covariance matrix and for the contemporaneous relationship; which can be done easily thanks to the benefits of BH methodology. Hence, centering the location and scale in the prior for the structural elasticities in reasonable values acknowledged by the literature can be vital for avoiding improper posteriors.

After visual inspection of the matching of identified shocks with recent historical events, I would like to proceed with some further analysis such as a historical decomposition of the estimated variables or a counterfactual analysis of "No energy crisis", similar to Güntner, Reif & Wolters (2024) for the whole EU instead of only for Germany.

5 Results

In this section, we present the estimation results of the baseline model and discuss the dynamics of the European natural gas market. We begin by examining the posterior distributions of the model parameters, focusing in particular on the short-run price elasticities of demand and supply. Then, we analyze the posterior impulse response functions, which capture the dynamic responses of the endogenous variables to structural shocks. Next, we quantify both the short- and long-term effects of these shocks on the variables included in the VAR system and assess their historical decompositions, highlighting their contributions to the variation in natural gas prices. Finally, we conduct a counterfactual analysis based on a hypothetical scenario in which European LNG imports were not available during the post-energy-crisis recovery period.

5.1 Posterior knowledge of the elasticities

We begin by comparing the prior and posterior distributions of the parameters in the contemporaneous relations matrix $\mathbf{A}$, with particular attention to the posterior medians of the short-run demand and supply elasticities. Figure 1 displays the prior distributions (red line) alongside the posterior ones (blue histograms), while the corresponding descriptive statistics are reported in the lower panel of Table 2. The main findings can be summarized as follows.

The posterior median of the short-run price elasticity of pipeline gas supply, γ_{qp}, is estimated at only 0.08, indicating a highly inelastic response of supply to price changes. This estimate is broadly consistent with the elasticities reported by Rubaszek et al. (2021) and Farag (2024) for the U.S. natural gas market, who find elasticities of approximately 0.01 and 0.02, respectively, and conclude that American gas supply is strongly price inelastic. It is also roughly half the elasticity estimated by Mason and Roberts (2018) for natural gas wells in Wyoming, who report a value of 0.026. Moreover, our estimate is comparable to the European supply elasticities obtained by Adolfsen et al. (2024) (around 0.859) and **?** (approximately $0.y$), further confirming the limited short-run responsiveness of natural gas supply to price movements.

Regarding demand elasticities, the posterior median of the short-run price elasticity, α_{qp}, is estimated at -1.21. In absolute terms, this value exceeds the prior and is more than twice as large as the estimates reported by Rubaszek et al. (2021) and Farag (2024) for the U.S. natural gas market, who find elasticities of -0.42 and -0.177, respectively. This result suggests that, in the short run, European natural gas demand is considerably more responsive to price changes what the American demand is. This was documented by **?**, suggesting that produce As for the income elasticity, α_{qy}, its posterior distribution remains relatively close to the prior, with a median of 0.881, broadly consistent with the estimate of 0.719 of Güntner et al. (2024) or 0.725 reported by Baumeister and Hamilton (2019) for crude oil. This similarity indicates that shifts in aggregate economic activity translate into comparable changes in demand across both energy commodities and across different markets.

For the remaining parameters, the estimates indicate that, in the short run, the effect of natural gas prices on economic activity, α_{yp}, is almost negligible, with a posterior median of -0.009. This value is well below both our prior belief and the estimates reported by **?**, yet it is close to the -0.002 obtained by **?** for the crude oil market. Regarding the parameters that capture the effect of changes in supply and prices on natural gas inventories, ψ_1 and ψ_3, the contemporaneous posterior medians are negative, amounting to -0.170 and -0.177, respectively. This suggests that natural gas inventories decrease in response to positive shocks in supply or prices.

