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Europe in World Natural Gas Market: International Transmission of European Price Shocks

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ABSTRACT

The paper applies the vector error correction model (VECM) framework with 250 days rolling window to the analysis of the interconnectedness of regional markets for natural gas in Europe, the Asia-Pacific region and the US. Transmission of European gas market fundamentals to other regional gas markets is assessed by using carbon price in the EU Emissions Trading System and European gas storage capacity utilization. The latter is proven to be a significant component in the cointegrating equation that links natural gas prices in Europe and the Asia-Pacific region. It is shown that gas prices in all three regional markets are pairwise cointegrated while cointegration between gas and oil prices is absent in Europe and the Asia-Pacific region and weak in the US. It is also concluded that fundamental factors of the European gas market influence gas price dynamics not only in Europe, but also in the Asia-Pacific region and, to a lesser extent, the US. In sum, the increasing importance of LNG import in European natural gas consumption has given a strong impetus to the formation of the global natural gas market.

Keywords: Gas Price, Oil Price, Carbon Price, Transmission of Price Shocks, LNG, Gas Storage Capacity Utilization, EU, Asia-Pacific Region, US
JEL Classifications: C32, Q35, Q37, Q41

1. INTRODUCTION

For the last two decades the EU and the UK have been systemically restructuring the gas market in three directions. First, the transition from oil-linked "take or pay" long-term contracts to spot market pricing based on gas-to-gas competition was pushed for. Presently 90% of European natural gas consumption rests on spot market pricing compared to only 20% in the Asia-Pacific countries (IGU, 2021). Second, gas supply was diversified via encouraging import of LNG (Trimble, 2018). The share of LNG import in total EU gas consumption rose from 8% in 2015 to 20% in 2020 (McWilliams et al., 2022). Third, the level of "coupling" of natural gas and electricity markets was enhanced. European energy regulators evaluate progress in all three directions as satisfactory (ACER's Preliminary Assessment of Europe's high energy prices and the current wholesale electricity market design, 2021).

In parallel Europe is pushing for an accelerated low carbon agenda. Share of variable renewable energy (VRE) sources in form of solar and wind energy in total electricity is constantly rising partly due to the rising costs of carbon emission allowances, which increasingly influences the price dynamics in the natural gas market (Szabo, 2022).

Additionally, the transformation of the European gas market is unfolding against the background of substantial changes in other regional gas markets. The global LNG market is being rapidly reshaped. The structure of global LNG supply has recently changed as the US entered the trio of the world's largest LNG exporters in 2020 and are expected to become the largest LNG exporter in 2022. For LNG imports Europe fiercely competes with the Asia-Pacific region, where demand for gas is rapidly increasing.

The European gas crisis of 2021/2022 is sometimes presented as an unintended result of unfortunate events. In our view the crisis is a natural outcome of the European recent energy policies. In a concise form our position regarding the crisis is the following. First, the epicenter and the driver of the crisis was the UK's electricity and power sector. Initially price hikes in the electricity sector spilled over to the gas market but not vice versa. Second, the crisis was triggered by a combination of factors, including relatively low solar and wind electricity generation activity, especially in June-September 2021, a policy-driven exit from coal generation supported by the market for carbon emission allowances, and temporal interruptions of electricity imports from France for technical reasons. All these factors combined pushed demand for gas to generate electricity up. Third, due to its specific market design gas sector started to generate waves of prices accelerations across interconnected energy markets.

Fundamentally the UK physical gas market has recently become much more vulnerable to shocks and crises. The inherent vulnerability is explained by the continuing gas production decline (Zachmann et al., 2021) as well as by the closure in 2017 of gas storage facility Rough, which accounted for 70% of national gas storage capacity (Ambrose, 2021). Being unable to cover the recovering demand for gas after COVID-19 by its own production the UK noticeably increased demand for gas import. In April-September 2021 net British gas import amounted to a record for such a time period of 15.7 bcm (Gridwatch database, n/y). Shortage of physical gas caused price rise at British gas hub NBP which immediately spilled over to the Dutch Title Transfer Facility (TTF) hub, as price dynamics in the two hubs are highly cointegrated (Broadstock et al., 2020). In its turn, due to the central role of the TTF in the European gas price formation, the price shock spread over the whole Europe. Moreover, via the LNG channel the European gas price shock strongly, however unevenly, impacted gas price dynamics in the Asia-Pacific region and Northern America.

