Natural Gas Pricing Mechanisms in Europe
from Oil-Indexation to Hub-Based

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Abstract. In this work, our aim is to assess the state of the evolution of natural gas' pricing mechanism across Europe. As the historical relation between natural gas and oil prices has begun to fade, it left room for a competitive hub-based pricing system, sensitive to actual market conditions. We first verify that cointegration between oil and gas prices does not exist anymore, then explore the new pricing mechanism through both regression and impulse response analysis, and confirm that natural gas price is indeed responding to its market fundamentals, extending previous research on this topic to the 2014-2020 time span.

Keywords: Natural Gas Price · Oil-Indexation · Hub-based · Cointegration · OLS Regression · Impulse Response Analysis.

1 Introduction

In the past decades natural gas (NG) has become a resource of primary importance for the global economy, playing a fundamental role in countries' development. While NG price has been linked to that of crude oil since 1960, at the beginning of the 21st century its pricing mechanism has experienced a substantial change within the European framework, moving from **oil-indexation** to **gas-on-gas**. This shift was induced by a combination of events, with two forces pushing in opposite directions: on one hand, the price of oil, which has covered a crucial role for the 20th century's global economy, has begun to lose its relevance mainly due to the ongoing shift in energy consumption from oil to green resources. On the other hand, the European energy **market liberalization process**, starting from 1996, has set the perfect environment for the development of an integrated hub network, in which NG could be traded at a **competitive price**, based on the actual demand and supply conditions.

In this work, we want to provide evidence concerning two issues, namely, that the long run linkage between gas price and oil price has *declined*, and meanwhile, gas prices are becoming more respondent to market fundamentals shocks than to oil price shocks.

Numerous works in the energy economics field have showed the co-integration between oil price and gas price at the beginning of the 21st century. Thus, we test our hypothesis of a declining long-run relation between the two prices series after the change in the pricing mechanism through the Johansen procedure. To evaluate the development of a competitive logic in gas pricing, we analyze the relation existing among gas price, oil price and gas market fundamentals, by employing **Ordinary Least Squares Regression** (OLS) and **Impulse Response Analysis**.

2 Theoretical Background and Literature Review

Before exploring the grounds for the pricing mechanism shift, it is important to point out the difference between contractual and economic oil-indexation. While the first explicitly embeds oil price in NG contracts, the latter derives from the substitution properties between the two fuels. In this work, we will explore the fall of economic indexation.

We shall consider the reasons why oil-indexation was introduced, and then became obsolete starting from the first decade of 2000th. In 1960 there was the necessity to have a benchmark for setting gas prices, and the idea of linking them to the substitute oil commodity seemed optimal. In fact, as Villar and Joutz [1] point out, the substitution properties of gas and oil allowed for an adjustment dynamics, in which as the price of oil rised, gas became relatively cheaper and demand increased, leading to a rise in gas prices as well. Nowadays however, most companies are renouncing oil, due to both the high maintenance costs, and the increasing attention towards **environmental standards**, requiring the shifting to green resources. Moreover, since the supply of gas was linked to the demand for oil, both consumers and suppliers could not receive a clear and transparent signal from the other side. This made it virtually impossible to find the equilibrium point, and thus to allow an efficient encounter between gas demand and supply. As a further point, this mechanism was very likely to overvalue natural gas, as oil is a more scarce resource on our planet.

From a regulatory point of view, oil-indexation was supported by Governments and State monopolies, which dominated the energy sector until the beginning of the European liberalization process in 1996. The monopolistic regime allowed incumbents to exert their power by undersigning long term contracts, which could last up to 30 years, based on a fixed oil-indexed price. This of course hindered any possibility to induce competition in such a sector, and thus to lower gas prices for end-consumers.

The first European Energy Package, and in particular directive 98/30/EC in relation to gas, began the process of monopoly dismantling. This first measure was accompanied by other three Energy Packages in later years, and by the creation of the first European gas hub, namely the UK's National Balancing Point (NBP) in 1996. In 2003 the dutch Title Transfer Facility (TTF) was born, followed by the two German hubs some years later. It was in this setting that the EC saw the possibility of giving a formal shape to its liberalization process. The aim was that of creating an **integrated liberalized energy market**, based on an European gas target model, which could facilitate communication among the newly born European hubs. This was eventually endorsed by the Council of European Energy Regulators (CEER) in 2012 [2].