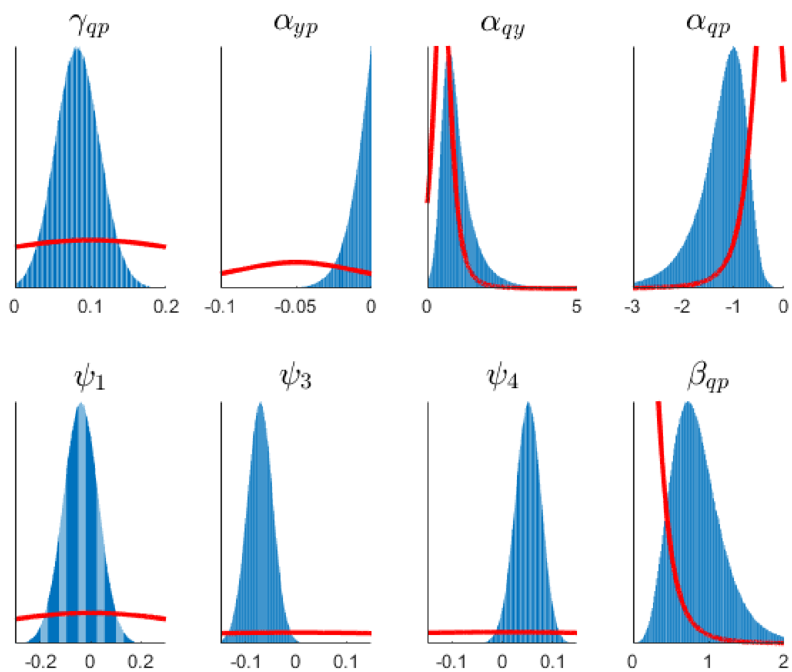

Figure 1: Prior and posterior of contemporaneous elasticities for the baseline model. Note:The baseline prior is represented using solid red lines, whereas the posterior is depicted using blue histograms. These distributions concern the contemporaneous coefficients in matrix **A** in the baseline model.

