A note on interactions between European and US natural gas prices

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Abstract

We apply a structural vector autoregressive model (SVAR) for three energy commodity prices: WTI crude oil, natural gas in the US and natural gas in Europe. The SVAR setup allows us to analyze the interactions among the three endogenous variables in a comprehensive framework. In particular, it allows to investigate how disturbances specific to the analyzed commodities are propagated within the system. Our findings are threefold. First, we show that oil prices are not affected by shocks specific to natural gas markets, whether in the US or in Europe. Second, we demonstrate that the dynamics of the US natural gas market is predominantly driven by idiosyncratic innovations and is only partially affected by oil shocks. Third, we indicate that over longer horizons, natural gas prices in Europe are mostly determined by oil specific shocks. These results present a new perspective on the decoupling of the US natural gas market from the crude oil as well as the European natural gas markets. In turn, for European natural gas prices we show only short-lived decoupling from oil prices.

Keywords: energy commodity prices; decoupling of natural gas market; structural vector autoregressions; impulse response functions

JEL Classification: C15, C32, Q31

1. Introduction

In 2019, natural gas was the third most important source of energy in the global economy, accounting for 22.2% of global primary energy supply (IEA, 2019), whereas the shares in European Union and the US stood at 24.6% and 31.7% respectively (Fig. 1). Understanding natural gas price differences between US and European markets might be interesting to many agents, including policy makers responsible for energy policy. For instance, the Polish authorities have recently signed a long term contract to import liquified natural gas from the US, aiming to diversify the natural gas supply as well as expecting that the currently observed price gap between the US and European markets will persist in the future.

The role of natural gas as a source of energy has been recently growing in importance. An increasing number of studies on the dynamics of its prices emphasize that, due to transportation

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costs and heterogeneous institutions, global natural gas market is geographically segmented into several localized markets, similarly to coal market (Papież and Śmiech, 2015). This is well illustrated by the divergence of its price quotations in America, Europe and Asia after the shale gas revolution in the US (Geng, Ji, and Fan, 2016b; Wakamatsu and Aruga, 2013; Zhang and Ji, 2018). This distinguishes natural gas from crude oil, whose prices are determined by global rather than local factors (Kilian, 2009). This dichotomy in terms of geographical coverage, combined with the fact that both energy commodities are substitutes, motivated researchers to investigate the relationship among the dynamics of regional natural gas and crude oil prices. One of the results is that the natural gas market is strongly influenced by the developments in the crude oil market, with the absence of reverse causality (Jadidzadeh and Serletis, 2017; Lin and Li, 2015). Additionally, the long-term relationship between both commodities in the US market has decoupled since mid-2000s, which did not happen in the European market (Erdos, 2012; Geng, Ji, and Fan, 2016a; Wang, Zhang, and Broadstock, 2019; Zhang and Ji, 2018).

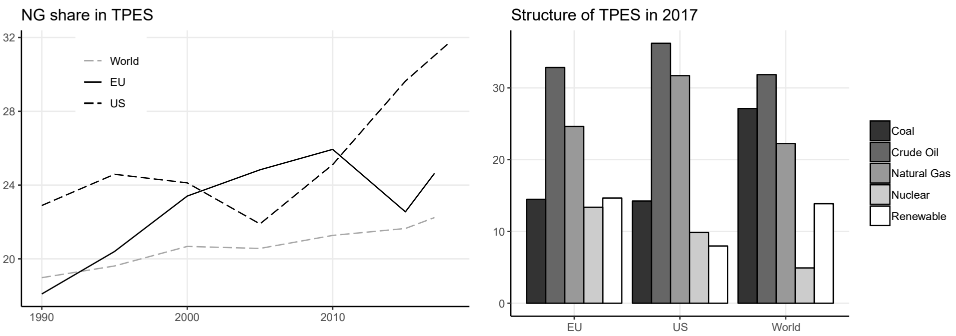

Figure 1. Total primary energy supply (TPES) by source and region

Notes: The structure of TPES for US refers to 2018. Source: IEA (2019).

Another issue is the question about the source of natural gas price fluctuations. The focus is predominantly on the US market, for which prices are usually approximated by Henry Hub spot and futures price quotations. Since the US market was fully deregulated following the Natural Gas Policy Act of 1978, it can be argued that, starting from mid-1990s, natural gas prices have been entirely determined by market forces (Joskow, 2013). This justifies the application of structural models in which natural gas prices are driven by supply and demand factors, e.g. the structural vector autoregression (SVAR) framework. The analyses with SVAR models point to two recurrent observations: demand rather than supply shocks seem more important in explaining the dynamics of natural gas prices (Arora and Lieskovsky, 2014; Hailemariam and Smyth, 2019; Hou and Nguyen, 2018) and an evidence of regime dependent dynamics of the US natural gas market (Hou and Nguyen, 2018; Wiggins and Etienne, 2017).