Many authors have investigated this topic, exploiting many different approaches. In the European setting, first Hulshof, van der Maat, Mulder [3] (2015), then Obadi and Korcek [4] (2020) have build an OLS regression model, identifying market fundamentals as the main drivers of NG price. As we will show in the following sections, our results are consistent with their findings. After 1980, when the spurious regression problem arising from integrated processes has been identified, Asche et al. [5] (2012) in the UK, and Villar and Joutz [1] (2006) in the USA, found evidence of cointegration between NG and oil prices. Our analysis shows that this relation does not hold anymore, as the shifting in pricing mechanism is reaching its completion.

3 Data Description

Limited to the data source, the European countries considered in this work are Belgium, Bulgaria, Czech Republic, Denmark, Germany, Estonia, Ireland, Greece, Spain, France, Croatia, Italy, Latvia, Lithuania, Hungary, Netherlands, Austria, Poland, Portugal, Romania, Slovenia, Slovakia, Finland, Sweden, United Kingdom and Turkey, 26 in all. All the data are collected monthly over the period 2014 - 2020. The main sources are Eurostat, the Joint Research Centre of the European Commission, Quandl, and Yahoo Finance.

3.1 Natural Gas and Oil

In 2003, the dutch **Title Transfer Facility** (TTF) natural gas hub was born, and it rapidly managed to acquire the role of main European benchmark, thanks to its ever increasing exchanged volumes and churn rates, the two main indices of a hub's liquidity [6]. Furthermore, as proven by Bastianin, Galeotti, and Polo [7], European natural gas prices are converging towards a common trend. For these reasons, for the purposes of our analysis, we compute the monthly average of the daily front-month Base Load Futures prices at TTF to proxy for European gas prices. The price is set in Euros for a contract size of 1 MWh.

Next, we use daily **Brent Crude** oil Financial Futures price and compute its monthly average. Brent is the European benchmark for crude oil prices, and is set at the Northwest Europe's physical and financial market. The price is expressed in USD dollars per 1,000 barrels (42,000 gallons).

Given the different currency in which NG and oil prices are measured (and coal prices as well, as we will shortly see), we also include the EUR-USD **exchange rate** in our analysis.

3.2 Market Fundamentals

To represent the market fundamentals which we expect to drive the pricing of NG, we introduce gas storage, weather conditions, and the price of the substitute fuel coal.

For **coal prices** we considered Coal (API2) CIF ARA (Argus-McCloskey) Futures, which are the industry standard reference prices for coal imported into northwest Europe. The series is measured in dollars for 1,000 metric tonnes. In **Fig. 1** we can observe the evolution of the three prices series of NG, oil, and coal. As it can be expected given that they all belong to the same sector, the same overall dynamics is shown by all the series: after a period of growth between 2016 and 2019, prices begun to decrease at the beginning of 2020, certainly due to the COVID pandemics.

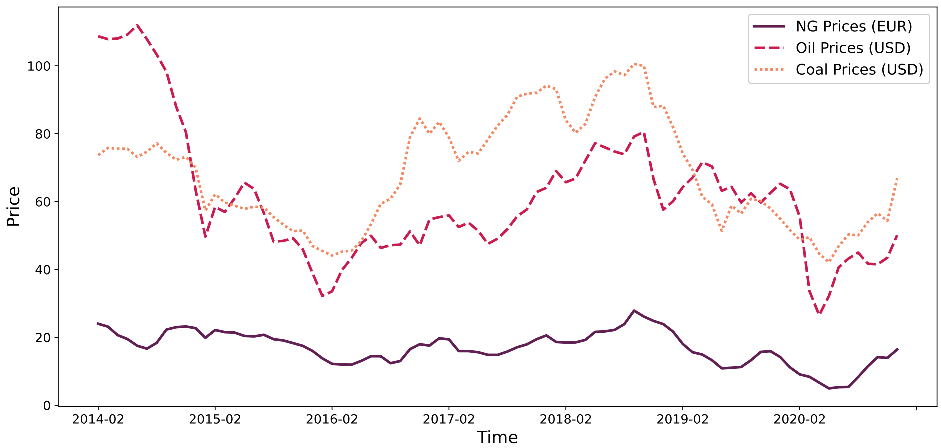


Fig. 1: Monthly NG TTF prices, Brent crude oil prices, API 2 Coal prices evolution from 2014 to 2021