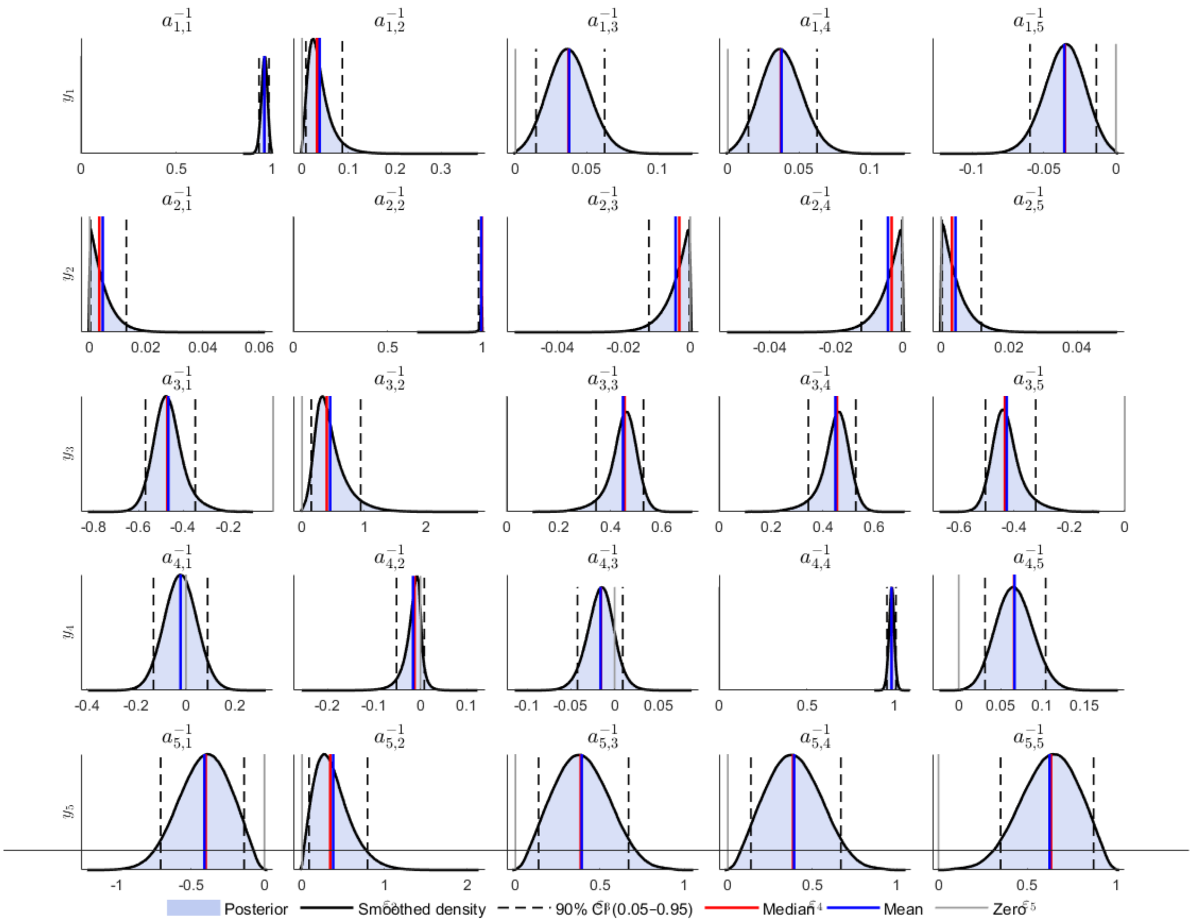

Figure 2: Posterior of parameters in the impact matrix for the baseline model. Note: The baseline posterior is represented using black solid line, blue and red lines represent mean and median respectively, vertical dashed lines represent 90% confidence bands. These distributions concern the contemporaneous coefficients in matrix $\mathbf{A^{-1}}$ in the baseline model.

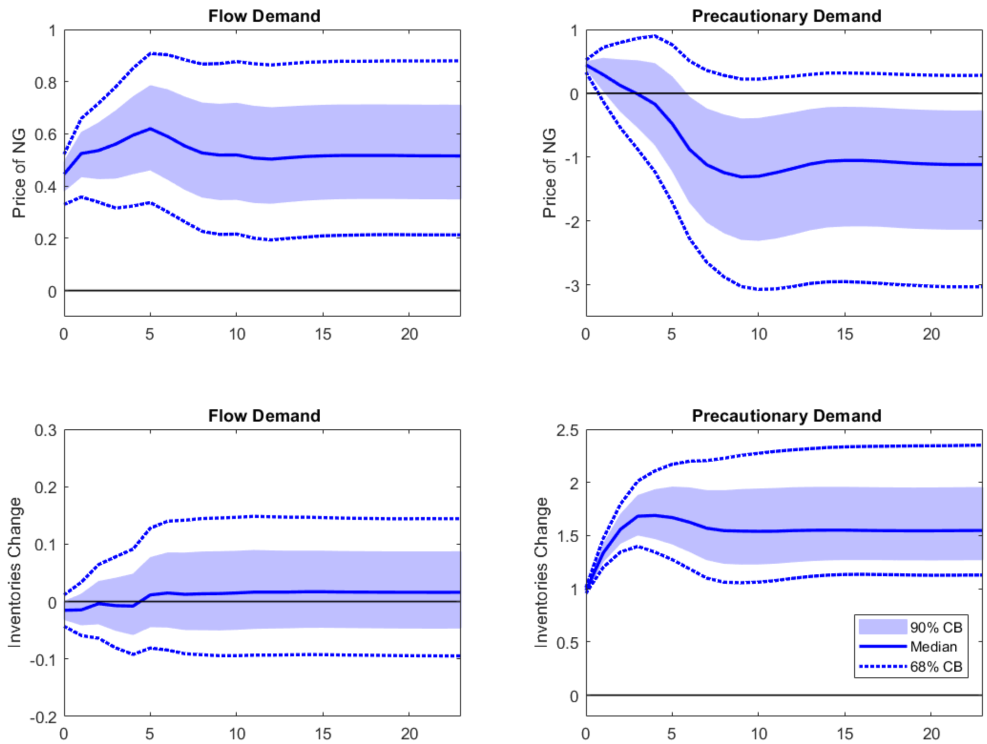

Figure 3: Impulse responses of the European gas price to supply shocks.

5.2 Impulse response Functions

5.3 Variance Decomposition

Table 3: Median FEVD of the Price

	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

Notes: This table reports descriptive statistics for the main variables in the sample. Data are monthly from 2010–2024.

5.4 Historical Decomposition

A historical decomposition allows us to break down the evolution of an observed time series into the cumulative contributions of the structural shocks identified in the model. In the context of a structural VAR, this tool is particularly useful for tracing the origins of large fluctuations and for quantifying the relative importance of different types of shocks at each point in time. It provides a narrative account of how observed variables, such as gas prices, were shaped by specific economic forces over history.

