DRIVERS OF NATURAL GAS PRICES IN EUROPEAN UNION

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ABSTRACT

Natural gas is a key source of energy and an important industrial input in electricity generation. The three gas directives from the beginning of the 21st century liberalised the European gas market. They incentivised a switch from Oil Price Indexing to a Gas-on-Gas price-setting mechanism, which made the deregulated market an interesting object of research. The drivers of natural gas prices in the European market are examinee. A VAR model with exogenous variable (VARX) is used to estimate the effects of chosen factors. The impulse-response function shows that in the short run, the European gas market is sensitive to imports of liquid natural gas and gas storage, whereas in the long run, it is highly dependent on coal, with air temperature and oil prices playing a negligible role. Forecast error variance decomposition results indicate the relationship between natural gas and coal prices in Europe. Cumulatively, approximately 64% of natural gas price variation is explained by variations in coal prices, gas storage and liquid natural gas imports, with coal prices being the single most important driver of natural gas prices, contributing to 35% of price variation.

1. INTRODUCTION

This paper aims to explore the drivers of natural gas prices in the European Union (EU) market. Apart from being a source of heating for residential and commercial properties, natural gas is an important input for the industry (has a more positive environmental footprint compared to other traditional energy sources and positively affects the competitiveness of the economy) and for producing electricity, especially when filling the gap of energy supply that stems from sometimes unreliable renewables. Due to this, understanding the factors that drive the price of natural gas is of great importance both to policymakers and to microeconomic agents, i.e. households and companies.

There is a significant gap in the literature that analyses the factors that affect how natural gas prices are formed in the EU. The reason lies in the complex modeling of the European market, whose natural gas supply comes from two sources: pipelines imports and liquefied natural gas (LNG) imports, while domestic production is almost negligible accounting for only 18% of EU's gas natural gas consumption in the 2016-2022 period. Another challenge in modeling this market comes from the liberalisation processes that happened in the last two decades. European natural gas markets experienced gradual liberalisation at different pace across countries. The liberalisation of the gas sector in continental Europe has led to the creation of several gas hubs with transparent prices. The first gas directive, adopted in 1998, opened the market and paved the way for easier transit, distribution, supply and storage of gas. The second directive (2003) made a distinction between gas transport and supply. The third directive in 2009 laid the foundation for the efficient functioning of the natural gas market, including subsidising the founding of new gas hubs. Opolska & Jakubczyk (2013) find that European markets with more concentrated gas import structures and higher import dependence (especially on Russia) tended to implement market reforms later, while countries with competitive market structures and higher initial gas prices liberalised faster.

Price setting in liberalised natural gas markets is complex due to numerous factors influencing supply and demand, such as weather conditions, the business cycle and international trade developments. Three gas directives, together with global developments in the gas market at the end of 2010 (global financial crisis, shale gas revolution, Fukushima nuclear power plant incident, oil prices decrease) led to a gradual but significant shift from the Oil Price Indexation (OPI) to Gas-on-Gas (GOG) gas price forming mechanism. All buyers required radical negotiations of contracts for gas imports that fixed the gas prices on oil prices, due to the big risk of prices significantly diverging from realistic market conditions. The separation of two pricing models initiated a revision of European gas contracts, while the indexation of oil was largely abandoned (Lorefice, 2017). From 2005 to 2020, the share of GoG contracts grew from 15 to 80% in total gas consumption, while the share of OPI contracts decreased from 78 to 20% (International Gas Union [IGU], 2021). This differentiation of prices in Europe is mostly associated with the development of liquid spot markets that incentivise competition in GoG, while simultaneously contributing to a gradual, but stable decrease of OPI.

The European Union influences and transforms its gas market through energy policy, allowing it to enhance resilience by investing and developing infrastructure. Baltensperger et al. (2017) analyse effects of planned infrastructure expansions on consumption, prices and social welfare in the EU's gas markets and highlight how new gas sources and infrastructure projects can decrease prices, increase social welfare and reduce suppliers' market power.

Natural gas trading hubs gained rapid importance following liberalisation. Trade in the National Balancing Point (NBP) gas hubs in the United Kingdom and Title Transfer Facility (TTF) in the Netherlands have become more important due to Brexit insecurity and declining endogenous gas production in the UK (Heather, 2012). In 2016 TTF became a hub with the highest trade volume in Europe and served as the primary hedging and general trade point of European gas subjects. The annual trade volume in TTF in 2022 is estimated at 63% of the total European trade (IGU, 2023).