To account for the weather conditions, we employ the **Heating and Cooling Degree Days index** (HCDD) provided by the Joint Research Centre, which is computed upon outside and inside temperatures. The country level data is aggregated through mean, to approximate the average need for heating and cooling in EU.

Gas storage data corresponds to Eurostat's Stock level for gas products measured in Millions cubic metres. These values are further divided by 100 for interpretation purposes, as this allows comparability with the other series. Data aggregation is performed by summing, to obtain the total European storage availability.

4 Methodology

In order to test whether the long-run cointegrating relation between NG price and oil prices still exists, we exploit the Johansen methodology. This procedure allows the tested co-integrating vectors to be more than one, thus providing a more specific overview on the possibly existing stationary combinations of the two integrated series.

After excluding the existence of cointegrating relations between all unit root processes in our dataset, it is vital to guarantee that the time-series data we use for the following analysis are stationary. Since both NG storage and HCDD show strong seasonality, we use the **Additive Decomposition Model** to remove the yearly cycles. After deseasonalization, we compute the first difference of all three Prices series, Exchange Rate, and deseasonalized NG Storage, and perform **Augmented Dickey–Fuller** (ADF) test to ensure all the time-series of interest are stationary.

The third step of our analysis consists in performing an OLS regression of NG prices on oil price, coal price, HCDD index, gas storage, and EUR-USD exchange rate. By means of it, we are able to detect the significant features in NG pricing and estimate their impacts on the determination of NG price. Moreover, following Obadi and Korcek [4], we build a binary variable which takes value 0 until September 2016. This is the date in which Britain announced the decommissioning of *Rough*, its main underground storage facility, leading the whole continent to depend more on flexible deliveries of Liquefied Natural Gas (LNG). The final model has the following form:

$$\begin{aligned} \Delta NGPrice_t = & \propto_0 + \beta_1 \Delta OilPrice_t + \beta_2 \Delta CoalPrice_t + \beta_3 \Delta\_des\_Storage_t \\ & + \beta_4 des\_HCDD_t + \beta_5 \Delta ExchangeRate_t + \beta_6 LNG\_dummy_t + \epsilon \end{aligned}$$

Besides the impact of each feature on NG price, we also want to explore the time-related relation of the components of interest and their dynamic behaviors. Hence, we use **Impulse Response** (IR) by employing a **Vector Autoregression** (VAR) model. To simplify the dynamic mechanism, we include only NG price, oil price, coal price and NG storage in this system. So, the VAR equation is built as follows:

$$\begin{bmatrix} \text{Oil Price}_t \\ \text{Coal Price}_t \\ \text{Gas Storage}_t \\ \text{Gas Price}_t \end{bmatrix} = \begin{bmatrix} \text{Oil Price}_{t-1} \\ \text{Coal Price}_{t-1} \\ \text{Gas Storage}_{t-1} \\ \text{Gas Price}_{t-1} \end{bmatrix} * \begin{bmatrix} a_{11} & a_{12} & a_{13} & a_{14} \\ a_{21} & a_{22} & a_{23} & a_{24} \\ a_{31} & a_{32} & a_{33} & a_{34} \\ a_{41} & a_{42} & a_{43} & a_{44} \end{bmatrix} + \begin{bmatrix} \epsilon_{1t} \\ \epsilon_{2t} \\ \epsilon_{3t} \\ \epsilon_{4t} \end{bmatrix}$$

For simplicity, here we represented the one lag model; however, the VAR we build takes two lags of each variable into account, as suggested by the Schwartz Information Criterion.

Since we are establishing a relation between the four variables, it is important to verify that lagged values of each of the series are actually significant, meaning that they are indeed useful for predicting the dependent variable in each equation of the system. For this purpose, we will exploit a **Granger-Causality** test for each pair of variables considering a maximum lag of 12, the econometric standard for monthly data.