Figure 4 presents the historical decomposition of the real natural gas price in Europe, based on the five structural shocks identified in the model. The black line represents the estimated log-level price series, while the colored bars indicate the contemporaneous contribution of each shock category: cheap supply (blue), aggregate demand (orange), flow demand (green), precautionary demand (purple), and expensive supply (yellow).

Several key episodes emerge clearly from the decomposition. Following the 2014 Crimea invasion and the subsequent deterioration in EU–Russia energy relations, the model captures a moderate rise in precautionary and flow demand pressures, though prices remained relatively contained. During the 2020 COVID-19 outbreak, prices fell sharply due to large negative flow demand and precautionary demand shocks, reflecting the collapse in industrial activity, transportation, and uncertainty. In the subsequent 2021 recovery, a rapid rebound in demand was met with supply-side constraints, including a global bottleneck in LNG deliveries and shipping capacity, which is reflected in the rise of expensive supply shocks and renewed flow demand pressure. This imbalance set the stage for the extreme price volatility that followed. The 2021–2022 energy crisis—triggered by Russia's weaponization of gas exports and amplified by tight global LNG markets—is characterized by dominant positive contributions from flow demand, precautionary demand, and expensive supply shocks. Aggregate demand plays only a limited role in this episode, reinforcing the narrative that the gas price surge was driven by supply insecurity and storage motives, rather than macroeconomic overheating.

The reversal of these shocks in 2023—helped by mild weather, energy-saving measures, and LNG infrastructure expansion—explains much of the subsequent price normalization.

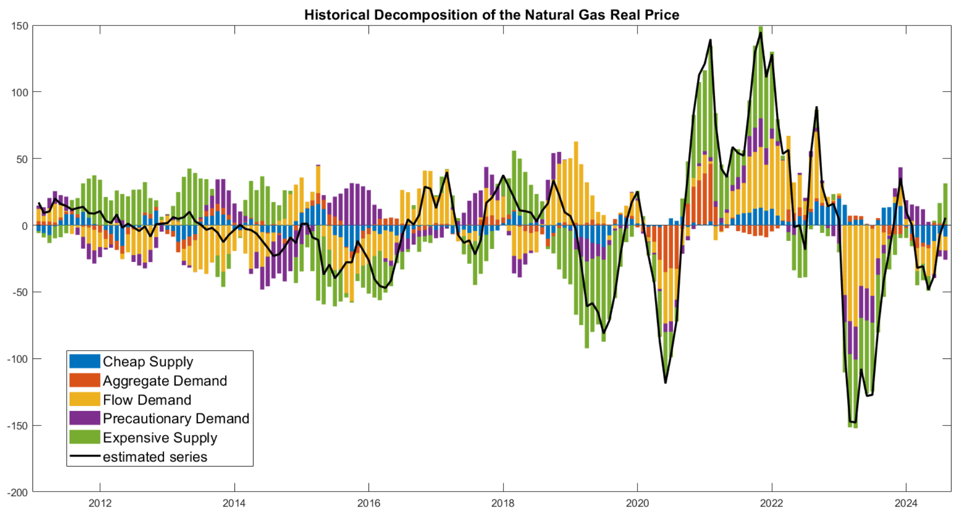

Figure 4: Impulse responses of the European gas price to supply shocks.

The dynamics of European natural gas real prices are best understood as the outcome of three interacting forces: (i) very low short-run demand elasticity, (ii) binding supply and infrastructure constraints, and (iii) the pivotal role of storage and expectations when supply security deteriorates. Because gas is hard to substitute in heating and many industrial processes in the short run, even moderate physical imbalances translate into large price movements. In Europe, these imbalances are magnified by the fact that pipeline supply is tied to specific corridors and contracts, while LNG is globally traded but constrained by liquefaction capacity, shipping availability, and regasification infrastructure. Hence, price spikes emerge when the market must simultaneously (a) replace lost pipeline volumes, and (b) rebuild inventories ahead of winter, especially under heightened uncertainty.