The research goal of the present article is threefold. First, to explore the presence of cointegration between regional gas prices and the world oil price. Weakening or lack of cointegration would prove statistically the decoupling of gas price from the world oil price. Second, to study the transmission of gas price shocks from the European to Asia-Pacific and American gas markets. Third, to determine the specific features of the European gas market which are propagated into the process of global price formation for gas.

2. LITERATURE REVIEW

There exist two main approaches in the literature to modelling regional natural gas markets and their interactions. In the first approach regional gas markets are treated separately. It allows to include a set of various factors that influence gas market dynamics including indicators of supply, demand, storage level, trade flows as well as other relevant variables such as oil price, temperature, carbon price, etc. Such models were developed for European (Nick and Thoenes, 2014), Northern American (Brown and Yücel, 2008) and Asia-Pacific (Zhang et al., 2018a) markets. The principal focus of this approach is studying the long-term relationship between natural gas and crude oil prices and its dynamic characteristics. The existence of cointegration relationship in all the three regional natural gas markets for various periods was found in many research works: in the US (Erdos, 2012), Europe (Asche et al., 2006; Regnard and Zakoïan, 2011) and Asia (Zhang et al., 2018a). It is also argued that gas prices linked to oil do not reflect market fundamentals both in Europe and Asia (Stern, 2014) and move to hub pricing in these markets could temper price volatility as it is more fundamentally driven with less room for speculation (Zhang et al., 2018b).

The second "global" approach focuses on interconnections between regional gas markets and the formation of global market for natural gas. Due to degrees of freedom constraints a limited set of variables is usually analyzed. Most often only regional prices for natural gas and the oil price are modeled (Siliverstovs et al., 2005; Neumann, 2009). In the modelling we follow the "global" approach as the understanding is amounting that regional gas markets work in concert.

Role of storage was studied in a number of papers using different methodologies with mixed results. Some studies (Mu, 2007; Brown and Yücel, 2008; Chiou-Wei et al., 2014) found negative impact of inventory changes on gas prices in the United States, while other works (Ramberg and Parsons, 2012; Erdos, 2012) did not confirm that conclusion. Nick and Thoenes (2014) showed that storage affects natural gas price in Germany in the short-term. Concerning the linkage between the carbon price and natural gas price in Europe a study (Hulshof et al., 2016) found that the price of CO2 did not influence the spot price of gas over 2011–2014.

3. DATA AND RESEARCH METHODOLOGY

Our main research tool is the vector error correction model (VECM), originally proposed by (Johansen, 1995). VECM is a standard technique for the estimation of both long-term equilibrium and short-term dynamics in commodities markets, including natural gas and crude oil (Campiche et al., 2007; Saghaian, 2010).

Error-correction representation of VECM takes the form:

$$\Delta Y_{\ddot{u}\ddot{u}\bar{\bar{u}}} = \prod Y_{-1} + \sum_{i=1}^{p-1} \Gamma \Delta Y_{-} + \Phi \Delta X + \varepsilon \tag{1}$$

where Y_t is the vector of K endogenous variables; X_t is the vector of exogenous variables; p is the number of lags; Π, Γ_i and Φ are coefficient matrices to be estimated; ε_t is the innovation term in the model. In all the VECM models the lag orders were determined individually according to minimizing Akaike information criteria.

In the case cointegration is present the matrix can be decomposed into $\Pi = \alpha\beta'$, where β is the $K \times r$ coefficient matrix of r cointegration equations that represent long-term equilibrium in the model and is $K \times r$ adjustment coefficient matrix that represents short-term dynamics of endogenous variables around the equilibrium. The equation (1) can be re-written as:

$$\Delta Y_{\ddot{u}\acute{u}\bar{u}\bar{t}} = \alpha\beta' Y_{-1} + \sum_{i=1}^{p-1} \Gamma \, \Delta Y_{-} + \Phi \Delta X + \varepsilon \qquad (2)$$

Johansen's test (Johansen, 1988; Johansen and Juselius, 1990) was used to determine the existence and number of cointegration equations. If there is only one cointegration equation in the model matrixes α and β are reduced to vectors of K elements. The economic interpretation of signs of short-term coefficients depends on the sings of respective β coefficients. If the sign of β_j is positive (negative) then the negative (positive) sign of α_j means that *j*-th endogenous variable adjusts toward restoring the equilibrium in the short run, while positive (negative) sign of α_j means that *j*-th endogenous variable moves further away from the equilibrium in the short run.