Unpredictable disruptions in gas supply can have significant repercussions, especially in continental Europe, which was exposed to interruptions during the Russia-Ukraine dispute on gas transport in 2009, production interruption in Libya in 2011, as well as the political decision to decrease dependence on Russian gas after the beginning of the war in Ukraine. Carvalho et al. (2014) investigate the vulnerabilities of Europe's gas supply network, particularly its dependence on Russian and North African sources, and propose strategies to enhance resilience against supply disruptions. Grabau & Hegelich (2016) emphasise the divergent positions of EU member states toward Russian gas imports, exploring how these differences influence the EU's external gas policy. They stress the disagreements surrounding projects like Nord Stream, South Stream and Nabucco and discuss how these debates affect the EU's supply security. Newell & Carter (2024) develop a framework to understand supply-side climate policies, focusing on fossil fuels. The authors discuss how these policies, including production restrictions and market interventions, influence supply-side factors in the natural gas market and contribute to climate change mitigation efforts.

2. LITERATURE REVIEW

Gas markets are regionally fragmented, in contrast to globalised oil market (Siliverstovs et al., 2005; Wiggins & Etienne, 2017; Wang et al., 2020). Natural gas prices are set independently in different markets, especially after the shale gas revolution in the USA (Geng et al., 2016; Wakamatsu & Aruga, 2013; Zhang & Ji, 2018). Gas prices in the USA are set in the Henri Hub gas hub, while European prices are a mix of gas prices from NBP and TTF hubs. Asian gas prices are still indexed to the Japanese oil price (JCC) where the indexation of oil exogenously sets the gas price and differentiates East Asian gas economies from other market-based economies (Shi & Variam, 2017). Wang et al. (2020) examine the impact of market reforms on natural gas import prices in China, and provide a valuable comparative perspective on how market reforms and unique regional characteristics shape natural gas prices in different parts of the world, reinforcing why direct comparisons between, for example, Asian and European gas markets may not be straightforward. This regional specificity means that pricing mechanisms and influencing factors can differ significantly across continents.

After the recent separation of USA gas and oil market, it is important to understand how European natural gas prices react to supply and demand shocks, to identify the effect of each shock on gas price volatility. Most authors, due to data availability, study the American market. Research shows that the correlation between gas and oil prices is weaker than in Europe and that a similar separation is happening in Europe as well, considering the recent shift to the GoG pricing model (Erdos, 2012). The European mechanism of price setting is still relatively unexplained, even though researchers tried to shed light on this issue in their national economies. Such examples are given for Germany by Nick & Thoenes (2014) or for the Netherlands by Hulshof, van der Maat & Mulder (2016) – but there is a lack of quality research on the European level. Nick & Thoenes (2014) use a structural VAR model to explain how gas prices in Germany are affected. Their findings indicate that short-run gas prices are significantly affected by factors such as air temperature, gas storage and supply disruptions. In the long run, however, they find that gas prices are primarily dependent on oil and coal prices. This study, while focusing on a national economy within Europe, provides a valuable benchmark for understanding the differing impacts of various drivers across time horizons and serves as a point of comparison for broader European-level research.

Hulshof, van der Maat & Mulder (2016) show that the TTF natural gas prices are only affected by oil price fluctuations in the short run, and that they react to factors specific to the European market (gas storage, air temperature and wind electricity generation). This study's findings contribute to a nuanced understanding of the factors that shape spot prices in Europe's leading gas hub, affirming the partial influence of oil in the short term while underscoring the role of regional market fundamentals.

Heather's two works are instrumental in understanding the evolution and significance of natural gas trading hubs in Europe. Heather (2012) highlights the growing importance of hubs such as the National Balancing Point (NBP) in the United Kingdom and the Title Transfer Facility (TTF) in the Netherlands, particularly in the face of Brexit uncertainties and declining UK domestic gas production. Building on this, Heather (2020) further emphasises the supremacy of TTF, which emerged as the main European and global reference for gas prices. By 2016, TTF surpassed NBP in trade volume and became the primary hedging and trade point for European gas. Its role has expanded to serve as a referent price point for global LNG trade, especially as Europe has increased its attractiveness to LNG exporters through infrastructure development and strategic decision to reduce reliance on Russian gas.

Our study focuses on a broader European market, which is to a great extent dependent on gas imports through pipelines, making it an interesting setting for researching the drivers of natural gas prices. We employ a vector autoregressive model with exogenous variable (VARX) to estimate the effects of different variables on gas prices. Six essential drivers of natural gas prices in the European market are identified. The interactions between supply and demand deviations from average air temperature values and gas storage levels, and coal and oil prices are analysed as variables affecting the price of natural gas. The model enables us to deal with the endogeneity of gas market variables, such as gas storage and supply from LNG. This is a key methodological contribution distinguishing our work from that of most other authors, such as Brown & Yücel (2008), Mu (2007), and Ramberg & Parsons (2012), who view gas storage as an exogenous variable and do not consider the growing role of LNG. The assumption of gas storage exogeneity shows that storage operators do not adjust their influx of gas to market conditions, which is a restrictive assumption for liberalised gas markets. Through this advanced methodology, our research provides novel empirical insights into the short and long-run determinants of European natural gas prices, notably confirming the significant role of coal prices and the limited impact of oil prices and temperature.