From a historical perspective, the decomposition in Figure 4 is consistent with broad event-driven regimes. After the Crimea invasion in 2014, concerns about EU–Russia relations became more salient, but the market adjustment was gradual and largely absorbed by existing contract structures and infrastructure. The COVID-19 shock in 2020 is associated with a collapse in flow demand and weaker precautionary motives, pushing prices down as industrial activity and mobility contracted. The post-COVID recovery in 2021 then produced the opposite configuration: demand rebounded rapidly, while global LNG supply was hit by outages and weather-related disruptions, and shipping capacity became scarce. This created an LNG bottleneck precisely when Europe needed flexible cargoes, so prices rose well before the 2022 war shock. The 2022–2023 energy crisis represents the extreme case: the sudden and massive loss of Russian pipeline deliveries forced Europe to compete aggressively for LNG, while storage demand and precautionary motives amplified price pressures. The subsequent normalization in 2023 reflects the unwinding of these forces, supported by demand-reduction policies, high storage levels, and expanding LNG import capacity.

A few statistics help anchor these mechanisms in the data:

- **Magnitude of the price spike.** Dutch TTF benchmark futures rose to **227 EUR/MWh** on 7 March 2022 and reached about **339 EUR/MWh** by late August 2022. **?**
- **Collapse in Russian supply.** EU imports of Russian gas fell from about **150 bcm in 2021** to **79 bcm in 2022** and **43 bcm in 2023**. **?**
- **LNG as the main adjustment margin.** In 2022, European LNG imports increased by about **64 bcm** (over **60%** year on year), effectively replacing lost Russian pipeline volumes, despite limited global incremental LNG supply. **?**
- **Demand curtailment as the balancing variable.** EU gas consumption fell by **19.3%** in August 2022–January 2023 relative to the 2017–2022 average, exceeding the EU's 15% reduction target for that winter period. **?**
- **Storage and risk compression in 2023.** In Q4 2023, the average EU gas storage filling rate was about **95%**, coinciding with markedly lower wholesale prices relative to 2022 and reduced import demand. **?**
- **Post-COVID LNG bottlenecks.** Pandemic-era shipping scarcity pushed LNG spot shipping rates to an all-time peak of roughly **$200,000/day** in early 2021, tightening the effective supply of flexible LNG to Europe during the recovery. **?**
- **Low storage entering winter 2021–2022.** By late September 2021, European storage was around **72% full** versus **94%** a year earlier, raising vulnerability to winter supply risk and contributing to the pre-war price run-up. **?**

Overall, the historical decomposition clarifies how the same structural mechanisms operate with very different intensity across episodes. Periods of stability are characterized by offsetting shocks that keep prices anchored, whereas crisis episodes arise when multiple supply- and risk-related forces reinforce each other. The analysis shows that large price movements emerge not from a single dominant shock, but from the interaction between constrained supply, expectations, and limited adjustment margins. This perspective helps rationalize both the severity of the 2022 price spike and the speed of its subsequent reversal.

5.5 Historical Decomposition

A historical decomposition expresses the evolution of an observed time series as the cumulative contribution of the structural shocks identified in the model. In the context of a structural VAR, this tool is particularly useful for attributing large movements in prices to distinct economic forces and for assessing how the relative importance of different shocks varies over time. Rather than focusing on impulse responses to isolated shocks, the historical decomposition provides a narrative interpretation of realized outcomes, allowing one to identify which mechanisms were most relevant during specific historical episodes.

Figure 4 reports the historical decomposition of the real natural gas price in Europe based on the five structural shocks identified in the model. The black line depicts the estimated log-level of the real gas price, while the colored bars show the contemporaneous contribution of each shock category: cheap supply, aggregate demand, flow demand, precautionary demand, and expensive supply. Together, these components sum to the observed price path at each point in time.

Several economically meaningful episodes emerge from the decomposition. Following the 2014 annexation of Crimea and the subsequent deterioration in EU–Russia energy relations, the decomposition indicates a moderate increase in precautionary and flow demand pressures. Although concerns about future supply security became more salient during this period, price effects remained contained, reflecting the gradual nature of the adjustment and the buffering role of long-term contracts and existing infrastructure.

The COVID-19 outbreak in 2020 marks a clear demand-driven episode. Gas prices declined sharply as a result of large negative flow demand and precautionary demand shocks, consistent with the collapse in industrial activity, transportation, and overall energy consumption. This episode stands in contrast to later periods, as reduced uncertainty and exceptionally weak demand temporarily alleviated supply pressures and pushed prices to historically low levels.