In order to streamline interpretation of signs of short-term coefficients we propose a simple modification:

$$\bar{\alpha}_j = \begin{cases} \alpha_j, \mathit{if}\ \beta_j < 0 \\ -\alpha_j, \mathit{otherwise} \end{cases} \qquad (3)$$

where $\bar{\alpha}_j$ represents modified coefficient of short-term dynamics. Interpretation of $\bar{\alpha}_j$ is straightforward: positive sign of $\bar{\alpha}_j$ always means that *j*-th endogenous variable adjusts toward restoring the equilibrium in the short run irrespective of the sign of the corresponding β_j.

Our research goes in two stages. First, we use a set of bivariate VECM models without exogenous variables to study the interconnections between regional gas prices and the global oil price. Second, we conduct a more detailed analysis of Europe-Asia market interconnections and international propagation of European-specific fundamental factors of the gas market using trivariate VECM models with one exogenous variable (carbon price) with 250 days rolling window in order to assess the stability of the results and detect time-dependent properties of the model following techniques proposed in (Zhang et al., 2021; Parot, 2019; Papaioannou et al., 2018). To our knowledge, the present paper is the first one that includes European gas storage capacity utilization in the cointegrating equation that links natural gas prices in Europe and the Asia-Pacific region. That allows shedding more light on both the long-term dynamics of the aforementioned variables and the international propagation of European storage shock. Given the dramatic rise of the carbon price in 2020–2021 we reexamine the relationship tested by (Hulshof et al., 2016) using the most recent data.

Natural gas price in North America hh_t is represented by the price in Henry hub, US the most liquid global and regional gas hub. For European gas market price in the TTF hub, Netherlands ttf_t was selected as it generally serves as the pricing benchmark in many of long-term contracts both for pipeline gas and LNG and also is strongly integrated with prices in other European gas hubs such as the NBP in the United Kingdom and the NCG in Germany (Hulshof et al., 2016; Kuper and Mulder, 2016). The Japan-Korea-Marker (JKM) price for liquefied natural gas (LNG) jkm_t was chosen for the Asia-Pacific market. Brent price $brent_t$ represents global price for crude oil. eu_carbon_t stands for price for emission allowances in the EU Emissions Trading System (ETS). All price variables were taken as natural logarithms. Where available, spot prices were used (hh_t, ttf_t, $brent_t$). Otherwise, prices of the prompt futures contracts were used (jkm_t, eu_carbon_t). $eu\_storage_t$ represents natural gas storage level in the European Union and the United Kingdom and enters the modelling as percentage of working gas storage capacity. $eu\_storage_t$ was adjusted for seasonal and calendar effects employing Ollech's methodology (Ollech, 2018).

The data source for most of the series is the Bloomberg database, except for *jkm* price before May 27, 2017 that was collected from Fusion Media (LNG Japan/Korea Marker PLATTS Future Historical Data, n/y). Natural gas storage data is publicly available from Gas Infrastructure Europe (Aggregated Gas Storage Inventory (AGSI+) database, n/y).

The models use daily data series from July 29, 2014 to November 19, 2021. The starting date is bound by the availability of jkm_t which is the shortest time series in the study. The last date represents the most recent data point available at the time of writing the article. In checking for robustness monthly time series calculated by averaging the daily data spanning over the same period were used.

Three different tests were used in order to examine the order of integration of time series in the data collected. Using significance level of 5% all tests show that four out of six variables (*ttf*, *jkm*, *brent* and *eu_carbon*) contain unit root in levels and are stationary in first differences (Table 1). So it can be concluded that these variables are integrated of order one (I(1)). The results for *hh* and *eu_storage* are mixed. For *eu_storage* two tests (ADF and PP) shows that it is I(1) and one test (KPSS) shows that its order of integration is more than one. Based on the results of two tests we treat *eu_storage* as I(1). For *hh* ADF and PP tests showed that it is a stationary process while KPSS test rejected the null of stationarity. Nevertheless, consistent with other studies (Caporin and Fontini, 2017; Hartley and Medlock, 2013) and the fact that price series generally are not stationary (Zivot and Jiahui, 2006) we treat *hh* as I(1).