For a correct interpretation of the impulse response functions, and to trace the actual time path of the various shocks on the NG price, we need to get rid of a recursive structure of the contemporary relationships of the four components. We obtain this orthogonalization by introducing the **Cholesky Decomposition**, in order to make the shocks independent on one another at the same time t. In addition, we employ accumulated impulse response functions to explore the overall *long-run* effects of the shocks.

5 Empirical Analysis and Results

5.1 Cointegration Test

As anticipated in the previous section, the first issue we want to address is the disappearance of the long-run cointegrating relation between oil price and NG price. Through ADF testing, we detect statistical evidence of the presence of a unit root for both NG price and oil price, meaning that they are *non-stationary* time series.

The same test is performed on all the unit root variables considered, to exclude the possibility of spurious results in the following steps of the analysis. Pairwise, all the series show no cointegration. Finally, through seasonality removal and differentiation we transform all the time series into their stationary state and perform ADF test again for confirmation. In **Table 1** we report the t-statistics with the associated significance level for all the considered variables, before and after the transformation to *stationary* series.

Hence, we can proceed with the Johansen test for cointegration. The hypothesis we want to test concerns the adjustment of NG prices to variations in oil price. In fact, if cointegration was still present in the European framework, the Vector Error Correction Mechanism between the two series would imply that, as oil price rises, NG price also rises, following oil's market dynamics rather than its own.

As we can see from **Table 2**, conditional on the assumption of a linear deterministic trend in the relation, both the trace and the maximum eigenvalue test results show that the null hypothesis of "no co-integrating relations" cannot be rejected with a 95% confidence level. In other words, the mechanism which led NG prices to adjust to oil prices is not at work anymore across Europe.

Table 1: ADF Test Results

	Levels	**Deseasonalization & First Differences**
Oil Price	-2.75	-5.58***
NG Price	-2.84	-5.51***
Coal Price	-2.32	-6.63***
NG Storage	-2.71	-7.56***
HCDD	-2.76	-7.03***
Exchange Rate	-2.47	-6.40***

$^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$

Table 2: Johansen Cointegration Test

	Trace		**Maximum Eigenvalue**	
	statistic	**P> |t|**	**statistic**	**P> |t|**
None	18.78	0.29	11.79	0.43
At most 1	6.99	0.35	6.99	0.34

$^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$

5.2 Ordinary Least Squares Regression

At this point, we can perform the OLS regression of NG prices on its candidate determinants. To verify the robustness of our results, we run two different specifications: the complete model, and a restricted model which excludes the LNG dummy. The summaries of both models are exhibited in **Table 3**. While performing our analysis we also run an alternative regression, exploiting West Texas Intermediate (WTI) as oil price. However, since the two oil price series are extremely correlated, the obtained results where virtually the same (this alternative specification is displayed in the Github repository linked in section 7).

Table 3: OLS Regression Results (dependent: *D_NG_price*)

	Complete model		**No LNG dummy**	
	coef	**P> |t|**	**coef**	**P> |t|**
const	-2.7698	0.011**	-2.345	0.027**
D_oil_price	0.0007	0.979	0.005	0.849
D_coal_price	0.2224	0.000***	0.216	0.000***
D_des_storage	-0.0082	0.032**	-0.0081	0.036**
des_HCDD	0.0194	0.022**	0.0184	0.031**
D_exchange_rate	-16.7155	0.029**	-12.957	0.079*
LNG_dummy	0.5102	0.096*	-	-

$^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$

Both specifications lead to the same consistent evidence. Remarkably, the market fundamentals variables are all found to be significant (*D_des_storage* and *des_HCDD* at the 95% confidence level, and *D_coal_price* at the 99% one). On the other hand, the coefficients on Crude oil price are widely within the non rejection region, meaning that oil prices do not have a significant effect on NG pricing.