3. MATERIALS AND METHODS

Our dataset consists of 96 observations of monthly data from January 2016 to December 2023 in the EU. It is a sample that spreads over the period of the deregulated European market in which the TTF became the single most liquid gas hub. The model consists of natural gas prices in Europe, Brent crude oil prices, Northwest Europe coal prices, deviation from the average heating degree threshold in the EU, deviation from the average filling levels of natural gas storage capacity in the EU and LNG imports in the EU27. Figure A.1 in the Appendix shows time series used in the analysis, while Table 1 summarises the variables used in our study.

Table 1. Description of Used Variables

No.	Variable name	Description	Unit	Data source
1	*stemperature*	Deviation of average and real HDD during the observed period	Degrees Celsius (°C)	Eurostat/Agri4Cast
2	*sbrentprice*	Brent crude oil European spot price	US Dollars per barrel	Energy Information Administration (EIA)
3	*scoalprice*	Northeast Europe coal price	US Dollars per tonne	McCloskey
4	*sLNG*	LNG imports in EU27 countries	Million cubic meters (mcm)	Eurostat Bruegel
5	*sstorage*	Deviation of real storage fullness from the monthly average	Percentage points (%)	Gas Infrastructure Europe (GIE)
6	*sgasprice*	TTF day-ahead natural gas price	British Thermal Unit	IMF

Source: Authors' compilation

The model includes six variables. Many factors of supply and demand determine natural gas prices and do not allow for a rudimentary model specification. Time series are first differenced to obtain stationarity. Then, they are seasonally adjusted by the moving average (MA) smoothing method that gives equal weights to all observations.

Natural gas prices. We use the day-ahead prices of TTF from the International Monetary Fund (IMF). The day-ahead price is set by the current supply and demand of subjects that operate in that market. Spot prices reflect valid signals, such as short-term shocks, a demand increase caused by temperature variations or an unexpected shortage, significantly affecting the spot market.

TTF is a good proxy, not only because it has become the main European gas hub, but it is also the global reference for gas prices (Heather, 2020). TTF surpassed NBP in 2016 and now represents the hub with the highest trade volume in Europe (IGU, 2017). It serves as a reference point for natural gas traded in Europe and most countries define their prices based on the prices of gas in this hub, especially those countries in northeastern Europe that are directly connected to the Netherlands' pipelines. In recent years, TTF has also become a referent price point for global LNG trade, as Europe once again became an attractive destination for LNG exporters, due to its many gas-powered power plants, large storage capacity and the decision of the EU to stop using Russian gas.

Deviation from the average heating degree (temperature) threshold in the EU. We consider the demand for natural gas, especially for heating purposes, to be highly sensitive to air temperature changes. In a liberalised market, such as the one in Europe, storage operators are expected to account for predictable seasonal demand volatility caused by air temperature variations. Because of this, we only consider unexpected air temperature variations to be relevant. Therefore, we focus on deviations from the normal seasonal weather patterns. We use Heating degree days (HDD) as an indicator. It is based on weather conditions and designed to describe energy needs for heating purposes. It starts from the internationally defined threshold of 18°C[1]. Based on the data obtained from the Agri4Cast, we calculate the deviation of HDD from average values for the reference period, to estimate the effect of unexpected weather shocks on the prices of natural gas.

Brent crude oil price. We adjust our model in monthly frequency for seasonal weather patterns and data on gas storage. The choice of this frequency limits the use of gross domestic product (GDP) as a proxy for the business cycle. However, spot oil prices can also partially reflect the macroeconomic environment in the long run (Xia et al., 2017). Another channel through which oil affects the European natural gas price is the imports of LNG from Asia. In Asian contracts, oil affects the LNG price setting by about 15%, with a downward trend of 11-12% (Pande, 2024).

Coal prices. The model accounts for spot coal prices from three key European ports – Amsterdam, Rotterdam and Antwerpen, to capture the interaction of gas and coal for electricity generation. Apart from oil, coal is as significant for heating and electricity generation. By accounting for oil and coal prices, we include the effects of electricity generation in our model.

Natural gas storage. European natural gas storage enables efficient and secure operation of the entire continental natural gas system. Storages represent an additional source of gas supply on winter days and allow for flexibility, as the consumption during winter doubles compared to summer.

We use data on the level of gas storage fullness, as storage operators constitute a part of the supply (the withdrawal) and a part of the demand (injection). Gas

1 If Tim ≤ 15°C then [HDD = ∑i(18°C - Tim)], else [HDD = 0] where Tim is average temperature of day, e.g.: if the average daily air temperature is 12°C, value of HDD for that day is 6 (18°C-12°C). Only the days with the average air temperature of 15°C or below are taken into consideration for the calculation of HDD.