4. EMPIRICAL RESULTS AND DISCUSSION

4.1. Bivariate VECMS: Three Regional Natural Gas Markets and World Oil Market

Results of estimation of bivariate VECM models between regional natural gas prices *hh*, *ttf*, *jkm* and global crude oil price *brent* are summarized in Table 2. The whole period of analysis is additionally split into two subperiods in order to take into account possible changes in the relationships caused by the COVID-19 pandemic.

Table 1: Tests for the presence of a unit root

Variable	Levels			First differences		
	ADF	PP	KPSS	ADF	PP	KPSS
hh	–4.441***	–3.374**	0.677**	–23.398***	–34.732***	0.091
ttf	–0.532	0.012	0.802***	–25.757***	–35.216***	0.453*
jkm	0.248	–0.127	0.714**	–23.135***	–33.832***	0.368*
brent	–1.775	–2.046	0.589**	–25.400***	–34.304***	0.073
eu_storage	0.101	–0.529	1.550***	–14.046***	–36.168***	0.719**
eu_carbon	–1.289	–1.253	4.180***	–22.823***	–34.623***	0.151

ADF refers to the Augmented Dickey Fuller test (Dickey and Fuller, 1979). The critical values are taken from (Hamilton, 1994) and (Dickey and Fuller, 1981), lag order was determined with the Akaike information criteria. PP refers to the Phillips-Perron test (Phillips and Perron, 1988). KPSS means Kwiatkowski-Phillips-Schmidt-Shin tests (Kwiatkowski et al., 1992). All tests include intercept and do not include trend. In ADF and PP tests H0 means that series contain unit root. In KPSS test H0 refers to stationarity

Table 2: Bivariate VECMs: Tests for presence of cointegration and significance of short run dynamics toward equilibrium

Variables in VECM	Cointegration	Variables, that adjust toward restoring the equilibrium in the short run
Whole period		
ttf, brent	1*	*ttf* (**), *brent* (***)
jkm, brent	No cointegration	–
hh, brent	1***	*hh* (**), *brent* (***)
jkm, ttf	1***	*jkm* (***), *ttf* (***)
hh, ttf	1*	*hh* (***)
hh, jkm	1***	*hh* (***)
First subperiod (before COVID-19 shock)		
ttf, brent	No cointegration	–
jkm, brent	No cointegration	–
hh, brent	1*	*hh* (***), *brent* (**)
jkm, ttf	1*	*jkm* (**), *ttf* (**)
hh, ttf	1***	*hh* (***)
hh, jkm	1***	*hh* (***)
Second subperiod (after COVID-19 shock)		
ttf, brent	No cointegration	–
jkm, brent	No cointegration	–
hh, brent	1*	*hh* (***), *brent* (**)
jkm, ttf	1*	*jkm* (**), *ttf* (**)
hh, ttf	1***	*hh* (***)
hh, jkm	1***	*hh* (***)
Robustness check: whole period, monthly data		
ttf, brent	No cointegration	–
jkm, brent	No cointegration	–
hh, brent	1*	*brent* (***)
jkm, ttf	1***	*jkm* (***)
hh, ttf	1*	*hh* (***)
hh, jkm	No cointegration	–

"1" means presence of cointegration. *, ** and *** denote statistical significance at 10%, 5% and 1% respectively

The first subperiod runs from July 29, 2014 to December 31, 2019. The second subperiod spans from January 01, 2020 to November 19, 2021.

Analysis of bivariate VECMS allows making the following conclusions. First, European and Asia-Pacific gas prices are cointegrated. That is true for the whole period and for both subperiods. The modeling shows that both regional gas prices are adjusting to restore the equilibrium. The characteristics of this process and its temporary properties are extensively dealt with at the second stage of analysis. Here it is important to state that the European gas market doesn't function in isolation. Even more important is the fact that the global LNG market has emerged and this market is tightly integrated with the European pipeline gas market as all the three regional natural gas markets are pairwise cointegrated.