The post-pandemic recovery in 2021 exhibits the opposite configuration. A rapid rebound in demand coincided with significant supply-side constraints, including outages in global LNG production, weather-related disruptions, and bottlenecks in LNG shipping capacity. These frictions limited the availability of flexible LNG precisely when European demand recovered and storage levels were unusually low. In the decomposition, this period is characterized by rising contributions from expensive supply shocks and renewed positive flow demand pressures, indicating increasing marginal supply costs and intensified competition for gas to rebuild inventories. Importantly, gas prices began to rise well before the outbreak of war in Ukraine, underscoring that supply tightness was already present prior to 2022.

The most pronounced regime shift occurs during the 2021–2022 energy crisis. The sharp reduction in Russian pipeline gas deliveries following the invasion of Ukraine generated a large negative supply shock, forcing Europe to rely heavily on LNG imports under conditions of tight global capacity. The decomposition shows that the resulting price surge was dominated by positive contributions from flow demand, precautionary demand, and expensive supply shocks. These dynamics reflect the simultaneous need to replace lost pipeline volumes, refill storage ahead of winter, and insure against the risk of further supply disruptions. Aggregate demand shocks play a comparatively minor role during this period, reinforcing the interpretation that the price spike was driven primarily by supply insecurity and storage-related motives rather than by macroeconomic overheating.

The subsequent decline in prices during 2023 is explained by the reversal of these forces. As demand-adjustment measures took effect, weather conditions proved favorable, storage levels reached historically high levels, and LNG infrastructure expanded, the contributions of precautionary demand and expensive supply shocks diminished substantially. The normalization of prices thus reflects an easing of supply constraints and a reduction in perceived scarcity rather than a fundamental shift in underlying demand conditions.

Overall, the historical decomposition highlights that large swings in European natural gas prices arise from the interaction of multiple structural forces whose relative importance varies across episodes. Periods of stability are characterized by offsetting shocks that keep prices anchored, whereas crisis episodes emerge when supply constraints, expectations, and limited short-run adjustment margins reinforce one another. This framework helps rationalize both the severity of the 2022 price spike and the speed of its subsequent reversal.

5.6 Counterfactual Analysis: No energy crisis

The structural VAR framework employed in this paper enables a rich set of counterfactual and scenario-based analyses, in line with Güntner et al. (2024) and Antolín-Díaz et al. (2021). By specifying alternative realizations of selected structural shocks, we can simulate how the system would have evolved under different hypothetical conditions and trace the resulting paths of the endogenous variables. Exploiting this feature, we construct a three different counterfactual scenarios to evaluate the effects of a hypothetical events. The first scenario consists on the absence of LNG imports starting in February 2022 which we saw had a substantial effect lowering the prices specially in 2023. The second scenario quantifies the contribution of reduced flow demand resulting from the European Union's energy-saving measures to the stabilization of natural gas prices toward the end of 2022. A final third counterfactual scenario is drawn, in which we impose no bottleneck in the trade of LNG and, therefore, we assume that every lost unit of pipeline gas after the beginning of the energy crisis is immediately substituted by the same unit provided by LNG suppliers.

5.6.1 First Counterfactual: No Availability of LNG

In response to the looming gas crisis in 2022, European policymakers moved swiftly to diversify gas supply by expanding imports of liquefied natural gas (LNG). Germany, which had relied entirely on pipeline gas until then, fast-tracked the construction of floating LNG terminals – the first of which became operational in December 2022. The EU also negotiated deals with alternative suppliers (for example, a joint EU–US task force secured additional LNG deliveries of at least 15 bcm for 2022) and maximized use of existing import facilities. As a result, Europe's LNG imports surged by over 60% in 2022, adding roughly 66 bcm to supply, primarily from the United States, Qatar and other partners.

This counterfactual assumes a zero contribution of LNG to natural gas prices from February 2022 to December 2023. The left panel of Figure 5 presents the counterfactual scenario (red dashed line), alongside the baseline median forecast (solid line) and the observed data for the log level of natural gas prices. For ease of comparison, both model-generated series are expressed in log levels by accumulating log growth rates over time, starting from the realized price level in January 2022.