Infrastructure Europe (GIE) publishes data on storage fullness. We first construct an average seasonal pattern based on that data. We use the percentage of fullness instead of absolute values to account for the change in total storage capacity. Then we calculate the difference between the real percentage and the average monthly fullness of storage capacity. The difference between the real and average monthly fullness is an indicator of deviation from the monthly pattern.

LNG imports into the EU. Considering that the EU is a net importer of LNG, whose role rose to prominence in 2022 with the EU's attempt to decrease dependence on gas coming through pipelines, we include this indicator in the model as it reflects the current situation on the supply side of the European market.

3.1. Methodology

The European market saw significant changes in the past years that need to be included in the study of gas price drivers. One of the tools for the analysis of the dynamics of multiple time series is vector autoregression (VAR). VAR expresses a vector of observed variables as a function of its lags. In getting to VAR we start from univariate autoregression, where a stationary time-series variable y_t can often be modeled as depending on its own lagged values:

$$y_t = \alpha_0 + \alpha_1 y_{t-1} \alpha_2 y_{t-2} + ... + \alpha_k y_{t-k} + \epsilon_t$$

When one analyses multiple time series, the natural extension to the autoregressive model is the vector autoregression, or VAR, in which a vector of variables is modeled as dependent on their lags and the lags of every other variable in the vector.

A two-variable VAR with one lag is expressed as following:

$$y_t = \alpha_0 + \alpha_1 \, y_{t-1} \alpha_2 x_{t-1} + \epsilon_{1t}$$

$$x_t = \beta_0 + \beta_1 y_{t-1} \beta_2 x_{t-1} + \epsilon_{2t}$$

The VAR model with endogenous variables may be written as:

$$Y_t = A_1 Y_{t-1} + A_2 Y_{t-2} + \ldots + A_k Y_{t-k} + \epsilon_t \quad (1)$$

$$(\varepsilon_t \varepsilon_t') = \sum \quad (2)$$

Some authors employ Markov switching or break the observed period into subperiods. Domfeh (2023) uses Markov switching but primarily to investigate the natural gas-coal relationship and ascertain gas price regime changes as explained by coal price variability. Hou & Nguyen (2018) do the similar. Another way is to split the observed period into samples to estimate the model separately for different regimes (before and after the structural breaks). Nick & Thoenes (2014) use this approach, as their analysed period includes the Russian-Ukrainian Gas Conflict of 2009, the Arab Spring and the Civil War in Libya in 2011, and Supply Interruptions of Russian Natural Gas Deliveries in February 2012.

We introduce a dummy variable in a VAR for the COVID-19 pandemic period to isolate its impact. Introducing a dummy variable helps to handle structural breaks as observations include the pandemic period. Therefore, we use VAR model with exogenous variable (VARX).

The VARX method is an extension of the VAR model that allows exogenous variables. VARX, the specific case of the VAR methodology, allows imposing restrictions by setting some variables as exogenous and by imposing certain restrictions on the relationship among endogenous variables. The VARX approach is particularly important when external influences, market interventions or policy changes affect research questions and ensures the model remains robust.

Relation (1) with exogenous variable (VARX) may be written as:

$$Y_t = A_1 Y_{t-1} + A_2 Y_{t-2} + \ldots + A_k Y_{t-k} + BX_t + \varepsilon_t \quad \text{............................(3)}$$

where Y_t is a 6×1 vector of endogenous variables at time t, A_i are 6×6 coefficient matrices for each endogenous variables lag i (where i=1,2,...,k), B is a 6×1 coefficient vectors for the exogenous variable, X_t is scalar exogenous variable at time t, ε_t is 6×1 vector of error terms (innovations) assumed to be white noise with zero mean and a covariance matrix Σ.

If all we care about is characterising the correlations in the data, then the VARX is all we need.

However, the VARX may be unsatisfactory for two reasons. First, (1) allows for arbitrary lags but does not allow for contemporaneous relationships among its variables. Researchers often link variables contemporaneously, and if we wish to use the VARX for it, it must be modified to allow for such contemporaneous relationships among the model variables.

This becomes a central issue in the impulse-response analysis, where it is important to know the contemporaneous effects of a shock. Usually, this is addressed using orthogonal impulse responses, where the correlation between the errors is obtained from the (lower) Cholesky decomposition of the error covariance matrix. Cholesky relies on a mathematical transformation that is sensitive to the ordering of variables and transforms residuals into uncorrelated shocks.

A VARX model that allows for contemporaneous relationships among endogenous variables may be written as:

$$A_0Y_t = A_1Y_{t-1} + A_2Y_{t-2} + \ldots + A_kY_{t-k} + BX_t + \varepsilon_t \text{ ....(4)}$$

With a 6×6 covariance matrix of residuals:

$$\Sigma = E[\varepsilon_t\varepsilon_t^T] \text{ ....(5)}$$

Here we have a new notation (the A_0) that characterises the contemporaneous relationships among the endogenous variables in the VARX.