The dynamics of the European natural gas market is relatively unexplored compared to the US market. The main difficulty is modelling the supply, which is predominantly based on imports from Russia, Norway and Algeria, complemented with domestic sources from UK offshore gas fields under the North Sea and a single giant onshore field in Groningen/Netherlands. Moreover, the European gas market has undergone considerable changes over the last decades. First, the industry has experienced the emergence of many trading hubs, which has led to higher gas-to-gas competition. Second, there has been a gradual progress in the creation of the Energy Union, aimed at integrating the European gas market, i.a. by joining the UK market to the European system of pipelines. Third, the practice of explicitly linking the gas price in contracts to crude oil prices has declined for the last two decades (Chyong, 2019). These developments lead to the question, whether natural gas prices at the European market are driven by changes in oil or US natural gas prices, or maybe by the fundamentals specific to the European natural gas market.

This question has been only partially answered in the literature. For instance, Brown and Yucel (2009) conclude that the co-movement of European and North American natural gas prices is driven by crude oil prices rather than gas-to-gas arbitrage across the Atlantic. In turn, Erdos (2012) applies vector error correction model to show that gas prices traded in the UK hub (National Balancing Point, NBP) remain in a long-term equilibrium with crude oil prices, but also react to deviations from a cointegrating relationship between US natural gas and WTI prices. On the other hand, Hulshof *et al.* (2016) find that daily spot prices at the Dutch gas hub (Title Transfer Facility, TTF) are over short-term horizon only mildly affected by changes in oil prices, but react to the level of natural gas inventories, temperature and the production of wind electricity.

In this study, we contribute to the above studies by investigating how the dynamics of oil and natural gas prices in the US affect changes in natural gas prices in Europe. We start by estimating an SVAR model for the three analysed variables. Next, we analyse impulse response functions, forecast error variance decomposition and historical decomposition. We show that, in the short horizon, European gas prices are predominantly determined by local shocks, whereas in longer horizons, they are almost entirely determined by crude oil innovations. In turn, the role of shocks specific to the US natural gas market is negligible for the European natural gas prices.

2. Data

We use monthly data from the period of January 1993 to August 2019, where the beginning of the sample is chosen to take into account the deregulation of the US natural gas market, which ended in the first half of 1990s (Joskow, 2013). From the World Bank commodity database we acquired three series: crude oil WTI (USD/bbl), US and European natural gas (USD/mmbtu) and deflated them by consumer price index in the US taken from the FRED database.

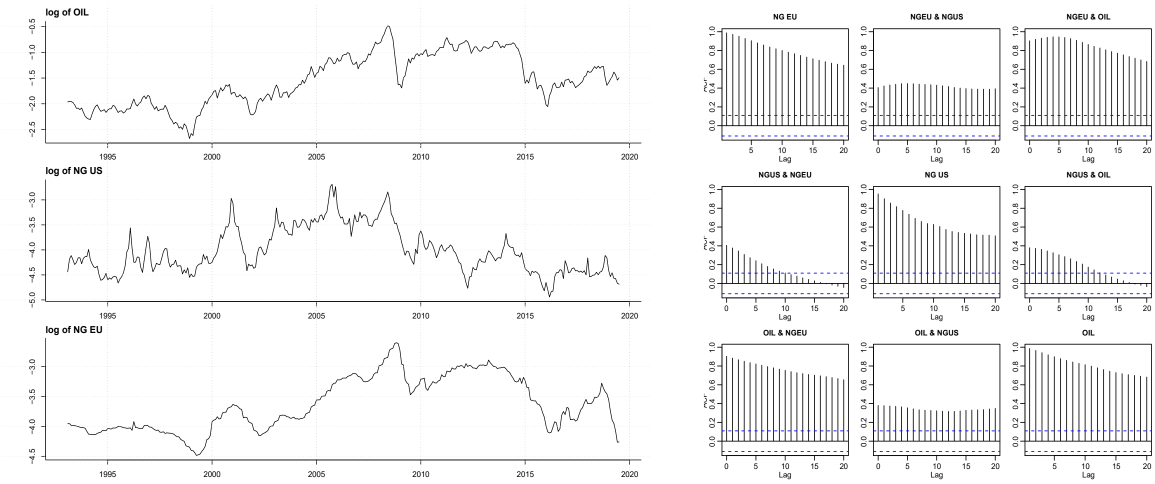

Figure 2. Series used in the analysis and their cross correlations for growth rates