Before exploring the regression outcome in detail, it is important to point out the possible *threats to internal validity.* First, the assumption on the exogeneity of the independent variables may not hold strictly, as both storage and coal prices may exhibit reversed causality with NG gas prices. However, due to the complex interconnection between macroeconomic phenomena, complete exogeneity is difficult to grant, as pointed out by Hulshof et al. [2]. Second, the model could further be expanded to take into account other possibly relevant determinants of European gas prices, as market-set prices are very likely to be intertwined with other macroeconomic variables, and with their expected values. The considered regression specification is nonetheless pertinent to the scope of our project, and we will leave possible model expansions for future work.

We can now proceed with the interpretation of the obtained results. To begin with, the sign of the **oil price** coefficient is positive, and it decreases by an order of magnitude once the LNG dummy is included; this suggests that to properly assess the strength of the relation between oil and gas prices it is vital to take the quality and availability of infrastructures into account. However, the probability of this effect of being 0 is almost 1, meaning that changes in crude oil prices are not statistically significant to explain the evolution of NG prices. This is a crucial finding, as it provides relevant evidence for the progressive disappearance of the relation between the prices of these two fuels. This also emerges in **Fig.2**, from which we cannot identify any consistent and evident relation between the monthly changes in oil and in NG prices.

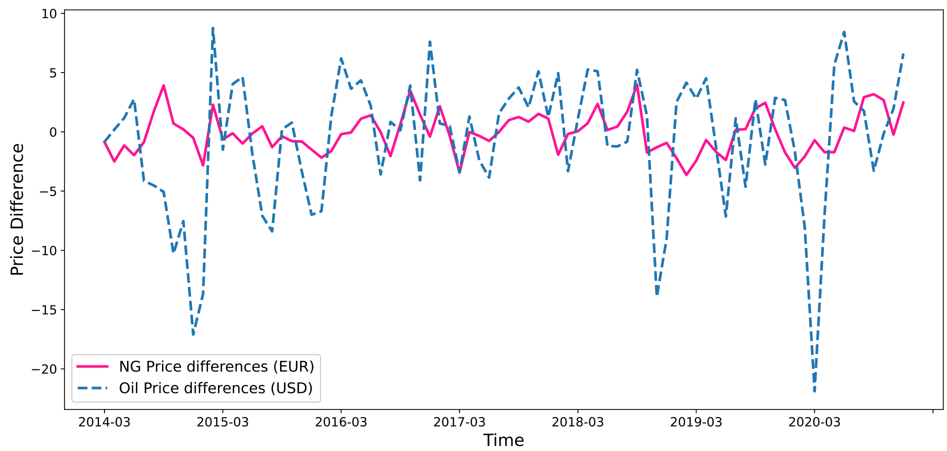


Fig. 2: Monthly differences in NG TTF prices and Brent crude oil prices from 2014 to 2021

Coal price movements are instead highly significant, and have a relatively large coefficient of approximately 0.2, meaning that an increase of 1 USD in coal prices' monthly variation leads to a 20 cents increase in the NG price variation. This can be explained by means of the competition existing between these two fuels. As noted by Harley and Medlock [5] in the USA case, as NG and oil are losing their substitution properties due to the progressive renunciation to oil usage, coal is likely to have undertaken the role of new competitor for natural gas. As it would be expected in a competitive setting, when the price of a substitute good raises, demand for the primary good also raises, bringing up its price as well. Contrary to what emerges when comparing NG and oil prices, in **Fig.3** we can now clearly detect a joint movement between the monthly changes in NG and in coal prices, in which the latter seem to be followed by shifts in the latter.

The coefficient on **NG storage**, significant at a 95% confidence level, emphasizes the negative relation existing between natural gas price and its stock levels, depicted in **Fig.4**. In fact, a lower stock availability imposes pressure on the NG market, which is then induced to raise its prices given the relatively higher demand level. The coefficient is quite small in magnitude, also considering that Storage is measured in 100 Millions of m^3. However, given the different units of measure and variability range, to properly assess the size of the impact of a variable we should consider their distribution.

As we can observe in **Table 4**, the standard deviation of NG Storage monthly differences is 31 times the mean, while this ratio is of about 18 for NG prices, meaning that variations in stock levels are much larger than price variations, and are likely to have a meaningful impact on NG prices, despite the small coefficient.