When writing down a VARX, one makes two basic model selection choices. First, one chooses which variables to include in the VARX (and which variable(s) to set exogenous). This decision is typically motivated by the research question and guided by theory. Second, one chooses the lag length using the formal lag-length selection criteria available. Once the lag length has been determined, one may proceed to estimation; once the parameters of the VARX have been estimated, one can perform post-estimation procedures to assess model fit. Using the Akaike Information Criterion (AIC) and Hannan–Quinn (HQIC), we define the VARX model with a length of seven lags. SBIC indicates a different lag length, but there is strong autocorrelation of the error term on it Σ.

The second deficiency of the VARX is that its error terms will, in general, be correlated. We wish to decompose these error terms into mutually orthogonal shocks. Why is orthogonality so important? When we perform impulse–response analysis, we ask the question, "What is the effect of a shock to one equation, holding all other shocks constant?" To analyse that impulse, we need to keep other shocks fixed. But if the error terms are correlated, then a shock to one equation is associated with shocks to other equations. To orthogonalise the residuals, we preform Cholesky decomposition on Σ:

$$\Sigma = PP^T \quad (6)$$

After applying Cholesky, the error term ε_t is replaced. The relationship between residuals (ε_t) and orthogonal shocks (u_t) may also be written as:

$$\varepsilon_t = Pu_t \quad (7)$$

Where:

- P: (6×6) lower triangular matrix obtained from the Cholesky decomposition of the covariance matrix Σ of ε_t ($\Sigma = PP^T$).
- u_t: (6×1) vector of orthogonal shocks with $u_t \sim N(0,I)$.

Rewrite relation (4) in a form where the contemporaneous relationships are disentangled. Premultiply the system by A_0^{-1} to isolate the endogenous variables. Also substitute $\varepsilon_t = Pu_t$:

$$Y_t = A_0^{-1}A_1Y_{t-1} + A_0^{-1}A_2Y_{t-2} + \ldots + A_0^{-1}A_kY_{t-k} + A_0^{-1}BX_t + A_0^{-1}Pu_t \quad (8)$$

Where:

- A_0^{-1} is the inverse of the contemporaneous relationship matrix.
- $A_0^{-1}P$ is a key matrix. It maps orthogonal shocks (u_t) into the system's innovations.

Moreover, we can write:

$$Y_t = C_1Y_{t-1} + C_2Y_{t-2} + \ldots + C_kY_{t-k} + DX_t + Pu_t \quad (9)$$

Where:

- $C_i = A_0^{-1}A_i$: Transformed coefficients for lagged endogenous variables.
- $D = A_0^{-1}B$: Transformed coefficients for the exogenous variable and its lags.
- Pu_t: The orthogonal shocks scaled by the P matrix.

In relation (9) shocks are orthogonal and interpretable, with a diagonal covariance matrix (I). The contemporaneous relationships are explicitly incorporated into P. The coefficients C_i and D are transformed by A_0^{-1}, reflecting how contemporaneous interactions influence lagged dynamics and exogenous effects.

4. RESULTS

By following these steps, we write down a model to obtain shocks and compute impulse-response functions (IRF). We use monthly observations on the Coal price, Brent price, LNG import, Gas storage and Temperature from 2016 to 2023 to trace the response of the endogenous variables to orthogonal shocks over time. We use VARX to model the factor's interrelationships in the European natural gas market. This approach analyses transmitting channels (mechanisms) that affect the variable of interest.

We generate IRF natural gas prices on variables impulses from a model, thus accentuating the dynamic effects of the natural gas market. Figure 1 presents the estimated IRFs for European natural gas prices.