Second, gas prices in the US are cointegrated with European and Asia-Pacific gas prices and exactly American gas prices are adjusting to restore the equilibrium. Economically that mirrors the increasing impact of European and Asia-Pacific gas demand on the US internal gas market as well as the growing role of the US as a supplier of gas to the two regions.

Third, the modeling doesn't reveal an integration between gas prices and the world oil price neither in Europe nor in the Asia-Pacific region. For Europe the hypothesis of the lack of cointegration between gas and oil prices for the whole period under the study can be rejected only at 10% of significance. For both subperiods that hypothesis cannot be rejected even at this significance level. For the Asia-Pacific region all the models reveal lack of cointegration between *jkm* and *brent* for the whole period and both subperiods. In the US contrary to Europe and the Asia-Pacific region bivariate VECMs reveal the cointegration between gas and oil prices which can be explained by the fact that the greater volume of natural gas is produced in association with oil extraction.

To check these conclusions for robustness similar bivariate VECMs using monthly data were run for the whole period under study (Table 2 Section D). The robustness test confirms the conclusion of the existence of a cointegration link between *jkm* и *ttf* prices. However, in the model based on monthly data only *jkm* price is adjusting to the long-term equilibrium, while *ttf* retains a leading factor role in the cointegration. That can be explained by a variable nature of the relationship between the two prices which is confirmed by using VECM model with a rolling window below. Also lack of cointegration between European and Asia-Pacific gas prices from the one side and world oil price from the other side is confirmed. Besides, the conclusion of the existence of a cointegration link between *hh* and *ttf* prices is confirmed, as well as the fact that only *hh* price is adjusting towards the equilibrium while the European gas price remains a generator of shocks.

Cointegration between *hh* and *brent* monthly prices is revealed only at 10% level of significance and only oil price is adjusting toward the equilibrium which contradicts economic logic. That indicates that the interrelationship between daily *hh* and *brent* is rather weak, which is in line with the existing literature (Ramberg and Parsons, 2012).

4.2. Trivariate VECMS with Exogeneous Variables: In-depth Analysis of European-Asian Natural Gas Markets

For a deeper understanding of the relationship between *ttf* and *jkm* prices we use VECMs with 250 days rolling window. For a more complete consideration of factors impacting gas price setting and for the study of price shocks transmission, level of filling of gas storage facilities in Europe is included into the cointegration relation and price of carbon allowances in the ETS is used as exogenous variable. Identification of cointegration relationship was made by normalizing the coefficient at *ttf* to 1.

Let's start with the results of running the regression for the last rolling window (most recent VECM) covering the period from November 20, 2020 to November 19, 2021. Johansen's test confirms the presence of one cointegrating vector (Table 3). All the coefficients in this cointegration relationship are statistically significant (Table 4). Leaving *ttf* at the left-hand side of the cointegrating equation and moving all other variables to the right-hand side it can be written as:

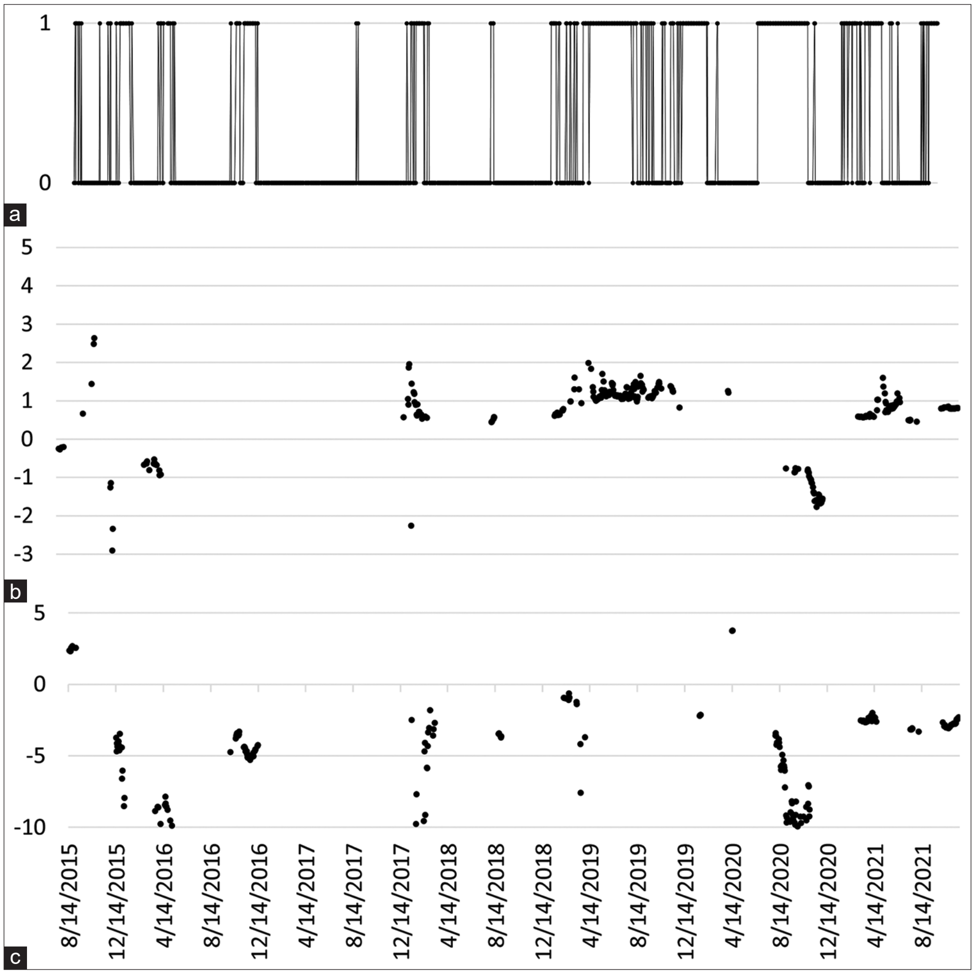
$$ttf=0.8*jkm-2.33*eu\_storage+1.71 \qquad (4)$$

Analysis of coefficients of short-term dynamics (Table 5) shows that both *ttf* and *jkm* adjust towards restoration of the cointegration equilibrium in a statistically meaningful way. The level of filling of gas storage facilities in Europe, on the contrary, is a destabilizing factor and adjusts away from the equilibrium, however relatively slow. Speed of gas stocks movement from the equilibrium is 12 and 20 folds slower the speed with which *ttf* and *jkm* respectively restore the equilibrium.

The short-term dynamics equation for *ttf* price (Table 6) allows concluding that the price of carbon allowances in the ETS positively and statistically meaningfully impacts gas price in the TTF hub.

Now let's analyze the dynamics of the above findings over the whole period under study. Modeling with VECM with 250 days rolling window shows that the cointegration relationship between *ttf* and *jkm* prices is unstable, however since February 2019 the

Figure 1: VECM with 250 days rolling window: Presence of cointegration and coefficients of the cointegrating equation. (a) Presence of cointegration. (b) Cointegrating equation: coefficient of *jkm*. (c) Cointegrating equation: coefficient of *eu_storage*



Notes: In section A 1 means that cointegration was detected (both of the following are true: hypothesis of no cointegration was rejected and the hypothesis that the number of cointegrating equations does not exceed 1 was not rejected with 5% significance level) and 0 means otherwise. In Sections B and C only statistically significant coefficients (5% significance level) for the windows with cointegration are shown. The time axis represents the end dates of the corresponding rolling windows

Table 3: Most recent VECM: Johansen's test for presence and number of cointegrating vectors

	Statistic	Critical values for different significance levels		
		10%	5%	1%
r≤2	2.5	7.52	9.24	12.97
r≤1	14.3*	13.75	15.67	20.20
r=0	25.1**	19.77	22.00	26.81

Table 4: Most recent VECM: Estimated coefficients in the cointegrating vectors

	Coefficient	t-statistic
ttf	1	NA (normalized)
jkm	–0.80***	–14.55
eu_storage	2.33***	4.36
Constant	–1.71***	–4.31

Table 5: Most recent VECM: Coefficients for error-correction terms for all endogenous variables