The last variable accounting for gas market fundamentals is the **HCDD index**, which is also significant at a 95% confidence level. As expected, the need for heating and cooling systems has a positive effect on NG prices: extreme temperatures increase the demand for natural gas, thus pushing up the market price. The size of the coefficient is also noteworthy, as a 1°C degree increase

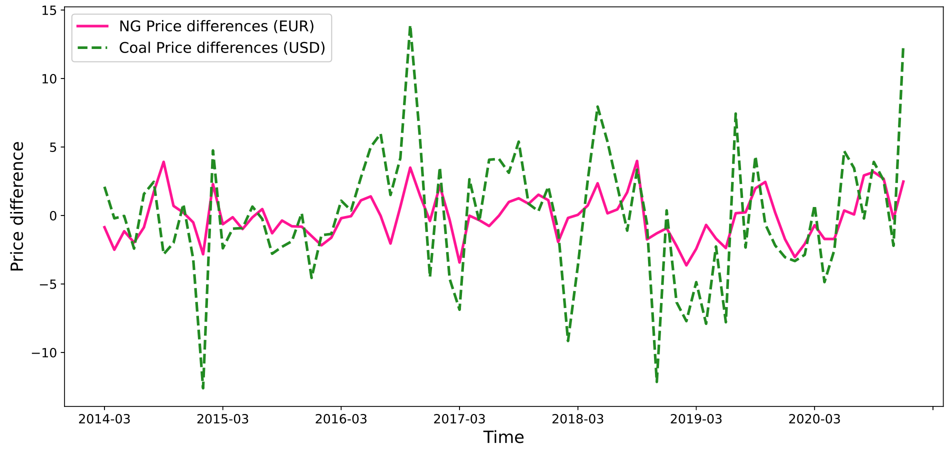


Fig. 3: Monthly differences in NG TTF prices and API 2 Coal prices from 2014 to 2021

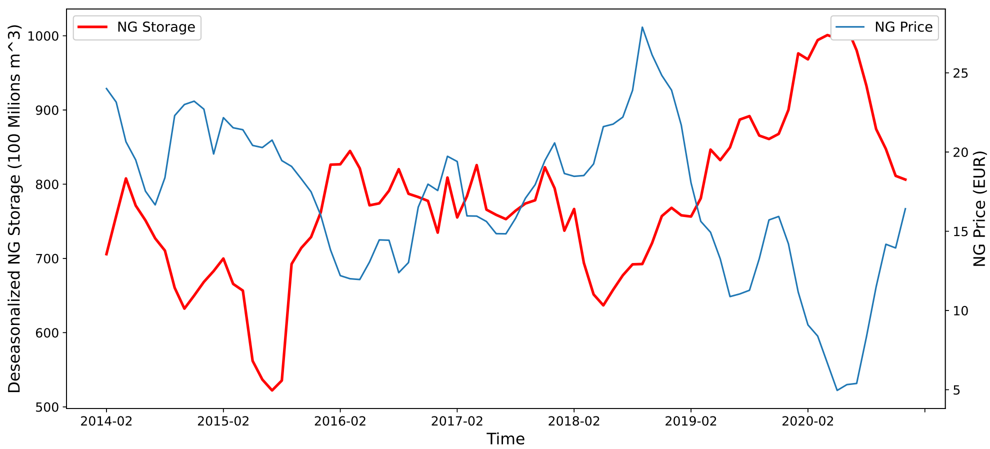


Fig. 4: Monthly NG TTF prices and NG deseasonalized storage evolution from 2014 to 2021

in the HCDD index leads to an increase of 2 cents in the price set at TTF, and the index has an average monthly deviation of about 17 °C degrees from its mean.

The effect of the variations in the **exchange rate** is consistent between the specifications, and the inclusion of the LNG dummy increases both the size and the significance of its coefficient. When running the regression without the exchange rate the coefficient on oil price is negative, meaning that its existence in the model is of critical importance for adequately assessing the relation between NG and oil prices (this alternative regression specification is presented in the Python code). The coefficient is the largest in size, as a unitary increase in the monthly exchange rate difference would lead to a decrease in NG price of almost 17 euros. Nevertheless the size of the effect is reasonable, given that the mean variation for EUR-USD exchange rates is -0.002 and the maximum is 0.037.