The series, after taking logs, are presented in the left panel of Fig. 2, which shows their strong correlation. However, both natural gas price series exhibit quite different dynamics, US prices being significantly more volatile than the European ones. This reflects locally different structures of US and European natural gas markets, which until recently did not influence each other significantly. We also observe that European natural gas prices closely follow oil prices, although in a smoother and lagged pattern. This may express the influence of European market by the significant, albeit declining, share of long term contracts, usually indexed in oil prices (Chyong, 2019).

In the first step we inspect the dynamic relationships among log-changes for these three energy commodities prices by looking at cross correlograms on the right panel of Fig. 2. It shows that oil prices react to its own lags but are less affected by past changes in natural gas prices. Moreover, the changes in the US natural gas prices are correlated with past dynamics at the crude oil market and natural gas prices in Europe react with lags to the situation in the crude oil market.

Table 1. Statistics for monthly log changes (×100) of real energy commodity prices

	Mean	SD	Min.	Max.	Skew.	Kurt.
Crude oil	0.15	8.10	-31.56	21.50	-0.65	1.22
US natural gas	-0.13	13.55	-40.30	47.56	0.12	1.13
EU natural gas	-0.09	5.85	-24.85	23.07	-0.58	4.04

The descriptive statistics of the series are presented in Table 1. They confirm that the dynamics of US natural gas prices is somewhat different from those of oil and European natural gas prices, which in turn behave in a similar way. In particular, changes in the US natural gas prices are relatively more volatile than the other two series and less skewed. Fig. 3, with all three series on one graph, clearly shows that European natural gas prices closely follow developments on the crude oil market, while US natural gas prices are only loosely linked to oil prices. It is especially visible in years 2010-2015, when an upward trend in oil prices was accompanied with a substantial drop in US natural gas prices.

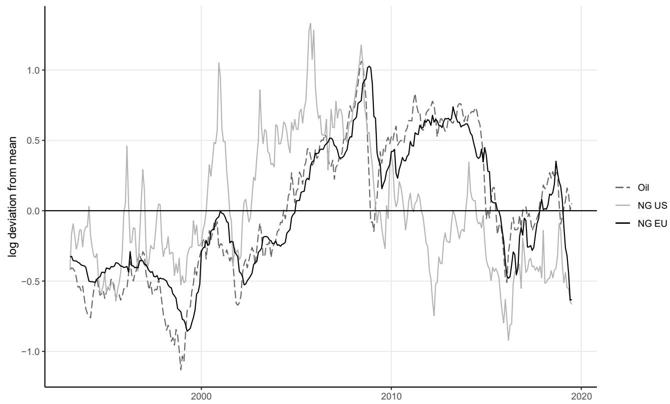

Figure 3. Decoupling of energy commodity markets

Note: Deviations of log prices from the sample mean.

3. Methodology

We analyse the dynamics of the natural gas market by considering a structural VAR model for a vector $y_t = (oil, ngUS, ngEU)'$ of the logarithms of real prices of crude oil, US natural gas and European natural gas respectively. This is the most parsimonious specification to analyze the dynamic interactions among the three markets. The specification of the VAR model with a lag length p is:

$$y_t = A_0 + A_1 y_{t-1} + \cdots + A_{t-p} + \epsilon_t,\ \epsilon_t \sim N(0, \Sigma),$$

where y_t is the vector of endogenous variables, A_0 is a vector of constant terms, A_j for $j = 1,2, \dots, p$ are matrices of coefficients and ϵ_t is the vector of reduced-form residuals. We consider ϵ_t to be a weighted average of three structural innovations to: oil (η^{oil}), North

American natural gas (η^{ngUS}) and European natural gas prices (η^{ngEU}), where the relationship between reduced-form and structural disturbances is assumed to be recursive:

$$\begin{bmatrix} \epsilon_t^{oil} \\ \epsilon_t^{ngUS} \\ \epsilon_t^{ngEU} \end{bmatrix} = \begin{bmatrix} * & 0 & 0 \\ * & * & 0 \\ * & * & * \end{bmatrix} \begin{bmatrix} \eta_t^{oil} \\ \eta_t^{ngUS} \\ \eta_t^{ngEU} \end{bmatrix}$$

or in matrix notation $\epsilon_t = D\,\eta_t$ where $\eta_t \sim N(0, I)$ and $DD' = \Sigma$. The first shock describes the situation in the crude oil market, whereas the last two shocks refer to unexpected changes in natural gas prices, in the US and Europe respectively, which are not accounted for by the oil shock.