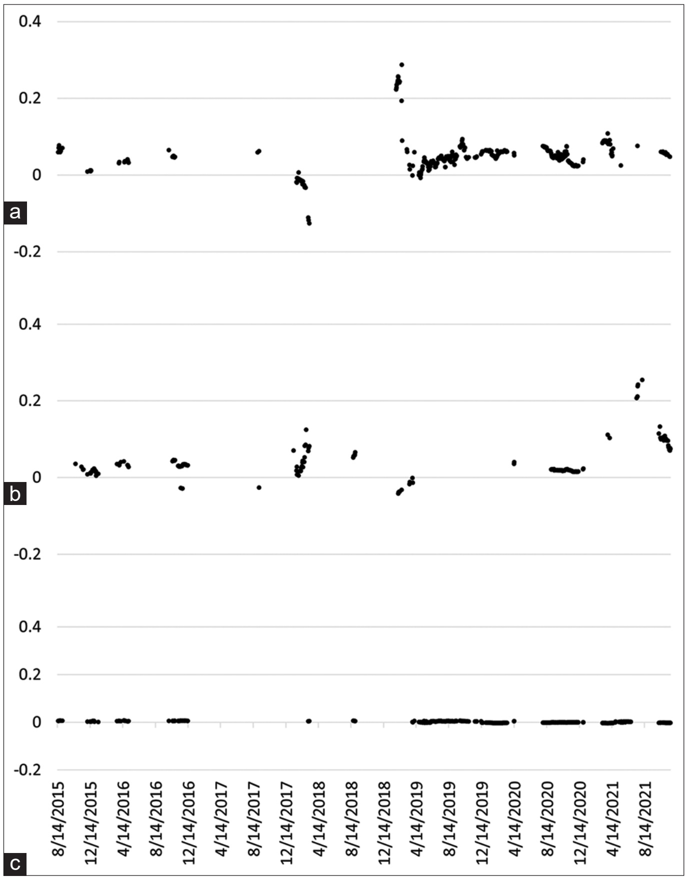
Dependent variable	Coefficient of ECM_{t-1} (α)	t-statistic	Modified coefficient of ECM_{t-1} $\bar{\alpha}$
Δ*ttf*	–0.04573*	–1.88901	0.04573*
Δ*jkm*	0.07475**	2.13604	0.07475**
Δ*eu_storage*	0.00369***	4.04008	–0.00369***

Table 6: Most recent VECM: Error-correction equation for *ttf* (dependent variable: Δ*ttf*)

ECM	Estimate	Std. error	t-statistic	P-value
	–0.046*	**0.024**	**–1.889**	**0.060**
Δ*eu_carbon*	1.086***	0.118	9.229	0.000
Δ*ttf*	0.095	0.059	1.613	0.108
Δ*jkm*	0.090*	0.047	1.921	0.056
Δ*eu_storage*	–2.645	1.684	–1.571	0.118
Δ*ttf (t–1)*	–0.184***	0.058	–3.148	0.002
Δ*jkm (t–1)*	0.015	0.048	0.304	0.761
Δ*eu_storage (t–1)*	4.802***	1.684	2.851	0.005

two prices are found cointegrated for most of the subperiods (Figure 1, Section A). Also, in the majority of subperiods with cointegration between the two prices levels of gas storage statistically meaningfully enter the cointegration equation with the expected negative sign (Figure 1, Section C). The coefficient of *jkm* in the cointegrating equation in most of the VECMs is positive, as expected, and statistically significant, with the exception of late 2020 (Figure 1, Section B). The negative coefficient of *jkm* coefficient during that period could be explained by the effects of the COVID-19 pandemic, which is confirmed by the increased absolute coefficient of the natural gas storage variable in the cointegrating equation.