To conclude, the LNG dummy is significant at a 90% confidence level. This variable accounts for the state of **LNG** storage facilities across Europe, upon which the supply need depends, and thus allows a correct assessment of the impacts of market fundamentals on NG price.

Table 4: Summary Statistics

	HCDD	D NG Price	D Exchange Rate	D Oil Price	D Coal Price	D Storage
mean	122.801	-0.092	-0.002	-0.715	-0.083	1.225
std	17.370	1.714	0.020	5.683	4.645	38.183
min	82.867	-3.639	-0.066	-21.895	-12.612	-94.646
max	163.158	3.985	0.037	8.761	13.910	157.014

5.3 Impulse Response Analysis

Before proceeding with IR analysis, we test Granger Causality pairwise among the four components which will be used to built VAR model, since we want to confirm the interdependent relation of the four. The null hypothesis is that variable X does not Granger Causes Variable Y. In the **Table 5**, we list variable X as columns, and response variable Y as rows, and fill in the table with the probability of not rejecting the null hypothesis. From the results, manifestly, all oil price, coal price and NG storage *Granger cause* NG price with a 95% confidence level.

Table 5: Granger Causality Results

	NG Price	Oil Price	Coal Price	NG Storage
NG Price	1.0000	0.0305^{**}	0.0001^{***}	0.0002^{***}
Oil Price	0.0716^{*}	1.0000	0.0002^{***}	0.1535
Coal Price	0.0062^{***}	0.1299	1.0000	0.0625^{*}
NG Storage	0.0003^{***}	0.0002^{***}	0.0097^{***}	1.0000

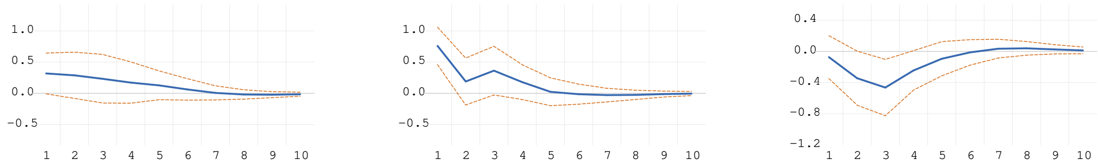
$^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$

To use Cholesky Decomposition for IR, the variables should be ordered by the degree of exogeneity. For the purpose of the analysis, we set oil price first and NG price last. Because of substitution effect, coal price will influence the demand of gas, and thus demand will affect the storage level. So we choose the order as "*oil price - coal price - NG storage - NG price*".

Fig.5 illustrates impulse responses: in each plot, the blue solid lines represent the response of NG price after one standard deviation of the respective shock. **Fig.5(a)** exhibits that NG price has a slight positive response after the shock on oil price, but this impact is not significant, consistently with the findings in the OLS model. For market fundamentals' shocks displayed in **Fig.5(b)** and **Fig.5(c)**, NG price has a negative response to NG storage, while it has a more significant positive response to coal price. In the long run, from accumulated impulse responses in **Fig.6**, manifestly, for NG price, oil price has a subtle positive effect, NG storage has a low negative effect and coal price has a high positive effect.

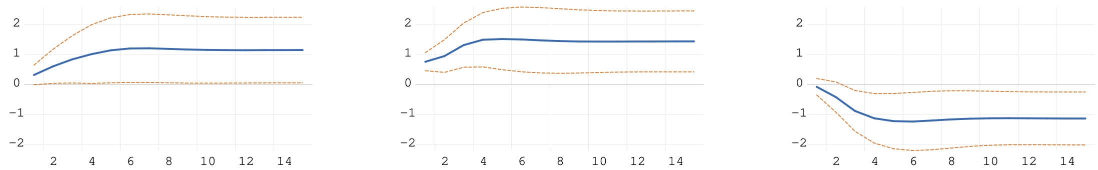
The impulse responses and accumulated responses of NG price are consistent with OLS analysis and economic theories. As oil price increases, gas price has an insignificant increase. The insensitivity delivers the signal that NG price no longer sticks to oil price. On the contrary, when coal price increases, NG price has an immediate and significantly strong increase as feedback, due to the substitution effect. Coal, as mentioned by Sebastian and Thoenes [10], competes with NG in the electricity sector, thus inducing a positive cross-price elasticity. Therefore, when there is a positive shock in coal prices, demand of NG increases, thus pushing the prices up.