4. Results

On the basis of information criteria, we set maximum lag p to four months and estimate the reduced form VAR with the least squares method. We use the estimated covariance matrix of residuals Σ to compute the identification matrix D and construct the structural VAR representation of the model. Next, we calculate impulse response functions to one standard deviation of three structural shocks, compute forecast error variance decomposition as well as historical decomposition for three series.

Impulse response functions. Fig. 4 presents the impulse response functions (IRF) of three endogenous variables to one standard deviation of three structural shocks. On top panels, we observe that oil market innovations are immediately leading to an increase in crude oil prices by about 8%, which in the subsequent two months reaches a peak of around 10%. After the initial jump, oil prices very slowly return to equilibrium, but even after five years their level is still over 3% above the level observed before the occurrence of the shock. Otherwise, oil prices are not significantly affected by shocks to natural gas prices, both in the US and Europe.

The reaction of US natural gas prices is presented in the centre panels of Fig. 4, which show that oil shock leads to an initial increase in US natural gas prices by 2.5%, subsequently accelerating to over 6% after one year. Afterwards, real natural gas prices revert to the pre-shock level relatively quickly, so that three years after the shock occurrence they are back at equilibrium. In turn, the response to the natural gas shock in the US causes an initial jump of prices by about 13% and its gradual reversion to equilibrium, which lasts about 5 years. Finally, the reaction to shocks originating in the European natural gas market is insignificant.

The bottom panels of Fig. 4 present the reaction of the natural gas prices in Europe, which do not exhibit an initial reaction to oil shock. However, after one year these prices are over 7% above their initial level, which is comparable to the reaction of oil prices at this horizon. As a result, the decoupling of European natural gas prices from oil prices is short-lived and disappears one year after the occurrence of oil shock. Furthermore, European gas prices are only slightly affected by the developments in the US natural gas market and idiosyncratic shocks to European natural gas market lead to a short-lasting upward shift in prices, with relatively small initial reaction in comparison to how oil prices or US natural gas prices react to their idiosyncratic shocks.

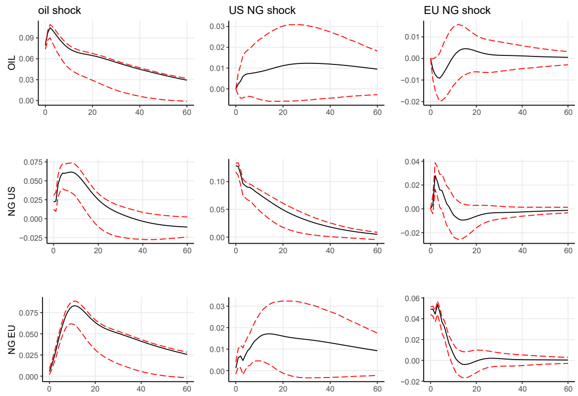

Figure 4. Impulse responses in SVAR model

Note: The solid lines represent the impulse response function at the mean value of parameters to three structural shocks. The dashed lines denote 75% bootstrapped confidence bounds.

The analysis of all IRFs leads to two main conclusions. First, a comparison of IRFs for crude oil and US natural gas prices indicates that after the occurrence η^{oil} as well as η^{ngUS} innovations, oil prices behave visibly different than natural gas prices in the US, which is especially evident after shocks specific to the US natural gas sector. This explains why we observe the decoupling of the US natural gas market from the crude oil market. Second, a comparison of IRFs for crude oil and European natural gas prices indicates that after η^{oil} as well as η^{ngEU} shocks there is a temporary decoupling of these two markets, but after one year from the occurrence of shocks the reaction is almost the same. In turn, after η^{ngUS} both variables behave very alike from the initial period. This would indicate that the dynamics of these two markets are very similar over medium and long-term horizons, but not the short-term ones.