Figure 2: VECM with 250 days rolling window: Modified coefficients of error-correction terms. (a) Modified coefficient of error-correction term for *ttf*. (b) Modified coefficient of error-correction term for *jkm*. (c) Modified coefficient of error-correction term for *eu_storage*



Notes: Only statistically significant coefficients (5% significance level) for the windows with cointegration are shown. Time axis represents the end dates of the corresponding rolling windows

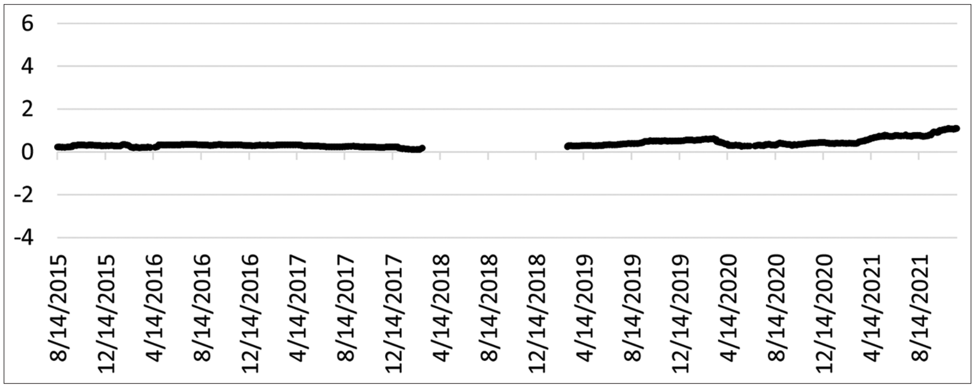
Rolling window analysis of short-term dynamic coefficients shows that after 2019 *ttf* price regularly adjusts to emerging violations of the cointegration relationship to restore the latter. Before 2019 *ttf* price adjustment was detected only in small number of rolling windows (Figure 2, Section A). That proves that before 2019 gas spot market in the Asia-Pacific region was not developed enough to impact meaningfully gas prices in Europe. That also explains the conclusion in Section 4.1 that on monthly basis only *jkm* price adjusts to restore the equilibrium relationship with *ttf*. The latter started to adjust in February 2019 only so the time span is too short to detect this adjustment on the monthly basis.

jkm price also adjusts periodically to the violations of the cointegration relationship with *ttf* price. Nonetheless after 2019 such an adjustment is detected more rarely and the relative speed of adjustment is comparatively low. This indicates the growing influence of *jkm* on the European gas market after 2019 when the development of the gas spot market in the Asia-Pacific accelerated. Nonetheless in Autumn 2021 during the energy crisis in Europe the speed of adjustment of *jkm* price increased significantly. That proves that the energy crisis in Europe was driven mostly by the European factors and it was the *ttf* price that drove *jkm* price up.

Speed of gas stocks adjustment towards and away from the equilibrium is quite low for the whole period under study, which confirms that gas stocks play the role of shocks generator not shocks absorber.

The price of carbon emission allowances was an important factor in setting the price for gas in Europe for the greater part of the period considered, excluding a short time span from February 2018

Figure 3: VECM with 250 days rolling window: Coefficients of error-correction terms



Notes: Only statistically significant coefficients (5% significance level) are shown regardless of cointegration. The time axis represents the end dates of the corresponding rolling windows

to March 2019. In 2021 during the European energy crisis impact of the carbon price on gas price increased significantly (Figure 3).

5. CONCLUSION

The analysis allows us to conclude that increasing LNG flows have facilitated the formation of the global natural gas market and the price of gas has decoupled from the oil price, at least in two major gas importing regions, Europe and the Asia-Pacific. In its turn that created channels for transmission of price and price volatility shocks between regional gas markets. As a result, fundamental factors internal for the contemporary European gas market started to increasingly influence gas price dynamics not only in Europe but also in the US and the Asia-Pacific region. First, structural features and regime of regulation of the gas market in the EU and the UK, including the state of physical infrastructure of gas transportation and storage, contributed to the unfolding of massive energy crisis in Europe in 2021/2022 which then led to a considerable increase in gas prices in the Asia-Pacific region and to a lesser extent in the US.

Second, intensive promotion of low carbon strategy and development of the market for carbon in EU and UK causes gas price increases not only in Europe but in other regions too, both in net gas importing (the Asia-Pacific region) and net gas exporting ones (the Northern America).

Third, the side effect of price decoupling in the European gas market from world oil price is increasing volatility of global and regional gas prices. Even in the US with its increasing own gas production and developed gas transportation and storage infrastructure gas price volatility is very high. Europe with its declining own gas production and still inadequate development of gas infrastructure strongly adds to the elevated levels of volatility of gas prices globally.

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