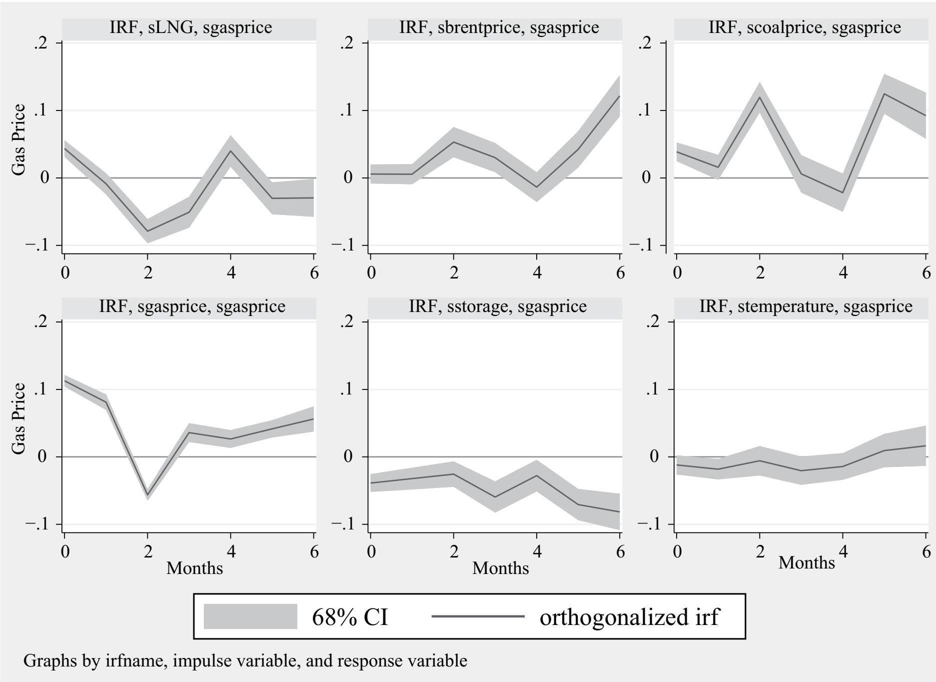

Figure 1. Responses of natural gas prices to shock from the other variable (response is to Cholesky one s.d. innovations 2 s.e.).
Source: Author's calculation

The impulsive response of natural gas prices is in line with the economic theory. There is a clear effect of shock caused by the LNG, which increases the supply and decreases the price of natural gas in the short run while stabilising it in the long run to a level lower than the one before the shock. Obadi & Korcek (2020) reach the same finding, as additional LNG supply has a negative effect, lowering the price of natural gas traded on the European market.

Functions of the impulse-response of natural gas to oil and coal prices provide evidence of different connections between energy products and reveal their interconnections. Gas prices react positively to shocks in oil and coal prices but have a different pattern. Shocks in coal prices promptly affect gas prices, causing a cyclical movement of gas prices. Nick & Thoenes (2014) find that oil and coal price shocks result in more persistent effects. Gas prices are much more affected by changes in coal than in oil prices and reach their peak in the fifth month after the shock occurs. On the other hand, oil prices affect gas prices in the medium run and have a delayed and weaker relationship, which is in line with Hulshof, van der Maat & Mulder (2016). Oil price has a small positive impact on gas prices, partly due to remaining oil-indexation contracts, which allow traders to arbitrage between spot and contract gas, influencing hub prices.

The model clearly shows a segmentation of the gas market, including a shift from OPI to GoG, as European prices have a stronger reaction to coal prices in the long run.

The interdependence of gas, oil and coal is at the core of the European energy market. Gas and coal, as the primary source of energy in electricity production, are mutually competitive. This implies that there is a positive cross-elasticity i.e. that a rise in coal prices increases demand for gas, and consequentially, a rise in gas prices.

The cyclical character is most prominent with variables Temperature and Storage (Figure A.1). A higher level of storage fullness has a negative effect on gas prices, as it indicates that there is no excess demand on the spot market. On the other hand, when storage is empty, increased demand on the spot market creates an upward pressure on gas prices because of the storage injection process. Brown & Yücel (2008) and Nick & Thoenes (2014) find storage shocks lead to short-lasting effects on the gas prices. Cartea & Williams (2008) argue that deviations from the expected storage cycle are most relevant for sport price development.

We expected cold weather would lead to a short but significant increase in gas prices, but the analysis of the impulse response has a different result. The temperature has a cyclical character and, due to its natural seasonality, does not have an excessive influence on explaining natural gas movements which is contrary to the observed *a priori* assumption.

After identifying the dynamics of the European gas market, we study the effect of these variables on the gas prices. We calculated the forecast error variance decomposition (FEVD) to quantify the effect of variable shocks and explain the role of each variable in the changes in gas prices. FEVD is presented in Table 2 and shows that coal prices, gas storage and LNG imports contribute the most to gas price volatility.

Table 2. Forecast Error Variance Decomposition for the European Natural Gas Price

	(1)	(2)	(3)	(4)	(5)	(6)
step	fevd	fevd	fevd	fevd	fevd	fevd
0	0	0	0	0	0	0
1	.007972	.001901	.084155	.084427	.106477	.715068
2	.018155	.002471	.06693	.097279	.075466	.739699
3	.009519	.054186	.300787	.059923	.15379	.421795
4	.014906	.061111	.258829	.108541	.173655	.382957
5	.017094	.06029	.250576	.113756	.187564	.37072
6	.013346	.063489	.35232	.137322	.145927	.287596

(1) irfname = IRF, impulse = stemperature, and response = sgasprice
(2) irfname = IRF, impulse = sbrentprice, and response = sgasprice
(3) irfname = IRF, impulse = scoalprice, and response = sgasprice
(4) irfname = IRF, impulse = sstorage, and response = sgasprice
(5) irfname = IRF, impulse = SLNG, and response = sgasprice
(6) irfname = IRF, impulse = sgasprice, and response = sgasprice

Source: Author's calculation

Contrary to presumptions, temperature does not play a significant role in forming gas prices. Even though the demand for natural gas is seasonal and varies depending on the weather, our results obtained with the IRF and FEVD do not indicate that this brings a significant change in gas prices. According to Gas Infrastructure Europe, European storages can hold 4 months of gas demand (Gas Infrastructure Europe [GIE], 2025), which is quite a long period (EU27 gas storage capacity is cca 115 bcm ≈ 30% of annual gas consumption in the EU27). Therefore, a possible explanation is that a flexible natural gas supply absorbs sudden (weather-caused) increases in gas demand.