The right panel of Figure 5 displays the statistical difference between the counterfactual and the baseline model-generated log prices. While the initial gap is modest, the most pronounced divergence emerges from the autumn of 2022 onward, coinciding with the period in which LNG inflows began exerting downward pressure on European natural gas prices. As expected, the difference remains zero for all dates prior to February 2022. Since both the baseline and counterfactual series are expressed in log levels, their statistical difference can be interpreted as the percentage change in natural gas prices under the counterfactual scenario of no LNG supply arrivals during the energy crisis. The results indicate that LNG supply played a substantial role in mitigating price pressures in Europe. In the absence of investments in LNG infrastructure, natural gas prices would have been more than 400% higher throughout 2024.

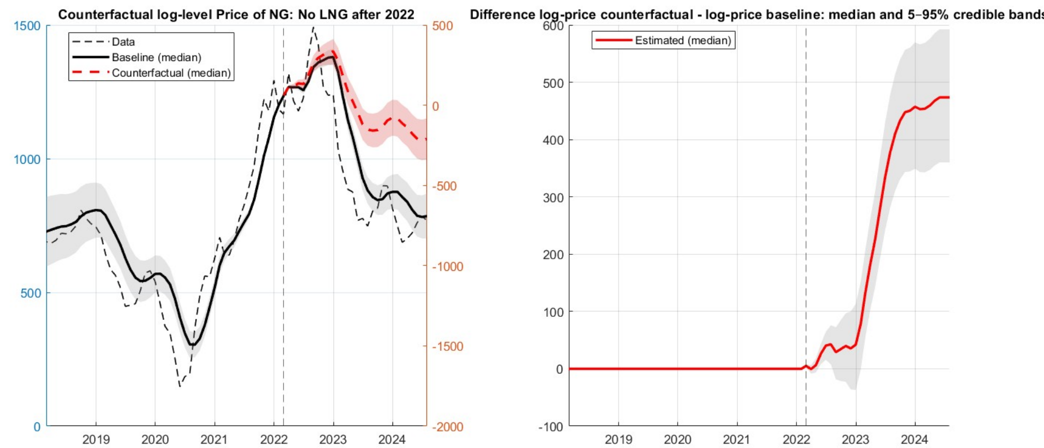

Figure 5: .

5.6.2 Second Counterfactual: No energy-saving measures

In parallel with supply-side responses, the European Union also took unprecedented steps to curb natural gas **demand** during the crisis. In July 2022, EU member states agreed to a coordinated plan ("Save Gas for a Safe Winter") to voluntarily reduce gas consumption by 15% between August 2022 and March 2023ieefa.org. National governments implemented measures such as public awareness campaigns, thermostat limits in buildings, fuel switching in industry, and other energy-saving regulations. High gas prices likewise incentivized consumers and firms to conserve energy. These efforts – combined with a milder winter – proved effective: EU gas consumption fell by roughly 18% in late 2022 compared to the five-year average, exceeding the target (about 56 bcm less gas used)ieefa.org. Now, we consider a counterfactual scenario in which these conservation policies had an even more pronounced impact on gas demand. Suppose that, from autumn 2022 onward, European gas consumers cut back usage significantly more (through stricter enforcement of rationing or exceptionally strong compliance with saving measures). In the SVAR model, this can be captured as a one-off negative demand shock (or equivalently, a positive shock to gas inventories) in late 2022, reflecting an abrupt drop in consumption relative to baseline. We again use full-sample parameter estimates and the actual 2022/23 winter temperatures. By comparing this conditional forecast (with extra demand reduction) to the unconditional forecast and actual outcomes, we can analyze how much the EU's energy-saving measures (had they been even more aggressive) might have alleviated the gas supply strain during the crisis.

5.6.3 Third Counterfactual: No bottleneck in LNG

Now suppose as a counterfactual that the EU had managed to import enough LNG to offset a large share of the lost Russian pipeline gas immediately after the invasion. For instance, imagine that every lost bcm of natural gas imported by pipeline is instead added to the LNG imports. This creates a situation in which the scarcity of natural gas in 2022 did not really happen, but instead a different composition in the supply. In our structural VAR framework, we can represent this policy scenario as a one-off positive supply shock (a sudden increase in LNG gas availability) in mid-2022, boosting LNG net imports. We maintain the same parameter estimates than in the full sample. This allows us to compare the conditional forecast under the "LNG surge" scenario with the baseline unconditional forecast and the realized data, to gauge how effective an accelerated LNG substitution might have been.