Forecast error variance decomposition. How important are the three shocks for the dynamics the real energy commodity prices? The left panel of Fig. 5 quantifies their contribution to forecast error variance for individual variables. First, fluctuations in oil prices are entirely determined by shocks specific to the crude oil market. This confirms that the situation in the natural gas market has virtually no impact on crude oil price developments. Next, natural gas prices in the US are predominantly driven by shocks specific to the US natural gas market. The contribution of oil shocks to forecast error variance increases with horizon to stabilize at around 25% after one year. It can also be seen that the contribution of European gas market shocks is not visible. Finally, in the short run, European natural gas prices are almost entirely determined by idiosyncratic shocks. However, for further horizons there is a visible increase of oil shocks contribution, which rises to about 75%. For longer horizons, there is also a visible, although small, contribution of shocks to the US natural gas market.

In general, the FEVD analysis leads to three conclusions. It confirms that developments in the natural gas markets, both in the US and in Europe, do not affect crude oil prices. Moreover, it illustrates that natural gas prices in the US are linked to oil prices neither in short nor in long horizons. Ultimately, it shows that natural gas prices in Europe are linked to oil prices in medium and long horizons.

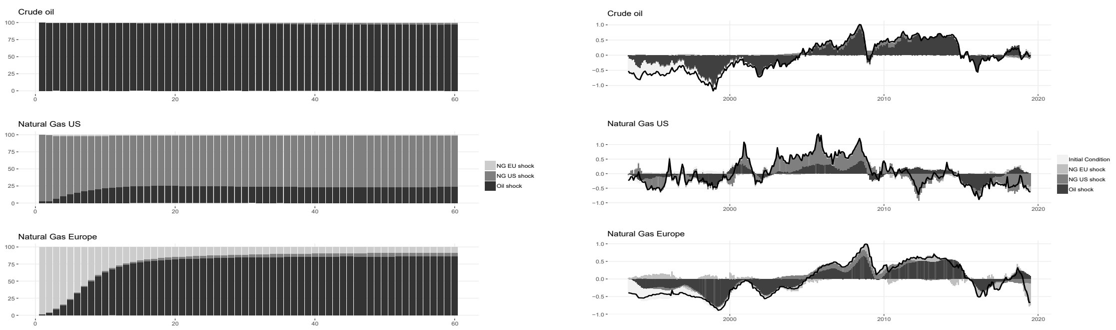

Figure 5. Forecast error variance decomposition and historical decomposition

Historical decomposition. To illustrate the contribution of the three shocks to real energy commodity price developments, we present historical decomposition of three analysed energy commodities on the right panel of Fig. 5. We observe that oil prices are not significantly affected by natural gas markets shocks but are driven by disturbances specific to oil market. Furthermore, the increase in the US natural gas prices in the first half of 2000s, as well as the subsequent rapid decline following shale gas revolution, were driven by shocks specific to the US natural gas sector. However, for this variable there is a visible and non-negligible contribution of oil sector shocks. Finally, the bottom graph summarizes well the dependence of European natural gas prices on crude oil market developments. It unambiguously shows that most of European natural gas price fluctuations closely follows crude oil market dynamics, with only a temporal impact of shocks specific to US and European natural gas markets.

5. Conclusions and policy implications

In this study, we have investigated developments of real prices for WTI crude oil as well US and European natural gas over the years 1993-2019. We have applied a structural VAR model framework, which is a comprehensive framework to model the dynamic interactions among variables. Our key results are threefold. First, oil prices are not affected by shocks specific to natural gas markets, whether American or European one. Second, the dynamics of the US natural gas market is predominantly driven by idiosyncratic innovations and is only partially affected by crude oil shocks. Third, over longer horizons natural gas prices in Europe are mostly determined by oil specific shocks, whereas in shorter horizons they are determined by shocks specific to the natural gas market in Europe. These results present new evidence on the decoupling of US natural gas prices from oil prices as well as from natural gas prices in Europe. They also indicate that any decoupling of European natural gas prices from oil prices is short-lived.

In a broader context our study shows that the impact of the shale gas revolution, originating in the US, on the European market has been so far hardly visible. On the contrary, the European gas market, by importing gas through pipelines from Russia, Algeria or Norway, and relying significantly on long-term contracts indexed to oil, is still strongly responding to oil market developments. However, this is gradually changing. For the last decade, the US has developed capacities to export shale gas through its liquefaction, which allows shipping LNG through the Atlantic to Europe. This change gives European countries a better bargaining position in negotiating new contracts for imports through pipelines from traditional sources. This is a factor that should help transforming European natural gas market from crude oil pricing into pricing based on market forces determined by supply and demand.

Acknowledgements

Supported by the Ministry of Science and Higher Education research subvention, project number KAE/S19/16/19.

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