We relate it to the findings of Nick & Thoenes (2014) and Domfeh (2023). They capture immediate temperature impact through heating or cooling demand, which loses intensity quickly over time, indicating a short-term impact of these shocks. Nick & Thoenes (2014) find that only extraordinarily cold weather results in an immediate and strong increase in the natural gas price; the increase lasts only for two weeks, indicating that temperature deviation has rather short-term effects.

Even in the short run, gas prices can be better explained using the developments in the market for coal, as variations in coal prices have the single strongest effect on setting the price of gas, explaining about 35% of gas price variations six months after the shock. Long-run gas price variations are affected by coal prices, storage and LNG. Their cumulative effect makes for 64% of gas price variations and can forecast gas prices up to six months in advance.

In the short run (up to two months), LNG imports and gas storage have a crucial role in setting the price of natural gas. These explain about a fifth of gas price fluctuations. This is in line with the fact that gas storage balances short-run mismatch of supply and demand in the natural gas market. This effect becomes stronger with time and is accompanied by the coal price effect that also becomes stronger. On the other hand, results confirm that oil prices do not have an impact on European gas prices, which is aligned with the switch from OPI to GoG. The explanatory power of oil prices and air temperature is low for all time horizons.

5. DISCUSSIONS AND CONCLUSIONS

We researched six factors in explaining the changes in European natural gas from January 2016 to December 2023. Our key research question was whether the chosen factors drive the natural gas prices in Europe, with a focus on the interconnection between gas, oil and coal.

A scientific contribution lies in providing a comprehensive, Europe-level analysis of natural gas price drivers, addressing a recognised gap in the existing literature. Methodologically, we advance the understanding by employing a VARX model that explicitly accounts for the endogeneity of critical market variables like gas storage and LNG imports, a more realistic approach for liberalised markets compared to prior studies. Empirically, our findings strongly demonstrate the decoupling of natural gas and oil prices in Europe, confirming the dominance of the Gas-on-Gas pricing mechanism. We reveal that coal prices are the single most significant determinant of European natural gas prices in the long run, explaining approximately 35% of price variations, and that LNG imports and gas storage play a crucial role in short-run price setting. Conversely, we show that temperature and oil prices have a limited explanatory power over European gas prices.

Air temperature variations, as well as oil prices, have limited explanatory power. Oil does not play a role in determining gas prices in Europe as many gas importers have stopped using OPI in their long-term contracts due to fear of contracted prices rising significantly above market prices because of OPI. In this context, the price elasticity of demand for gas from Russia, Algeria and Norway is a noteworthy field of future research.

The natural gas market in Europe experienced a profound transformation. Similar to the developments in the USA, European gas prices have diverged from oil prices and are completely shaped by market forces. This is confirmed by our findings.

Both the IRF and FEVD show that coal prices are the most relevant explanatory factors for gas prices in the observed period. Our results point out that we need to focus on the interdependence of gas and coal to better understand the dynamics of gas prices. Results of FEVD indicate that shocks in coal prices are the most important determinant of natural gas prices in this period which is marked by deregulation of the gas market. The rest of the variance in gas prices is attributed to other shocks specific to the European market, such as gas storage and LNG imports.

The next important finding is that there is a visible effect of LNG. We expect that with the development of the LNG infrastructure, European markets will become more integrated with other gas markets which will diminish the gap between regional gas prices. Prices in the European and US market are at the time still set independently. However, with further development of the critical infrastructure, intensified by Europe's efforts to become independent of Russian gas, these countries should definitely have a better position in negotiating gas prices. This will further bring the European natural gas price-setting mechanism closer to market conditions.

The results obtained cannot be generalised outside Europe due to the regional character of the markets. There are limitations to our study as the observed time frame is limited and there are potential explanatory variables that were not included in the analysis. Temperature shocks not substantially affecting gas prices could be due to flexible natural gas supply amortising gas demand changes without major price fluctuation. Capturing temperature effects is challenging as researchers must "catch" storage levels at the moment of temperature oscillations; when storage is low, a sudden drop in temperature drives higher natural gas demand (injection). When storage is high, the impact is minimal due to withdrawal.

It is not entirely surprising or unexpected that temperature shocks have a limited impact on natural gas prices, given the resilience and elasticity of supply along with storage mechanisms that smooth price fluctuation, but we expected at least some level of impact. Additionally, data and model limitations may not capture the temperature effects accurately, as gas storage levels play a crucial role in this dynamic.