As described in the previous section, NG storage negatively correlates with NG price. This also emerges from the IR: as we can see in **Fig.3(c)** a positive shock in storage lowers t; moreover, the response of price to stock levels innovations is not as quick as the response to coal price shocks, reaching the peak at period 3. In summary, while the response to oil price is not significant, the NG price responses to shocks from its market fundamentals are quite relevant, and consistent with the findings from the OLS regression.



(a) Oil Price shock **(b)** Coal Price shock **(c)** NG Storage shock

Fig. 5: Impulse Responses of NG Price



(a) Oil Price shock **(b)** Coal Price shock **(c)** NG Storage shock

Fig. 6: Accumulated Impulse Responses of NG Price

6 Conclusions

In this work, by means of the analysis above, we have provided several crucial evidences for the NG pricing mechanism shift from oil-indexation to hub-based. *Firstly*, through a co-integration test between oil price and NG price, we prove that the old economic oil-indexation pricing mechanism has dramatically lost its importance in the European market. *Secondly*, from the empirical results of the OLS regression we detect that, for the current NG pricing mechanism, oil price does not show a statistically significant impact. On the other hand, the substitute fuel coal price, NG storage and HCDD index, which play the role of market fundamentals, and also the EUR-USD exchange rate, have statistically significant effects on the price of natural gas. *Thirdly*, the impulse response analysis results reveal that NG price has a more significant and stronger response to shocks from market fundamentals, while subtle insignificant changes in response to oil price shocks, implying that NG pricing is more sensitive to market fundamentals rather than oil price. Noticeably, the impulse response analysis results are perfectly in line with the findings from the regression framework.

Consequently, we can conclude that within the European energy market the shift in natural gas' pricing mechanism is being successfully achieved, and the current gas-on-gas pricing responds to the actual NG market conditions.

This has relevant policy implications, as it is a sign of a certain degree of competitiveness in the natural gas market, which was the main objective of the European liberalization process. In fact, in a competitive framework the price is free to adjust to the actual needs of suppliers and demanders, hence yielding efficiency and lower prices for the consumers.

7 Appendix

Our analysis is performed through Python language, and code is shared on Github; for the time series analysis part, we also relied on Eviews software.

References

1. Villar, José and F. Joutz. , "The Relationship Between Crude Oil and Natural Gas Prices", *Economics*, 2006
2. Jonathan Stern, Howard Vaughan Rogers, "The Evolution of European Gas Pricing Mechanisms", *book: The European Gas Markets (pp.359-391)*, 2017
3. Daan Hulshof, Jan-Pieter van der Maat, Machiel Mulder, "Market fundamentals, competition and natural-gas prices", *Energy Policy*, 2015
4. Saleh Mothana Obadi, Matej Korcek, "Driving Fundamentals of Natural Gas Price in Europe", *International Journal of Energy Economics and Policy*, 2020
5. Frank Asche, Petter Osmundsen, Maria Sandsmark, "The UK Market for Natural Gas, Oil and Electricity: Are the Prices Decoupled?", *The Energy Journal. 27. 27-40.*, 2012
6. Patrick Heather, "European Traded Gas Hubs: the supremacy of TTF.", *The Oxford Institute for Energy studies*, 2020
7. Andrea Bastianin, Marzio Galeotti, Michele Polo, "Convergence of European natural gas prices", *Centre for Geography, Resources, Environment, Energy and Networks*, 2018
8. Peter Hartley, Kenneth Barry Medlock, "The Relationship between Crude Oil and Natural Gas Prices: The Role of the Exchange Rate", *The energy journal*, 2013
9. Ludovico Grandi, "European gas markets: From oil indexation prices to spot prices?", *Energy Brains – Energy Analysis*, 2014
10. Sebastian Nick, Stefan Thoenes, "What Drives Natural Gas Prices? – A Structural VAR Approach", 2013