Figure 6 displays the evolution of the log-level of natural gas prices, comparing the observed data with both the unconditional median forecast and the counterfactual scenario. In this counterfactual, it is assumed that LNG supply fully offset the pipeline supply disruptions experienced in 2022. This is implemented by reassigning the negative pipeline supply shocks as equivalent positive LNG supply shocks, effectively modeling a situation in which LNG entirely absorbed the shortfall from reduced pipeline inflows.

The left panel shows that, under this assumption, the counterfactual median price path (red dashed line) remains substantially below the baseline forecast (black solid line) and the realized data (black dashed line) throughout most of 2023 and 2024. This suggests that a perfectly elastic LNG substitution mechanism would have significantly mitigated the price surge observed during the energy crisis. The gap between the counterfactual and baseline series widens notably from mid-2022 onward, precisely when pipeline flows from Russia declined sharply. The right panel shows the log-level difference between the counterfactual and baseline scenarios, which becomes increasingly negative through late 2022 and 2023, eventually exceeding a gap of 200 log points. This implies that, in a scenario where LNG fully offset the pipeline supply losses, natural gas prices would have been significantly lower—by a margin exceeding 200 log points—throughout 2023 and into 2024. As expected, the difference remains exactly zero before February 2022, when both the baseline and counterfactual scenarios are identical by construction.

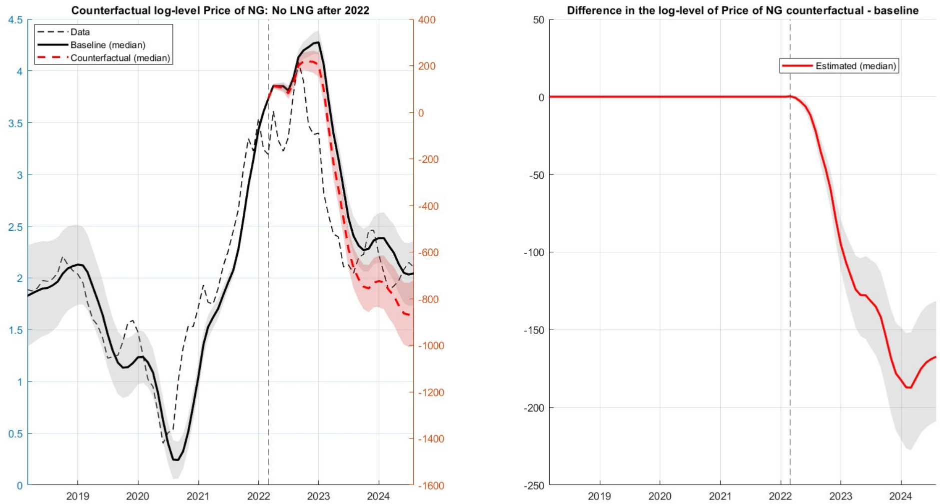

Figure 6: .

5.7 Local Projections

I am still investigating how to proceed with the second step of the model. By now, I plan to run a local projection (LP) of several sectorial EU stock market indices one horizon ahead of the identified structural shocks. Endogeneity should not be a problem in regression because once we control for a proper set of factors that are usually used for explaining returns, the structural shocks are expected to be independent for any other idiosyncrasy in the financial market residual. Furthermore, there is no reverse causality in the regression, as the returns at $t+1$ are expected to react contemporaneously to all variables in the NG market, but not the reverse, due to adjustment costs in imports or persistence in industrial production. The reason of exploiting only 1 horizon is because the Market Efficient Hypothesis reflects that share prices reflects all the available information in the market, therefore the best estimator of tomorrow's price is the one of today. Hence regressing with 2 horizons or further would not have sense.

6 Conclusions

Although this idea is in its very first stage, it can help policy makers better understand the implications of a shortage of natural gas or answer relevant questions such as which types of company are more vulnerable under different fluctuations of the gas market, providing some help to do forecasts or other types of analysis. Therefore, I think that this research can be very oriented to fit well with the ongoing research of the European Central Bank. Preliminary results are available upon request.

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