One of the directions of future research is constructing a more comprehensive model that would include financial indicators. Another one is developing a theoretical model that would explain the functioning of the European market in different geographical zones of the continent, as the market is not homogenous, and these zones have different patterns in natural gas consumption.

Bearing in mind the limitations, our findings contribute to a better understanding of the dynamics of the European gas market. Insights enhance the understanding of European gas market dynamics and highlight policy implications related to energy security and demand elasticity. An important implication of our study is that we proved that there was a divergence between natural gas and oil prices during the process of deregulation of the European gas market. Another noteworthy finding, based on the developments after the beginning of the war in Ukraine, is that the price elasticity of demand for natural gas in Europe is low due to its geographic position (proximity to Russia and Algeria enabled building pipelines from these countries, which Europe became reliant on). Low elasticity causes high natural gas prices (Figure A.1) during supply disruptions, often raising the question of whether gas prices should merely be defined by the market.

Conflict of interests

The authors declare there is no conflict of interest.

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ПОКРЕТАЧИ ЦИЈЕНА ПРИРОДНОГ ГАСА У ЕВРОПСКОЈ УНИЈИ

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САЖЕТАК

Природни гас је кључни енергент и важан инпут у индустрији и производњи електричне енергије. Три директиве о гасу са почетка миленијума су либерализовале европско тржиште природног гаса. Директиве су подстакле прелазак са индексације цијене на нафту на механизам формирања цијене гаса на основу понуде и потражње на тржишту, што је дерегулисано тржиште учинило занимљивим предметом истраживања. У овом раду испитују се покретачи цијена природног гаса на европском тржишту. За истраживање утицаја одабраних фактора користимо VAR модел са егзогеном варијаблом. Анализа импулсног одзива показује да је европско тржиште природног гаса краткорочно осјетљиво на увоз течног природног гаса и складиштење гаса, док је у дугом року уско везано за угаљ, остављајући по страни утицај нафте и температуре. Резултати декомпозиције варијансе прогнозе грешке откривају повезаност европских цијена природног гаса са кретањем цијена угља, складиштења гаса и увоза течног природног гаса збирно објашњавајући 64% варијација у цијенама гаса. Појединачно гледано, угаљ има највећу моћ објашњења с обзиром да одређује 35% варијабилности за период узорка.

Кључне ријечи: *цијена природног гаса, европске цијене гаса, природни гас, енергетска економија, тржиште природног гаса.*

APPENDIX

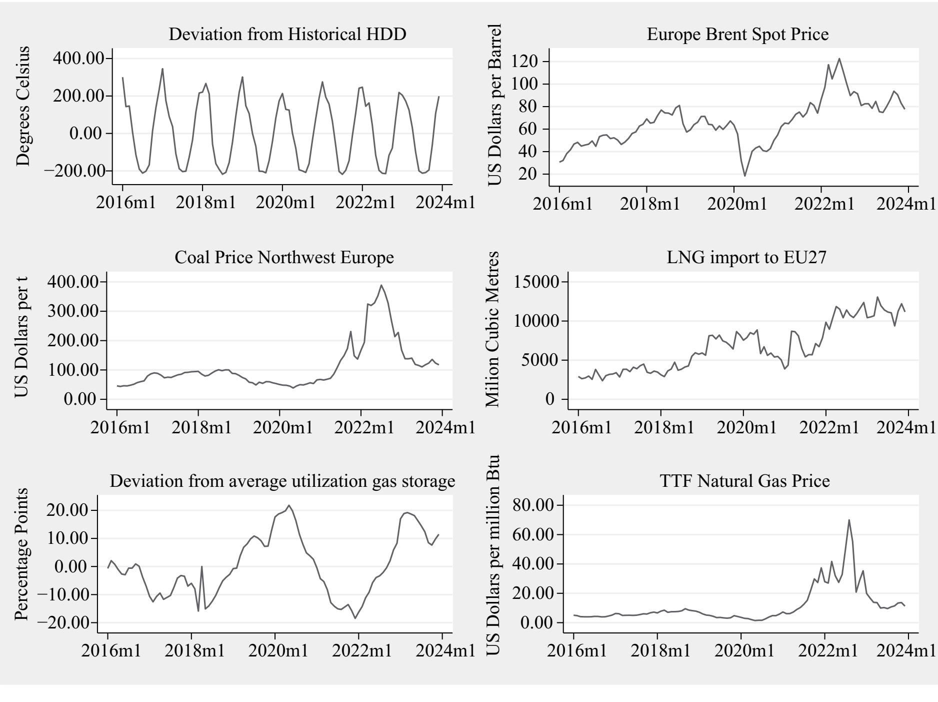

Figure A.1. Time Series of Used Variables
Source: Author's calculation